Global Assessments and Guidelines for Sustainable Liquid Biofuel Production in Developing Countries

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Institut für angewandte Ökologie
Institute for Applied Ecology

AUTHORS:

Bernd Franke (ed.), Horst Fehrenbach, Guido Reinhardt, Susanne Köppen, Maria Mueller-Lindenlauf, Nils Rettenmaier, Sven Gärtner, Julia Münch
IFEU Heidelberg, Germany (IFEU)

Jérôme Malavelle, Martina Otto, Punjanit Leagnavar
United Nations Environment Programme, DTIE, Paris, France (UNEP)

André Faaij, Janske van Eijck, Bothwell Batidzirai, Floor van der Hilst
Utrecht University, The Netherlands (UU)

Uwe R. Fritsche
International Institute for Sustainability Analysis and Strategy, Darmstadt, Germany (IINAS)

Katja Hünecke, Klaus Hennenberg
Öko-Institut, Darmstadt Office, Germany (OEKO)

Diego Masera, Emese Kottász,
United Nations Industrial Development Organization, Vienna, Austria (UNIDO)

Rainer Krell
Food and Agriculture Organization of the United Nations, Rome, Italy (FAO)

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Edited by:
Bernd Franke
ifeu - Institut für Energie- und Umweltforschung Heidelberg GmbH
Wilckensstr. 3, 69120 Heidelberg, Germany
phone: +49-6221-4767-0, fax: +49-6221-4767-19
Email: bernd.franke@ifeu.de, Website: www.ifeu.de

Report overview

This report consists of a main report, appendices and databases. The authorship of chapters and databases is shown in the following table.

Component	Description	Authorship/ Responsibility
Executive Summary	EXECUTIVE SUMMARY	IFEU, UNIDO
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Chapter 2	Biofuel settings	IFEU, UU, OEKO/IINAS
Chapter 3	Life cycle energy and greenhouse gas (GHG) assessment	IFEU
Chapter 4	Economic viability of the production of liquid biofuels	UU
Chapter 5	Global non-GHG environmental impacts of	OKEO/IINAS
Chapter 6	Social impacts of liquid biofuel production	OEKO/IINAS
Chapter 7	Next generation of liquid biofuel production	UU
Chapter 8	Fuel and vehicle compatibility	UNEP-DTIE
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Appendix I	Social and socio-economic impacts of cassava and sugarcane ethanol production in Thailand	OEKO/IINAS
Database 1	GEF Biofuel Greenhouse Gas Calculator http://www.unep.org/bioenergy/Activities/TheGlobalEnvironmentFacilityGEFProject/tabid/79435/Default.aspx	IFEU
Database 2	Data on air, water and waste (GEMIS format) http://www.iinas.org/gemis-download-en.html	OEKO/IINAS

Steering committee

The following persons served as steering committee members:

Jérôme Malavelle (UNEP-DTIE, Paris)
Prof. N.H. Ravindranath (STAP)
Peerke de Bakker (UNEP DGEF, Nairobi) (until December 2009)
Conrado Heruela (UNEP, Nairobi) (starting January 2010)
Martina Otto (UNEP, Paris)
Diego Masera (UNIDO, Vienna)
Rainer Krell (FAO/NRC, Rome)
Anselm Eisentraut (IEA, Paris)
Bernd Franke (IFEU)
André Faaij (UU)
Uwe Fritsche (OEKO until March 31, 2012 - after that: IINAS)

The first project steering committee meeting was held via teleconference on 30 September, 2009 where a detailed *Project Work Plan* was discussed and endorsed by the members. A second steering committee meeting took place on 20 July 2010 in Paris. The steering committee members reviewed and commented on the draft final report prepared on 15 September 2011. A further round of comments was received on the draft final report of February 2012.

Disclaimer

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Abbreviations

AEZ	Agro-Ecological Zones
AFREPREN	Energy Environment and Development Network for Africa
ASTM	American Society for Testing and Materials
AZE	Alliance for Zero Extinction
BAU	Business As Usual
BC	Black Carbon
BCR	Benefit / Cost Ratio
BEFSCI	Bioenergy and Food Security Criteria and Indicators (FAO project)
BEI	BEI International, LLC, American harvester producer
BioNachV	Biomassenachhaltigkeitsverordnung (Biomass Sustainability Ordinance; in Germany)
BLCAO	Biofuels Life Cycle Assessment Ordinance
BOD	Biological Oxygen Demand
BSI	Better Sugarcane Initiative (Bonsucro)
BTL	Biomass-to-Liquid
BTRR2	Soybean breed
CaO	Calcium oxide
CAPRI	Common Agricultural Policy Regionalized Impact analysis
CARB	California Air Resources Board
CBD	UN Convention on Biological Diversity
CEC	Council of the European Communities
CEN	European Committee for Standardization
CEPAGRI	Centre for the Promotion of Agriculture
CENIPALMA	Investigación e Innovación Tecnológica en Palma de Aceite
CFB	Circulating Fluidised Bed (gasification)
CGE	Computable General Equilibrium
CGEE	Centro de Gestão e estudios estratégicos, Brasilia
CGP	Central Gathering Point
CH_4	Methane
CIFOR	Centre for International Forestry Research
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2 eq	Carbon dioxide equivalents
CPO	Crude Palm Oil
CRL	Composite Residue Log (biomass bundle)
CS	Central South
dLUC	Direct Land Use Change
DTIE	Division of Technology, Industry and Economics
EC	European Community
EU	European Union
EJ	ExaJoule(s) (10^{18} J)
EPA	Environmental Protection Agency (USA)
EtOH	Ethanol
EC	European Commission
FAME	Fatty Acid Methyl Ester (biodiesel)
FAO	Food and Agriculture Organisation of the United Nations
FASOM	Forest and Agricultural Sector Optimisation Model

FFB	Fresh Fruit Bunches
FFV	Flex-Fuel-Vehicles
FT	Fischer Tropsch
FQD	Fuel Quality Directive of the EU (Directive 2009/30/EC)
GAP	Good Agricultural Practices
GBEP	Global Bioenergy Partnership
GDP	Gross Domestic Product
GEB	Global Environmental Benefits
GEF	Global Environment Facility
GEMIS	Global Emissions Model for Integrated Systems
GGL	Green Gold Label
GHG	Greenhouse Gas(es)
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für internationale Zusammenarbeit (German Society for International Cooperation)
GJ	GigaJoule(s) (10^9 J)
GWh	GigaWatt-hour(s)
GWP	Global Warming Potential
GP	Gathering Point
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
GTAP	Global Trade Analysis Project
GWP	Global Warming Potential
HC	Hydrocarbons
HLPE	High Level Panel of Experts on Food Security and Nutrition
IA	Implementing Agencies
IBA	Important Bird Area
IBAT	Integrated Biodiversity Assessment Tool
ID	Indonesia
IDB	Inter-American Development Bank
IEA	International Energy Agency
IFEU	Institute for Energy and Environmental Research, Heidelberg/Germany
IFPRI	International Food Policy Research Institute
IIAM	Mozambique National Institute of Agronomic Research
IIASA	International Institute for Applied Systems Analysis
IIED	International Institute for Environment and Development
ILO	International Labour Organization
iLUC	Indirect Land Use Change
IPA	Important Plant Area
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
ISCC	International Sustainable and Carbon Certification
ISO	International Standardization Organization
JME	Jatropha Oil Methyl Ester (Jatropha biodiesel)
KBA	Key Biodiversity Area
K_2O	Potassium oxide
l	Litre
LCA	Life Cycle Assessment
LCFS	Low Carbon Fuel Standard (California)

LHV	Lower Heating Value
LPG	Liquefied Petroleum Gas
LUC	Land Use Change(s)
MAI	Mean Annual Increase
MJ	MegaJoule(s) (10^6 J)
ML	Mali
MWel	MegaWatt (electric)
MY	Malaysia
MZ	Mozambique
MZM	Mozambique Metical (Mozambique currency)
NBER	National Bureau of Economic Research
NE	North East
NH_3	Ammonia
NH_4	Ammonium
N_2O	Nitrous oxide
NO_x	Nitrogen oxides
NPK	Nitrogen, Phosphorus, Potassium (fertilizer)
NPV	Net Present Value
NTA	Dutch Technical Agreement
OAE	Office of Agricultural Economics
OECD	Organisation for Economic Cooperation and Development
OEKO	Oeko-Institut - Institute for Applied Ecology, Darmstadt/Germany
OEM	Original Equipment Manufacturer
O&M	Operation and Management (costs)
PA	Protected Area
PBP	PayBack Period
PE	Partial Equilibrium
PIF	Project Identification Forms
PM_{10}	Particles on the order of ~10 micrometers or less
P_2O_5	Phosphorus Pentoxide
POME	Palm Oil Mill Effluent
PV	Present Value
RD&D	Research, Development and Demonstration
RED	Renewable Energies Directive of the EU (Directive 2009/28/EC)
REMBIO	Red Mexicana de Bioenergía
RFS2	Renewable Fuel Standard (USA)
RSB	Round Table on Sustainable Biofuel
RSPO	Roundtable on Sustainable Palm Oil
RTRS	Round Table on Sustainable Soy
SBA	Sustainable Biodiesel Alliance
SEKAB	Swedish Ethanol Chemistry AB
SO_2	Sulphur dioxide
SO_2 eq	Sulphur dioxide equivalents
SOC	Soil Organic Carbon
SRC	Short Rotation Coppice
SRWC	Short Rotation Woody Crops
SRF	Short Rotation Forest
STAP	Scientific and Technical Advisory Panel to the GEF
SVO	Straight Vegetable Oil

t	Metric Tonne
THB	Thailand Baht
TJ	TeraJoule(s) (10^{12} J)
TOPs	Torrefied and Pelletized Biomass
UA	Ukraine
UNCTAD	United Nations Conference on Trade and Development
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
USD	U.S. dollar
UU	Utrecht University, Utrecht/The Netherlands
VOC’s	Volatile Organic Compounds
WB	The World Bank
WCMC	World Conservation Monitoring Centre (UNEP-WCMC)
WGCB	GBEP Working Group on Capacity Building for Sustainable Bioenergy
WHO	World Health Organisation
WWF	World Wide Fund for Nature
WTO	World Trade Organization
XJAEPS	Xinjiang Academy of Environmental Protection Science

SI system

T	=	tera-	=	10^{12}	= 1,000,000,000,000
G	=	giga-	=	10^{9}	= 1,000,000,000
M	=	mega-	=	10^{6}	= 1,000,000
k	=	kilo-	=	10^{3}	= 1,000
m	=	milli-	=	10^{-3}	= 0.001
µ (u)	=	micro-	=	10^{-6}	= 0.000 001
n	=	nano-	=	10^{-9}	= 0.000 000 001
p	=	pico-	=	10^{-12}	= 0.000 000 000 001
f	=	femto-	=	10^{-15}	= 0.000 000 000 000 001
a	=	atto-	=	10^{-18}	= 0.000 000 000 000 000 001

EXECUTIVE SUMMARY

DEVELOPMENT OF A BIOFUELS SCREENING TOOLKIT

AN INTEGRATED GLOBAL RESEARCH PROJECT

The *Global Environment Facility (GEF)* aims to set clear policies and priorities for future work and investments in biofuel related projects and to provide guidance to countries on how to select sustainable biofuel projects. Three UN agencies, UNEP, UNIDO and FAO, in collaboration with three research institutions have worked together to prepare this report, with the aim to develop a ***Biofuels Screening Toolkit***, that can be used by the GEF and/or other actors to address sustainability issues concerning biofuels. The research looked at environmental, economic and social impacts of biofuels with the overall objective of identifying and assessing sustainable systems in developing countries for the production of liquid biofuels for both transport and stationary applications.

The research project was conducted in full awareness of other initiatives to develop sustainability criteria and policy tools for the promotion of sustainable biofuels, such as the UN Energy Decision Support Tool for Bioenergy (2011), the Global Bioenergy Partnership's (GBEP) work on sustainability criteria and indicators, the European Union's Directive on the promotion of the use of energy from renewable sources which contains sustainability criteria for biofuels (2009), and the Inter-American Development Banks's Biofuels Sustainability Scorecard 2.0 (2009), as well as various certification schemes available on the market.

THE TRAFFIC LIGHT APPROACH

Biofuels are considered sustainable when their entire production and supply chain is deemed to deliver positive environmental, social and economic impacts. This not only means that biofuels must deliver greenhouse gas savings compared to fossil fuels, but also that the cultivation, processing and distribution of biofuels do not cause any adverse impacts on the environment or society. At the same time, the benefits of biofuels in terms of giving an affordable alternative to fossil fuels, creating jobs and making enterprises more competitive have to be considered. A full analysis of these issues can be time-consuming and costly.

The Biofuels Screening Toolkit aims to provide a tool for first screening of biofuels projects to identify potentially critical issues. A "traffic light" approach is used, whereby **thresholds** for a variety of indicators signal whether the project should go ahead or whether further assessment is needed to make that decision. For **each** sustainability indicator, the following approach allows identifying project conditions where there are:

- **no** relevant risks, or **adequate project design** mitigating such risks **(GO)**.
- **potential** risks which **could** be mitigated by specific project designs (**CHECK**); and,
- **high** risks which cannot be mitigated (**STOP**).

ENVIRONMENTAL SUSTAINABILITY

A. Greenhouse gas (GHG) emissions and the GHG calculator

The saving of fossil energy resources and the mitigation of climate change are among the main drivers for implementing biofuel systems. For many years, life cycle assessment (LCA) methodology has been used to calculate energy and greenhouse gas balances of biofuels. To make this methodology applicable to GEF screening processes, an Excel-based 'Biofuel Greenhouse Gas Calculator' was developed[1]. The calculator has two main functions. First, it provides GHG balances for 74 biofuels settings in a transparent way[2], and second, it can be used to adapt settings or perform own calculations based on user-defined input data. With these two levels of detail, the tool can be used in different project application phases and for project evaluation.

From the GHG calculations of the 74 settings, the following conclusion can be drawn: principally, **all biofuel settings assessed show GHG emission savings** provided that no direct and indirect land use change occurs. In cases where direct land use change is given, emissions depend on the actual change in carbon stock between the previous status of the land and the subsequent farming system. On a per hectare basis, high yielding crops such as sugarcane for ethanol, cassava for second generation ethanol, or poplar and switchgrass for Biomass-to-Liquid (BtL) show the best results. Main influencing factors are yields, the use of co-products and production management, such as whether methane emissions from e.g. palm oil mill effluent (POME) are captured. In contrast, **emissions from transport and different agricultural management systems** (tillage versus no-tillage, low input versus high input) **have marginal influences on results**.

Concerning the application of the calculator within GEF activities, the calculation of a GHG balance could be part of all GEF-funded biofuel project proposals. The calculation of GHG savings raises awareness among project applicants of the correlation between improving GHG balances and making biofuel projects more efficient[3].

Table ES-1 presents the screening tool for GHG assessments and Figure ES-1 shows the decision tree project applicants can follow to provide evidence of the GHG calculation.

Table ES-1 Screening tool for greenhouse gas assessment

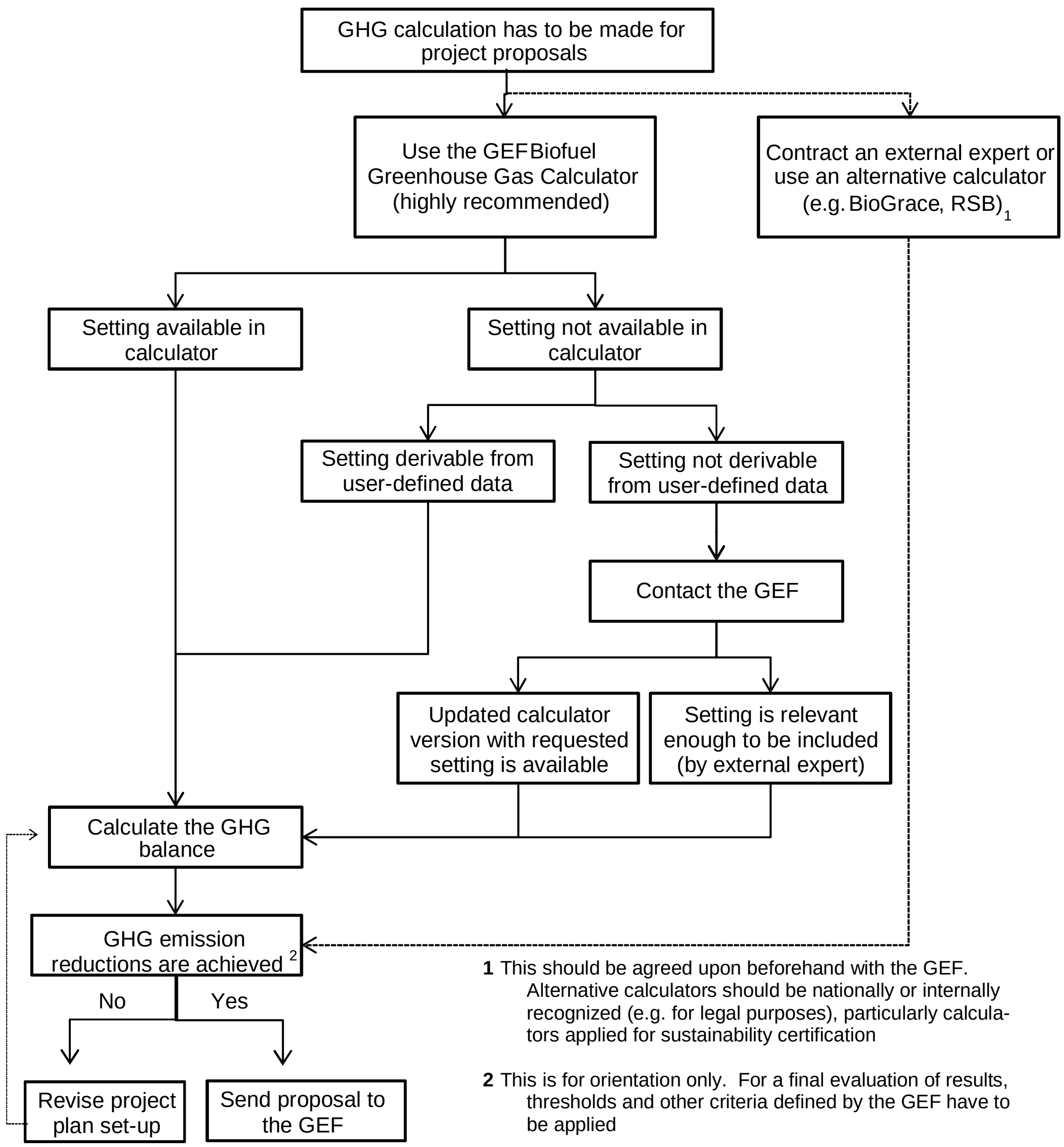
Factors to consider	**GO**	**CHECK**	**STOP**
Net CO_{2eq} savings relative to fossil reference system	More than 50%	Less than 50%	No greenhouse gas savings

[1] The Calculator is made publically available at: http://www.unep.org/bioenergy/Activities/TheGlobalEnvironmentFacilityGEFProject/tabid/79435/Default.aspx
[2] These include both first generation (sugarcane, soy, palm oil) and second generation (cassava, poplar, jatropha, straw, eucalyptus, switchgrass) biofuels in 11 different countries
[3] Airborne life-cycle emissions of non-GHG pollutants from bioenergy also occur during feedstock production, e.g. due to burning of crop wastes (without energy-recovery), and ammonia emissions from fertiliser application, and these should be no higher than those of competing fossil fuels.

Where calculations are made based on individual data (and do not form part of the 74 settings), data requirements are as follows:

- All relevant input data has to be collected along the whole life cycle such as harvest levels, consumption of fertilizers and auxiliary materials, energy inputs etc. Since the GHG calculation is an ex-ante evaluation, advanced data is not yet available and the project development is difficult to predict accurately. Therefore, calculations have to be based on assumptions and expert judgments.
- The background data (emission factors, efficiencies, heating values) needed for calculating the GHG balances of all settings currently implemented are included in the calculator. They can and should be checked by the user. Any need for an update or supplementation should be communicated at the appropriate time in the GEF project.

Figure ES-1 Decision tree for providing a GHG calculation



1 This should be agreed upon beforehand with the GEF. Alternative calculators should be nationally or internally recognized (e.g. for legal purposes), particularly calculators applied for sustainability certification

2 This is for orientation only. For a final evaluation of results, thresholds and other criteria defined by the GEF have to be applied

For the screening process, the following data input is necessary:

- Evidence (literature citations, for example) that the above mentioned assumptions and judgments are within a realistic range given the project's specific circumstances. Furthermore, a consistent and plausible strategy should be provided on how the assumptions will be put into practice.
- Certain life cycle steps have a strong influence on the results, therefore, special attention should be paid to documenting the following factors:
  - o Cultivation step: land use changes, feedstock yields and amount of nitrogen fertilizer.
  - o Processing step: use of co-products, amount and type of energy used, treatment of effluents (especially POME).

Applicants should clearly identify how they will achieve the reported emission saving practices and / or avoid emissions from certain practices assumed in the calculator.

Example land use change:

The conversion of carbon rich ecosystems (e.g. forests) into biofuel feedstock plantations should be avoided at the starting of a project but also during the entire project and after project closure. This means that it has to be guaranteed that cultivation will take place at exactly those areas identified to be suitable and that a switch to any other area with the risk of high carbon emissions can be avoided.

Example use of co-products:

Any co-product occurring during cultivation and processing can be used for allocation as long as it is not disposed of as waste. Therefore, the type and envisioned use of the co-products should be clearly described and documented. For example, oilseed cake evolving from the production of vegetable oil can be used as animal feed and therefore has a market value.

The use of the GHG calculator in GEF-funded biofuel projects is highly recommended as it guarantees high quality, consistent and objective impact estimations. However, the use of alternative methodologies and tools may be acceptable especially if they are well-documented, have been shown to be credible, and are available publically or whose methodologies are published (see Appendix B of the final report for detailed guidance on GHG calculation methodologies used in major certification schemes).

B. Biodiversity

Due to the land use associated with biofuel feedstock cultivation, the protection of biodiversity should be considered a core global benefit concern by the GEF (i.e. going beyond GHG balance), and as such a key issue for biofuel projects. Effects can be positive or negative, strongly depending on location, agricultural and forestry practices, previous and indirect land-use, and the conversion systems used in the downstream chain (processing, distribution and consumption). As a starting point, the information should consider existing GIS data. National authorities responsible for nature protection should be consulted to request further datasets indicating areas of significant biodiversity value. If no adequate mapping data is available, an on-site assessment is needed to verify that the cultivation area has no significant biodiversity value.

The collection of organic wastes and secondary biomass residues bears very low risks to impact biodiversity, as this biomass is not related to a specific production area. Thus, these biomass sources can be used without further requirements. Table ES-2 shows the thresholds for biodiversity (datasets to be considered are listed in the main report).

Table ES-2 Screening tool for biodiversity protection

Factors to consider	**Applicable to**	**GO**	**CHECK**	**STOP**
Conservation of areas of significant biodiversity value	All setting except those using wastes	GIS data or on-site assessment proves that cultivated land is **not** located in area of significant biodiversity value	If located in such an area: management plan to ensure cultivation and harvest do not interfere with nature protection purposes	If located in such an area and management plan is missing or not detailed enough to demonstrate non-interference
Promotion of agricultural practices with low negative impacts on biodiversity	**Not** applicable for **low-input** settings	Proof that management practices lead to cultivation practices with low negative impacts on biodiversity	Description of management practices not detailed enough to determine impacts on biodiversity	Description of management practices missing

C. Land productivity and resource use efficiency

Sustainability of biofuels largely depends on the productivity of the land used, in particular when feedstocks are being directly converted to biofuels production (as opposed to from biogenic residues and wastes which stem from "earlier" biomass production or are co-products from agriculture or forestry). The efficiency of converting feedstocks directly into biofuels should be considered in terms of useful biofuel energy per hectare of land used for feedstock production. Based on the study results, the suggested thresholds for biofuel land use efficiency (productivity) are shown in Table ES-3. For second generation biofuels that convert biogenic residues and wastes, a minimum value for the resource use efficiency has been suggested below in Table ES-4.

Table ES-3 Screening tool for biofuel land use efficiency

Factors to consider	**Applicable to**	**GO**	**CHECK**	**STOP**
Land productivity ($GJ_{biofuel}$/ha)	Low input, marginal land	>25	10-25	< 10
	Intermediate input, marginal land	>50	25-50	< 25
	High input, good land	>100	50-100	< 50

Table ES-4 Screening tool for secondary resource use efficiency

Factors to consider	GO	CHECK	STOP
Conversion efficiency of biogenic wastes and residues (%)	>60	50-60	< 50

D. Soil protection

Land conservation and rehabilitation are an essential part of sustainable agricultural development. To prevent soil degradation from agricultural changes, improved agronomic practices will play a key role. Various types of human activities and natural causes may result in direct soil degradation impacts, which need to be evaluated in the light of biofuel feedstock production. The thresholds for soil protection given in Table ES-5 are applicable to all setting except those using wastes.

Table ES-5 Screening tool for soil impacts

Factors to consider	Applicable to	GO	CHECK	STOP
Productive Capacity of Soil	All settings except those using wastes; **not** applicable for conversion	Soil conservation measures are in place guaranteeing that Soil Organic Carbon (SOC) will not decline within the applied crop rotation scheme	No measurements for positive SOC balance. Proof needed that cultivation/residue extraction will not negatively affect SOC balance	Cultivation area on land with low SOC (e.g. < 1%; threshold depending on soil conditions)
Soil Erosion		Area has low erosion risks (e.g. flat slope) and low salinization risk (e.g. climate and salt content of ground water	Site has risks of erosion, proof needed on suitable soil protection measures adapted to site conditions	No soil conservation measures planned

E. Water protection

The management of water resources is a key global environmental challenge. Freshwater is scarce in some regions of the world and under heavy threat from overexploitation due to growing population, changing diets, pollution, and climate change.

Rain-fed cultivation should be preferred, as under most circumstances, these cropping systems rely on water from precipitation, and competition with other water demands is limited. The greatest potential for increases in yields is in rain-fed areas, especially through enhanced management of soil moisture and improving soil fertility management.

Displacement of former natural vegetation (e.g. forests or woodlands) may decrease evapotranspiration and soil absorption capacities, potentially increasing groundwater table levels and water run-offs. If these additional water resources are used for irrigation or industry, rain-fed feedstock cultivation with high water use rates may result in water competition. Table ES-6 presents the screening tool for water protection.

Table ES-6 Screening tool for water impacts

Factors to consider	Applicable to	GO	CHECK	STOP
Water scarcity risk, catchment and downstream	All settings except those using wastes	**No** irrigation, **or** irrigated cultivated land in risk area **and** water management plan exists	**No** irrigation, **no** data on risk area; water management plan exists	Irrigation, **no** data on risk areas
Water contamination		Local/regional legal requirement met	Legal requirement unclear	**No** legal requirement

ECONOMIC SUSTAINABILITY

The economic analysis focuses on two methodologies: A) cost-benefit analysis (by means of the calculation of the Net Present Value (NPV), and B) life cycle cost calculations (methodology for calculations contained in the main report). Data quality is especially critical for economic calculations and should be site specific since localized conditions can have a major influence. Main factors that influence the outcome are; yield, labor requirements and costs, costs of other inputs such as land costs, packing expenses and fertilizers and the value of by-products that are produced.

A. Cost-benefit analysis using net present value

The calculation of Net Present Value (NPV) can be used as a tool to assess, in advance, the financial impact effects that a project is likely to give rise to and therefore to take go/no-go decisions.

In general, a project is considered to be an attractive investment opportunity for an investor if the net cash flows arising from investment are estimated to be higher than the costs of financing the project. A positive NPV indicates potential profitability, but a negative NPV indicates that the net cash inflows over the total project lifetime are lower than the cost of financing the project and thus, should not be undertaken. When the NPV is close to zero (which indicates the scenario is expected to be no-profit no loss), then the financial viability of the project could be further researched using an extended Cost Benefit Analysis, including other indicators such as, Internal Rate of Return (IRR), Benefit/Cost Ratio (BCR) and Pay Back Period (PBP).

B. Life cycle cost calculation

Calculation of biofuel production costs should include all relevant lifecycle costs, i.e. feedstock production, transportation, pre-treatment and conversion and distribution. It is very important to ensure that the data used in the calculation is of high quality while giving as much spatial detail as possible. Use of generic data is not advisable as biomass costs are highly context specific.

Feedstock production costs: For the production of energy crops or residues up to the farm gate or road side, all the key activities/stages in the development of energy crop plantations and procurement of residues must be itemized and taken into account. The cost items that are typically included are land rent, labor, fuel, agro-chemical inputs, machinery investment and operational and maintenance costs. It is important to note that biomass costs are site specific and localized conditions (e.g. soil, water, climate, yields, terrain, accessibility, land and labor costs) need to be taken into account as much as is practically possible, as this can have an important influence on the final costs. Specific crop production activities depend on the site quality and location which influences many variables such as: site preparation, choice of species, planting density and rotations, required cultural management and soil amendments, degree of mechanization, transport and logistics, and the market value of fossil alternatives.

Transport and conversion costs: For biomass logistics calculations, it is important to have regional specific data (such as distribution of biomass, percentage of land under energy crops, infrastructure by type, transport distance by mode) and conversion plant specifications (including location, scale, efficiency, and load factors). The number of stages in a supply chain varies depending on the feedstock characteristics, pretreatment requirements and infrastructure, but a clearly defined chain with detailed logistical capacity indications (e.g. truck capacities, speed, operational costs per ton-km; specifications for sizing, drying, densifying, conversion, transfers, storage) as well as relevant mass balance is necessary.

It is important in a developing country context to determine what processes are cost effective at small scale and can be carried out locally, and to identify the more capital intensive conversion processes that benefit from scaling effects and centralized processing. Biofuel conversion (especially for second generation biofuels) benefits from economies of scale and it is important to determine the optimal scale of production beyond which feedstock transportation costs become prohibitive. To ensure competitive delivery of biofuels, it is important to optimize the various chain elements against the required logistic capacity (i.e. volumes of biomass being handled), taking into account the supply operating windows and need for maintaining high equipment load factors. Examples of optimization options include using large capacity trucks and ships, early densification of biomass, open air drying, improving effective use of equipment, maximizing the operating window and improving equipment load factors.

For second generation biofuels, the fuel conversion stages are especially capital intensive and thus it is critical that appropriate equipment is identified and costed (given the many potential conversion equipment combinations). It is also important to take note of the relevant equipment specific cost factors (lifetime, interest rate, etc.) and different cost type information (capital-related and installation, consumption-related and operation related). As second generation technologies are not yet mature, it may be necessary to incorporate aspects of time dependent technological learning and scaling up effects in the economic analysis. The establishment of second generation biofuels will entail technology transfer in developing countries and thus involve import dependency risk. However, there are also opportunities for utilization of agricultural and forestry by-products, developing of new supporting industries and skills.

Table ES-7 Screening tool for economic aspects

Factors to consider	GO	CHECK	STOP
NPV	The NPV is positive and compares well to other feedstocks in the region or the same feedstocks in other regions.	The NPV is close to zero.	The NPV is negative.
Life cycle costs	The life cycle costs compare favorably to other feedstocks or countries.	The life cycle costs are neutral compared to other feedstocks or countries.	The life cycle costs do not compare favorably to other feedstocks or countries.
Data quality	Specific regional setting data on costs, yields etc.	Specific cost data is lacking or only generic literature available	Not applicable
Sensitivity (i.e. a measure of whether NPV and life cycle costs remain stable under varying market conditions (e.g. yield, discount rate, wages, land rent etc)	Robust performance, NPV and life cycle costs remain positive/competitive under varying market conditions	No robust performance of NPV and life cycle costs: they are only marginally positive or slightly negative under varying market conditions.	Highly negative performance of NPV and life cycle costs, therefore high risk of project negatively affected by varying market conditions.
Technological complexity and maturity	Technical and industrial capabilities available	Relies on new, (whether proven or not) technology and/or new infrastructure	Not applicable

Results from the current study can be used as benchmark, to identify the ranges in cost prices of 1st and 2nd generation feedstocks per region. Total life cycle cost varies between below US$10/GJ to above US$40/GJ for 1st generation and from US$12-30.3 /GJ for second generation feedstocks, while BtL production costs range between US$10-24/GJ.

SOCIAL SUSTAINABILITY

A. Food security

A key element of social sustainability is food security. The impact of biofuels on food security is not only a function of crop grown, land and conversion technologies used, and how bioenergy supply chains are integrated into agricultural, social and economic systems - it also depends on the level of poverty, potential positive effects of rural development, household income dynamics and overall governance.

Furthermore, food security impacts of biofuel development are different for net agro-commodity exporting or net food importing countries, and differ within countries between rural and urban populations, i.e. the vulnerability towards negative food security effects varies and cannot be easily translated to a given project.

The suggested approach evaluating food security impacts of biofuel projects is, therefore, structured into three tiers. The initial simplified screening is assessed at the feedstock level, being a near-term, ready-to use option which looks at information on the land in which biofuel feedstock cultivation will occur (if any), presented in Table ES-8[4].

Table ES-8 Screening tool for food security – feedstock level

Factors to consider	Applicable to	GO	CHECK	STOP
Food security – tier 1 (feedstock level)	All settings	**Non-edible** feedstock grown on marginal land **not** in competition with food/feed, or intercropping or agro-forestry or unused/underused marginal land	**Non-edible** feedstock grown on marginal land for which competition is unclear	**Edible** feedstock or **non-edible** feedstock grown on land **in competition** with food/feed

B. Labor conditions and human health

For biofuel projects to be considered sustainable, key labor standards and principles of the ILO Declaration on Fundamental Principles and Rights of Work should be met.

Table ES-9 Screening tool for labor and human health

Factors to consider	Applicable to	GO	CHECK	STOP
ILO standards on wages, labour, discrimination and health and safety	All settings	**Fully** implemented in country, **enforced & monitored** on project level	Implemented in country, enforcement & monitoring on project level unclear	**Not** implemented in country or **no** enforcement & monitoring on project level
Scheme of small-scale farmers		Smallholder or outgrower schemes	Centralised outgrower scheme, use of non-local workforce	Non applicable

C. Land tenure

The social use of land is primarily related to the theme of access to land, water and other natural resources. Land access is conditioned by land tenure. From a social sustainability perspective, this might be one of the major concerns associated with bioenergy development in some areas (Table ES-10). If the land is recognized as land with secure rights by national legislation, it is important to provide evidence of the negotiation agreement for any contingent compensation between the investor and the land owner.

[4] The more detailed 2[nd] and 3[rd] tier analysis should be considered as strategic options for biofuel policy development of countries where biofuel projects are under consideration.

Table ES-10 Screening tool for impacts on land tenure

Factors to consider	Applicable to	GO	CHECK	STOP
Land rights	All settings except those using wastes	Titles, contracts/ other formal registration of land tenure held by actors in a national/local registry, traditional land rights are recognized and upheld/defended by formal legal system	Titles, contracts or other formal registration of land tenure subject to negotiations	No titles, contracts or other formal registration of land tenure available, no or unclear recognition of traditional land rights
Public land allocation		Procedure follows due process	Procedure unclear	No procedure if dispute between public and traditional land access, ownership, rights
Dispute settlement		Effective access to fair adjudication, including court system or other dispute resolution processes	Access to settlement unclear; open disputes are unresolved	No access, no evidence of effective and fair judicial processes can be demonstrated
Inclusion of landless people		No restriction on access	Access unclear	No access, uncompensated displacement risk

D. Gender considerations

Gender discrimination has to be given attention because men and women may face different risks associated with biofuels production, in terms of access to land and employment, employment conditions and food security. Women and female headed households should have the same opportunity as men; and male headed households to engage in and benefit from the sustainable production of biofuels[5]. Especially for the growing number of households headed by women, particularly in food insecure countries, the access of women to land to provide for their livelihoods must be ensured.

Table ES-11 Screening tool for gender considerations

Factors to consider	Applicable to	GO	CHECK	STOP
Land rights, employment rights and conditions	All settings	Men and women have the same opportunities and benefits	Women have higher risks and are vulnerable due to socio-economic shocks	Project **threatens** food security of households due to unequal land rights, employment conditions etc.

[5] The GEF's policy on gender mainstreaming (GEF/PL/SD/02, dated May 1, 2012), and on agency minimum standards on environmental and social safeguards (GEF/C.41/10/Rev.1, November 18, 2011) should meet the gender considerations being suggested.

RECOMMENDATIONS

The **Biofuels Screening Toolkit** aims to provide first level guidance on reviewing project proposals for biofuels in developing countries. The full report provides further details on how the “traffic light” system and thresholds have been developed and the tools available to provide evidence for reaching the suggested thresholds.

Below, a list of main conclusions and recommendations are presented for the GEF to consider for prospective work in prioritising and selecting biofuel projects in developing countries, as well as for potential future research and capacity building activities in this field.

- *GHG calculator should be used in project applications, and to ensure higher savings, investments to focus on biofuel crops with higher yields, using co-products and improving production management.* The advantage of having an interactive GHG calculator is that GEF or project developers can tailor biofuel projects to the national circumstances and the specific needs of recipient countries, by inputting local data into the calculator.
- *GEF and implementing agencies are encouraged to support capacity building with regard to the main factors influencing GHG emissions and to raise awareness on the correlation between an improved GHG balance and a more efficient (and thus often cheaper) biofuel production.*
- *Given the higher cost of second-generation biofuels, consideration should be given to capacity-building activities and investments that allow harnessing the potential benefits of innovative technologies that do not cause land use and food security issues.*
- *Projects that address synergies with other development objectives in addition to GHG reduction should be promoted.* Projects involving biofuel production may be designed to have positive benefits in other development areas in a cost-effective, synergistic way. Therefore, it is recommended to pursue a broader perspective in project design that takes into account other development objectives, such as improving productivity, generating employment, increasing access to locally produced energy, reducing land degradation etc.
- *Improving local data collection is key for determining impacts, and improved global land-use mapping/ GIS data are necessary to act as proof for land-use.* GEF could support activities at national, regional or global level to strengthen data availability. Governments and ministries should be supported in collecting comprehensive and current data which can support decision making for biofuel projects.
- *GEF should consider extending the scope of this study to more settings including to decentralised stationary uses of biofuels, such as households where replacing fire-wood and charcoal could reduce pressure on forests, and other negative impacts.* Applications such as biofuels for cooking, conversion of biogenic residues and bioenergy crops into biogas for heating and electricity, could be integrated in many biofuel production systems which would help reducing methane leakage (e.g. in palm oil mills).

The aim of the *Biofuels Screening Toolkit* is to make available a first order screening using the traffic light system. This should give project developers and the GEF an overview of the issues to consider when preparing new projects.

The next step and follow-up to this project could be to study impacts at the national/ regional level, as has been done in a separate report for three countries: Argentina, Mozambique and Ukraine. Such detailed level of analysis at national/ regional level can give better indications to project developers where (geographically) and in what (feedstock-wise) investments should be focusing. At the project level, support of the development of sustainability standards and the take-up of certification schemes could help to simplify biofuel project development. Future work may also be considered for providing more detailed guidance for project developers on how to collect and provide evidence on each of the sustainability indicators.

1 Introduction

Based on a recommendation of the Scientific and Technical Advisory Panel of the Global Environment Facility (GEF STAP) in the 2006 Workshop on Liquid Biofuels, UNEP/DTIE agreed to collaborate with FAO, UNIDO and the IEA in the joint execution of a *GEF Targeted Research Project* that aims to identify and assess sustainable systems in developing countries for the production of liquid biofuels both for transport and stationary applications worldwide.

The outcome of this study should enable the GEF to set clear policies and priorities for future work and investments in biofuel related projects while providing guidance to countries that are keen to engage themselves in this sector. UN agencies in intimate collaboration with scientific institutions worldwide address issues such as life-cycle energy and greenhouse gas assessments, economics, social/food security and pricing and overall environmental impacts, fuel and vehicle compatibility plus stationary applications, scale-up impacts and next generation biofuels in order to arrive at a set of concise and comprehensive recommendations for future use in GEF and beyond.

After approval by the GEF, the project team at IFEU, UNEP, UU and OEKO were contracted in December 2009 to carry out the project. The work was defined in a work and management plan including specification of settings that are considered in the analysis that was developed and agreed on by the members of the project team and endorsed by the steering committee. The set of environmental and social impacts and indicators covered was determined during the inception phase of the project. All 7 main executing partners (DTIE, FAO, UNIDO, IFEU, OEKO, UU and IEA), plus STAP, were actively involved in this exercise through the preparation and participation to the Project Inception Workshop and follow-up discussions.

1.1 Report structure

Nearly all steps within bioenergy fuel-cycles vary with location and time, and each step can be realised with different processes, intensity and efficiency, emission characteristics, land use patterns, etc. and under very different social and economic circumstances. To allow for a conceptual framing of these broad varieties of cases, the so-called setting approach has been developed. “Setting” is defined as a generic representation created by combining fuel chains (“life-cycles”) with socioeconomic (e.g. ownership structure, intensity and scale of production) and environmental (geo- and biophysical, climatic) categories. The concept is explained in more detail in **Chapter 2**.

A thorough life cycle energy and greenhouse gas (GHG) assessment is a major step in determining the sustainability of biofuel development. **Chapter 3** consists of a report about guidance and information for future GEF policies and interventions on GHG and energy balances, certification systems concerning GHG savings and provides an introduction to the Excel-based spread sheet tool, the *GEF Biofuel Greenhouse Gas Calculator*.

The economic viability of the production of liquid biofuels is addressed in **Chapter 4**, allowing the GEF, and others, to identify current and future economically viable biofuels options, and identify GEF interventions that can help achieve economic viability for otherwise promising (i.e. low GHG, resource efficient, environmentally sustainable) options.

The global environmental impacts -other than GHG emissions balance- of the production of liquid biofuels such as biodiversity and land degradation are the focus of **Chapter 5**, to ensure that besides climate change benefits, projects would not bring global environment "*dis*-benefits". This includes a description of a GEMIS-based database.

Chapter 6 contains a report on social standards, criteria and indicators for biofuels to guide GEF project development, including methods for their determination as well as food security impacts and direct and indirect employment effects of biofuel production.

The evaluation of potential future (next generation) types of biofuels is provided in **Chapter 7**. Perennial cropping systems, waste and residue collection systems, pre-treatment technologies and supply systems and two next generation liquid biofuels production technologies are analysed.

In setting mandates and targets, issues of fuel/vehicle compatibility need to be assessed and addressed to ensure feasibility, acceptability and cost-efficiency. The challenge of fostering sustainable transport solutions globally as well as fuel and vehicle compatibility is assessed in **Chapter 8**.

Liquid biofuels used can be used in non-transport applications in the developing world, such as grid or off-grid electricity generation, household cooking and heating. The advantages and disadvantages of biofuels used in stationary applications with regard to cost and environmental effects are analysed in **Chapter 9**.

An integrated scenario-based analysis of the potential and the environmental and socio-economic impacts of biofuel production in Mozambique, Ukraine and Argentina are presented in **Chapter 10.**

Recommendations for future GEF policies and priorities for future biofuel related investments are provided in **Chapter 11**.

The **Annex** provides Definition of Biofuel Supply Chain System Components.

Supporting documents and special studies are provided in the **Appendices.** Details about the life cycle energy and greenhouse gas assessment are found in **Appendix A**. A detailed evaluation of GHG calculations in certification systems in the context of GEF is summarised in **Appendix B**. An important case study *Assessment of next generation biofuel production in the Xinjiang Uyghur Autonomous Region* is provided in **Appendix C** and was prepared by the Xinjiang Academy of Environmental Protection Science (*XJAEPS*), Urumqi/PR China. Data for the economic analysis of settings is summarised in **Appendix D**; for the assessment of next generation biofuels, the data is summarised in **Appendix E**. A report with field data on biofuels from sugarcane in Mexico was prepared by *Red Mexicana de Bioenergía* (*REMBIO*), Morelia/Mexico and is found in **Appendix F**. Background data for global non-GHG environmental impacts of biofuels are provided in **Appendix G**. An assessment of the employment and social effects of biofuels are provided in **Appendix H** and **Appendix I**, respectively.

1.2 Databases

As part of the project, an Excel-based spread sheet tool, the ***GEF Biofuel Greenhouse Gas Calculator*** was developed. This tool has three functions (a) to increase awareness on GHG emission results for biofuel pathways relevant for GEF eligible countries, (b) to make GHG results transparent and replicable and (c) to customise GHG calculations. It is available for download here: http://www.unep.org/bioenergy/Activities/TheGlobalEnvironmentFacilityGEFProject/tabid/79435/Default.aspx.

A second database, the ***GEF Non-GHG Environment Database*** is GEMIS-based and contains data on water use, selected air emissions and water effluents as well as solid wastes from biofuel supply chains for selected settings. It is available for download here: http://www.iinas.org/gemis-download-en.html

1.3 Elements of a GEF project Biofuels Screening Toolkit

The proposed toolkit uses a traffic light system for biofuel project applications submitted to the *Global Environmental Facility* (GEF) under the GEF-5 programme (i.e. fifth replenishment of resources of the GEF Trust Fund). The objective of the screening toolkit is to enable the GEF and its *Implementing Agencies* (IA) to assess on the bases of the *Project Identification Forms* (PIF) if a biofuel project brings adequate *Global Environmental Benefits* (GEB) and any other additional benefits. Furthermore, it can be used by applicants in GEF eligible countries to improve their applications. The toolkit covers two sectors of environmental issues: those identified as *Global Environmental Benefits* (GEBs) and additional benefits, i.e. social benefits and economic viability.

1.4 Cross-cutting methodological issues

Throughout this study, two key methodology issues arise which needs consideration upfront that are briefly discussed below:

- indirect effects of biofuels, and
- the “traffic light” concept for screening biofuel project.

Direct and Indirect effects

Throughout this report, a cross-cutting issue is the occurrence of **indirect effects** which always can arise if the analytical scope for a complex system is reduced to a certain aspect. In the case of liquid biofuels for energy (including transport), the complex system is the provision of feedstocks and their downstream processing which delivers not only energy carriers, but also several by- and co-products. Furthermore, the land on which cultivation of feedstocks takes place could have a previous use (or an alternative use potential) so that land use changes are an important issue to be addressed (see Chapter 3).

Indirect effects of biofuel feedstock cultivation can occur when the cultivation of feedstocks and co-products **displace** former biomass production (“growing-out”), and the demand for the previously cultivated feedstocks will most likely still remain, i.e. they will be produced, somewhere else; in the neighborhood or, due to global markets, elsewhere in the world, and may cause direct effects at the new production site.

Due to this “non-local” nature of indirect effects they are not under the control of a specific project and, thus, are difficult to address. Indirect effects may especially impact biodiversity (Hennenberg et al. 2009) and to some extent soil. However, in contrast to GHG emissions (see Chapter 3) no methodological approach is currently available to assess indirect effects with regard to the non-GHG environmental categories[6].

Further indirect effects result from the **price** feedbacks of the economic system: once a commodity is used more, but supply is constrained, prices tend to increase. Depending on the elasticity, the demand for that commodity will adjust to the new price, and this will in turn affect production levels, and - hence - adjust prices again. A key issue in these feedbacks is the **volatility** of prices, i.e. their fluctuations, which can negatively affect both producers and consumers, especially for food and feed (see Chapter 4).

The indirect effects cannot be “observed”, as only direct effects of land use and price changes can be monitored, and cause-effect chains must be added to those. This means that indirect effects can be addressed adequately only through complex modeling which allows for (price) feedbacks, substitution, and market segmentation.

This report does not carry out own modeling for that, but refers to most recent literature and studies addressing indirect effects. It should be noted, though, that **a broader biomass policy approach** which considers all land uses in all countries could avoid indirect effects by extending the focus to all relevant sectors, and the full geographical scope.

The traffic light approach

To analyze potential biofuel projects with regard to sustainability, a multitude of criteria and indicators is needed, which makes both the analysis and the assessment of options a time-consuming activity.

To allow for a first screening of projects in order to identify potentially critical issues, and separate projects with a very good sustainability performance, this study developed the so-called “traffic light” approach which is compatible with the logic of the UN Energy Decision Support Tool for Bioenergy (2010).

This approach determines three levels of quantitative and qualitative “thresholds” for each of the criteria and respective indicators expressed as “Go” (green), “Check” (yellow) and “Stop” (red). Although the overall concept is easy, it needs implementation and description on the level of each sustainability criterion, and the respective indicators.

This is provided in the respective sections of this study.

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6 In JRC (2011), a limited approach to quantify indirect biodiversity effects is suggested, but has not been used in a broader context so far.

2 Biofuel settings

2.1 The settings concept

Nearly all steps within bioenergy fuel-cycles vary with location and time, and each step can be realised with different processes, intensity and efficiency, emission characteristics, land use patterns, etc. and under very different social and economic circumstances. Among the variables are the type of fuel produced, the feedstock used, the soil characteristics and climate conditions where production occurs, the type of cultivation, socio-economic conditions (e.g. price of labour and fuels, (un)employment rate, availability of land for energy crop production, ownership of land), among other factors. There is a multitude of farming and forestry systems, residue extraction or waste collection systems, downstream conversion routes, and waste treatment options as well as their respective links to auxiliary energy, as well as fuel and material inputs and associated transports.

To allow for a conceptual framing of this broad variety of cases, the so-called setting approach has been developed. “Setting” is defined as a generic representation created by combining fuel chains (“life-cycles”) with socioeconomic (e.g. ownership structure, intensity and scale of production) and environmental (geo- and biophysical, climatic) categories. All settings form a multidimensional matrix with dimensions describing the full multitude of combinations. In practical terms, this can be represented by a sequence of matrices (e.g. spread sheets) which is valid for a specific sub-set. A schematic overview is shown in Figure 2-1.

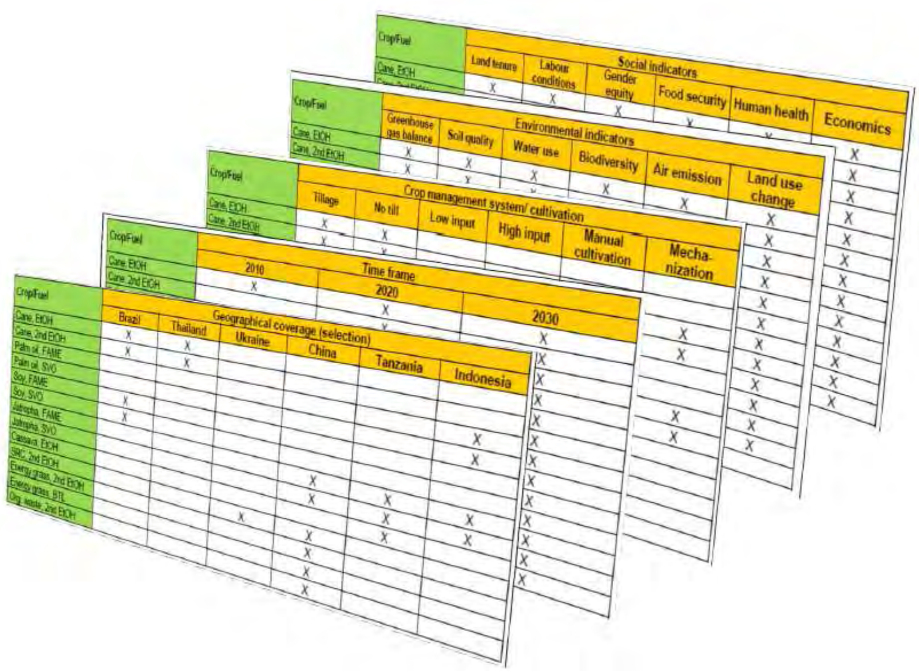


Figure 2-1 Multi-dimensional settings scheme

2.2 Overview on settings used in this report

Environmental impacts, the scale of production, social and economic impacts can be either regarded as separate setting dimensions or as sub-components of the analysis. In order to keep the structure of the settings approach manageable, the number of settings has been kept small and they have been analysed on the impact side. Consequently, the following dimensions are being considered:

- Fuel output
- Feedstock input
- Geographical scope
    - Soil and climatic conditions (within geographical scope)
    - Socio-economic conditions (within geographical scope)
- Crop management system / cultivation
- Time frame

2.2.1 Fuel output

All liquid fuels that have reasonably large market shares are considered:

- SVO (Straight Vegetable Oil)
- Biodiesel, 1st generation FAME (Fatty-acid methyl ester)
- Biodiesel, 2nd generation BTL (Biomass-to-Liquid)
- Ethanol, 1st generation
- Ethanol, 2nd generation (enzyme-enhanced lignocellulose conversion)

There are further fuels such as bio-butanol, bio-methane and bio-electricity for transport, but they are outside of the scope of the study.

2.2.2 Feedstock input

The list of potential feedstocks is long. The selection of feedstocks that are considered for analysis is the result of discussions at the inception meeting in Paris, April 15-16, 2009. It reflects a compromise between the goals of a representative list that applies to many geographical regions and a manageable list given the resources available. The following feedstocks (with reference – between parentheses – to the liquid fuels they are converted to) were selected:

- Sugarcane (1st and 2nd generation EtOH)
- Cassava (EtOH)
- Oil palm (FAME, SVO)
- Energy grass (2nd generation EtOH, BTL)
- Soy (FAME, SVO)
- SRC: short rotation coppice (BTL, EtOH)

- Jatropha (FAME, SVO)
- Organic residues such as rice straw (2nd generation EtOH)

Some other feedstocks are worth mentioning, such as maize, rapeseed, sweet sorghum, pongamia, castor, cotton, sunflower, and algae, but those were not selected at this time for the purpose of this *targeted* research project.

2.2.3 Geographical coverage

The combinations of feedstocks and geographical coverage that have been selected for the project are listed in Table 2-1. Often several AEZ (agro-ecological zones) exist in a given country. These are considered as a sub-component in the analysis. The selection of feedstocks and geographical areas is believed to provide a representative selection from the multitude of potential settings. The settings that are used in further analysis on land availability for energy crops in Chapter 10 are shown in **bold**. These settings are also used to exemplify methodological issues of energy and greenhouse gas assessments in Chapter 3.1, where jatropha from Tanzania is used as an additional example.

Table 2-1 Combinations of feedstocks and geographical coverage

	Soy	Sugar cane	Oil palm	Jatro-pha	Cassa-va	Energy grass	SRC	Residu es
Africa								
Mali				X				
Mozambique		***X***			***X***		***X*** a)	
Tanzania				X	X			
Americas								
Argentina	***X***					***X*** *b)*		
Brazil		X					X a)	
Columbia			X					
Asia								
China								X d)
India				X				
Indonesia			X					
Malaysia			X					
Thailand					X			
Europe								
Ukraine							***X*** *c)*	***X*** *d)*

a) eucalyptus, b) switchgrass, c) poplar d) cereal straw

2.2.4 Crop management system

The management systems are described per feedstock. Three differences of management systems are taken into account:

- Tillage / no tillage
- Low inputs / intermediate inputs / high inputs
- Low level of mechanisation / high level of mechanisation / no mechanisation

Tillage/no tillage

Tillage practices affect various aspects of agricultural systems, such as soil functions and other soil characteristics. Soil characteristics have impacts on the amount of residues that can be removed from the fields and water retention, and thus affect crop yields. Also the amount of chemical fertilisers and herbicides applied depends on the type of tillage practice.

Low inputs/intermediate inputs/high inputs

The level of inputs influences the labour requirements for feedstock production, affecting the expenses and the yields. Table 2-2 provides a detailed overview of the different activities that are included per level of inputs. Also the quantities of fertilisers and pesticides vary between the levels.

Table 2-2 Activities included in the different input systems

	Field clearing	Filed preparation	Planting	Weed control	Pruning	Fertilisation	Pest and disease control	Irrigation	Harvesting	Post-harvest activities
Low inputs	●	●	●	●					●	●
Intermediate inputs	●	●	●	●	●	●	●		●	●
High inputs	●	●	●	●●	●	●●	●●	●	●	●

Low level of mechanisation / high level of mechanisation / no mechanisation

The level of mechanisation has an influence on production expenses (field clearing, field preparation, planting, weed control, fertilisation etc.) and potentially on the socio-economic impacts. There is a 'normal' or most common level of mechanisation (referred to as 'low level') and a level of mechanisation that can be realised in the future (referred to as 'high level') including quantities per level of input, and related changes in, e.g. labour requirements, yields etc..

2.2.5 Time frame

Two timeframes are included; 2010 and 2020 (for 2nd generation biofuels: 2020 and 2030). For 2020/2030 estimations were made from yield and cost developments.

2.2.6 Impact categories

For a given setting (i.e. combination of dimensions), an array of impact categories are considered. The following **environmental impact categories** are addressed:

- Greenhouse gas emissions
- Soil quality and erosion

- Water use
- Biodiversity
- Land use change
- Solid and liquid waste products
- Air emissions

The following **social impact categories** are addressed**:**

- Economics
- Land tenure
- Labour conditions
- Social (including gender) equity impacts
- Food security
- Human health impacts

2.2.7 Selection of settings for analysis

The theoretical matrix of 5 fuel types, 8 feedstock types, 12 geographical areas, 8 combinations of crop management/cultivation systems and 3 time frames would result in 11,520 different settings. The combinations were limited as described in Chapters 2.3 and 2.4. A total number of 74 representative, though partially overlapping, settings for further analysis were selected and are shown in Table 2-3. A detailed description of all settings is presented in Appendix D-1.

Table 2-3 Selection of representative settings for analysis

Feedstock	**Fuel**	**Time frames**	**Geographical areas**	**Crop management systems**	**Number of settings**
Sugar cane	EtOH	2	2	2	8
	next EtOH	2	1	1	2
Palm oil	FAME	2	3	2	6
	SVO	1	1	1	1
Soy	FAME	2	1	3	6
	SVO	1	1	1	1
Jatropha	FAME	2	3	13	16
	SVO	1	1	1	1
Cassava	EtOH	2	3	3	15
Short rotation crop	next EtOH	2	2	1	6
	BTL	2	1	1	4
Energy grass	next EtOH	2	1	1	2
	BTL	2	1	1	2
Organic residues	next EtOH	2	2	1	4
Total					**74**

The settings are the basis for the environmental, economic, social and technical assessments in the following chapters. In each chapter, the settings' impacts are evaluated in a way that is adapted to the availability of data, the required depth of the analysis and need to generate results for the GEF decision making process. For certain impacts (e.g. social impacts), an aggregate of settings or selected representative settings are considered. The medium-term impact from climate change (i.e. impact resulting from increased climate variability) on settings characteristics is acknowledged to the extent possible.

3 Life cycle energy and greenhouse gas (GHG) assessment

The following sections deal with different aspects of life cycle energy and greenhouse gas assessments of liquid biofuels. Chapter 3.1 gives some general notes on how energy and greenhouse gas balances are calculated and on the key parameters influencing the results. Chapter 3.2 presents the GEF GHG calculator that calculates GHG balances for all 74 biofuel settings that were identified in Chapter 2. Chapter 3.3 provides an overview on greenhouse gas calculation methodologies as they are applied in certification schemes, i.e. in a more political context.

3.1 Energy and greenhouse gas (GHG) calculation of liquid biofuels

Biofuels for transport have been promoted for their environmental virtues since they are said to save non-renewable energy resources and to mitigate greenhouse gas (GHG) emissions as the raw material (i.e. biomass) is renewable. However, when looking at the entire life cycle of biofuels – from biomass cultivation (including the input of fuels, fertilisers and pesticides) through conversion into liquid biofuels and combustion – considerable amounts of (mostly non-renewable) energy resources are used which are associated with greenhouse gas emissions. In addition, changes in organic carbon stocks (due to land use changes) and the resulting GHG emissions have to be taken into account. The question is whether liquid biofuels generate fewer emissions than the fossil fuels that they replace i.e. whether their use is beneficial for the climate. Life cycle assessment is a tool used to answer this question.

This section explains the methodology of life cycle assessments and key methodological issues that influence the results of life cycle energy and GHG balances (Chapter 3.1.1). Subsequently, compliance of life cycle GHG calculations with the EU Renewable Energy directive (EU 2009) and United Nations Framework Convention on Climate Change (UNFCCC 2009) is reviewed (Chapters 3.1.2 and 3.1.3).

3.1.1 Life cycle energy and greenhouse gas balances of liquid biofuels

Numerous publications on life cycle energy and greenhouse gas balances of biofuels can be found (see reviews by Quirin et al., 2004, Larson, 2006, Menichetti & Otto, 2009). Interestingly, their results sometimes differ quite substantially, even for the same biofuel pathway. Most often, differences in goal and scope definition and/or methodological choices are responsible for this (Gnansounou et al., 2009, Cherubini et al., 2009). The objective of this chapter is to highlight key methodological issues associated with the calculation of life cycle energy and greenhouse gas balances which are two constituent parts of a life cycle assessment (LCA). Further (global) environmental impacts are discussed in Chapter 5.

3.1.1.1 A brief introduction to life cycle assessment

The environmental impacts of a product are typically quantified by performing a so-called life cycle assessment (LCA) which looks into primary energy consumption and greenhouse gas emissions associated with the product. LCA is a structured, comprehensive and internationally standardized method (ISO, 2006) and considers:

- **The entire life cycle of the product** from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (a so-called “cradle-to-grave” or “well-to-wheels” approach). Moreover, all co-products are accounted for.
- **All inputs and outputs** such as biomass and other raw materials, ancillary inputs and energy carriers as well as all co-products and emissions.
- **Potential environmental impacts**, e.g. the use of non-renewable primary energy carriers and environmental consequences of releases such as climate change induced by greenhouse gas emissions.

Taking a life cycle perspective, i.e. considering the entire life cycle including all co-products and land use changes, is essential for avoiding a shift of environmental burdens from one stage of the life cycle to another, from one geographic region to another or from one impact category to another. The ISO 14040 and 14044 standards (ISO, 2006) provide an indispensable framework for LCA, however, they leave the individual practitioner with a range of choices, which can affect the results of an LCA study. This flexibility is essential in responding to the large variety of questions addressed, but complicates the comparison of studies.

There are four iterative phases in a LCA study: (1) goal and scope definition, (2) inventory analysis, (3) impact assessment, and (4) interpretation. The first phase (goal and scope definition) is most important. It determines the intended application of the study, identifies the targeted audience and defines the object of the study, i.e. the question(s) to be answered. These parameters already pre-determine or at least influence the choice of applicable methodologies. As a consequence, the large variety of questions potentially addressed inevitably leads to different choices and results. In the inventory analysis phase, all inputs and outputs are collected, e.g. the emission of greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4) or nitrous oxide (N_2O). To account for differences in global warming potential (GWP), all GHG are converted into so-called CO_2 equivalents in the following impact assessment phase. Per definition, the GWP of CO_2 is 1 and the conversion factors are 25 for CH_4 and 298 for N_2O (IPCC, 2007a).

3.1.1.2 Key methodological issues

In the following section, the most important methodological issues in the context of biofuels are described and discussed. In Figure 3-1, these issues are marked with red numbers.

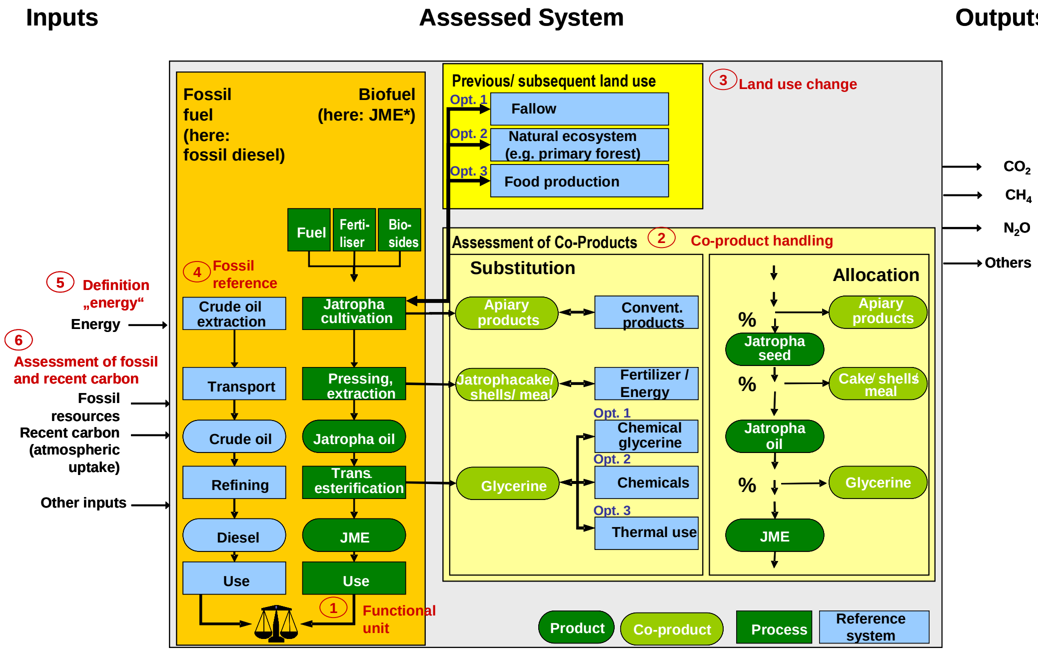


Figure 3-1 Life cycle comparison between Jatropha biodiesel (Jatropha oil methyl ester, JME) and conventional diesel. Key methodological issues are marked with red numbers.

Subsequently, the effects of methodological choices on LCA results are exemplified for selected GEF case studies. Further details and examples are given in Appendix A. Very often, a so-called comparative LCA is performed, in which the product's environmental impacts are compared to the impacts of a superseded conventional product. Figure 3-1 depicts a life cycle comparison between a biofuel and a conventional fuel.

① Functional unit

An LCA is always anchored in a precise, quantitative description of the function(s) provided by the analysed system, the so-called functional unit. The functional unit is supposed to reflect the goal and scope definition. The results of energy and greenhouse gas balances of biofuels are often related to functional units such as:

- 1 MJ of biofuel (absolute results, product basis)
- 1 hectare of cultivated land (absolute results, area basis)
- percentage of energy / greenhouse gas (GHG) emission saving (relative results).

Due to the large variety of questions addressed in LCA studies, there is no universal 'best choice'. It is impossible to directly compare the results of studies with different functional units as the chosen functional unit affects the interpretation of results.

② Co-product handling

Biofuel production typically entails multiple output products (i.e. main product and co-products) with different functions, e.g. biodiesel, press cake and glycerine. For each process, it is necessary to account for the energy consumption and GHG emissions associated with each of the obtained products (functions). There are two different approaches to solve this multifunctionality:

- *Substitution:* A co-product is substituted with an alternative way of providing it, i.e. the process that the co-product supersedes. This means that the avoided environmental burden of another system is subtracted from the analysed system.
- *Allocation:* The amounts of the individual inputs and outputs are partitioned between all output products according to some allocation criterion. Allocation can be performed in accordance with underlying causal physical relationships (mass, volume etc.) or with another relationship (energy content, market price etc.).

According to the ISO standards for LCA, allocation should be avoided wherever possible. However, for the purpose of regulation, e.g. legal acts stipulating the compliance with GHG emission saving thresholds, the substitution method is considered less suitable. As a consequence, allocation based on energy content is often chosen as it is easy to apply, predictable over time and indisputable. What is not reflected, however, is the fact that the specific use of co-products actually does affect the results considerably (cf. Figure 3-3).

③ Land use change

The cultivation of dedicated crops for biofuels requires land which, in consequence, cannot be used for other purposes such as food, feed production or nature conservation. Land-use changes comprise any change in land use which is directly or indirectly induced by the cultivation of dedicated crops. Two types of land use change are distinguished (Fehrenbach et al., 2008):

- *Direct land use change* (dLUC): Cultivation of dedicated crops on existing agricultural land which formerly was not used for crop production (e.g. replacing fallow / set-aside land or grassland) or on new cropland resulting from the conversion of (semi)natural ecosystems such as grassland, forest land or wetland.
- *Indirect land use change* (iLUC): Cultivation of dedicated crops on agricultural land which so far was used for food and feed production. Provided that the demand for food and feed is constant, food and feed production is displaced to another area where again unfavourable land-use changes might occur.

Land use changes affect the carbon stock of above- and below-ground biomass, soil organic carbon, litter and dead wood. The resulting release (or sequestration) of carbon – mainly in form of CO_2 – has to be accounted for in GHG balances.

Regarding dLUC, two issues are debated: (1) the magnitude of the carbon stock change and (2) the annualisation of emissions resulting from singular events, i.e. a partitioning over a certain period of time. The magnitude of change depends on the previous land use, the type of dedicated crop (annual or perennial) and the subsequent land use, the latter being omitted in many studies. In terms of annualisation, the ISO standards do not specify any time span.

Both above mentioned issues significantly affect the results. Regarding iLUC, however, there is no commonly accepted method on how to quantify its effects, let alone how to integrate iLUC into LCA studies (Rettenmaier et al., 2010).

④ Fossil reference product

The so-called fossil reference product (or fossil fuel comparator) is the conventional product which is replaced by the biofuel. The fossil reference product must be clearly defined in the goal and scope definition phase. Depending on this, the results may vary because of:

- Differences in definitions, e.g. average vs. marginal fuel (or fuel mix). In the EU for example, the emissions of the fossil fuel comparator are defined as the 'latest available actual average emissions from the fossil part of petrol and diesel consumed' (EU 2009).
- Quantitative differences in emissions related to fuel (or fuel mix) production due to regional fuel origin (e.g. Brent, WTI etc.) and utilised refinery technology.

The choice of reference product considerably affects LCA results (for further details cf. Appendix A).

⑤ Accounting for primary energy consumption (only relevant for energy balances)

The life cycle energy consumption of biofuels is usually expressed in terms of primary energy[7]. However, it must be further specified which type of primary energy is considered and how the primary energy content of biomass is calculated:

- *Non-renewable vs. total primary energy:* the majority of LCA practitioners choose non-renewable primary energy demand, however, studies reporting total primary energy demand can be found.
- *Primary energy content of biomass:* although most commonly defined as the lower heating value (LHV) of the harvested biomass, deviating definitions can be found.

LCA results differ significantly depending on these definitions (cf. Appendix A)

⑥ Accounting for fossil and biogenic carbon (only relevant for GHG balances)

Carbon dioxide (CO_2) emissions can originate from either (recent) biogenic or fossil carbon stocks. In the case of biofuels, the amount of CO_2 released into the atmosphere from direct biofuel combustion equals the amount of CO_2 that recently has been taken up by the plants. This release of biogenic CO_2 is considered carbon neutral, i.e. it does not fuel climate change. There are two approaches to handle recent and fossil carbon stocks:

- Distinguishing between biogenic and fossil CO2 and accounting only for the latter
- Considering all CO2 emissions as well as all CO2 uptakes.

In this context, fatty acid methyl ester (FAME, biodiesel) is an interesting example as the FAME molecule consists of biogenic (fatty acids) and fossil carbon (methanol) (cf. Appendix A for more information).

[7] Primary energy is defined as the energy content of primary energy carriers (e.g. fossil fuels, uranium ore, biomass) and primary energy flows (e.g. wind, solar radiation) which have not been subjected to any transformation.

3.1.1.3 Results exemplified for selected GEF case studies

The key methodological issues described above significantly affect the results of the energy and greenhouse gas balances. Figure 3-2 to Figure 3-4 show selected results for the GEF case studies “Jatropha oil Fatty Acid Methyl Ester (FAME)” and “Eucalyptus next generation ethanol”. More results can be found in Appendix A. In the following, a few findings are highlighted:

- The choice of functional unit may lead to diametrically opposed results and interpretations: Jatropha FAME from marginal land performs better than next generation ethanol (next EtOH) from eucalyptus if GHG emissions are related to the unit product (GJ biofuel) but vice versa if related to the unit area (hectare).
- The specific use of co-products has a considerable impact on the results: if the substitution method is applied in the example chosen, the results differ up to a factor of two. The range of results is narrower if the allocation method is used.
- Both the magnitude of the carbon stock change and the annualisation of GHG emissions significantly affect the results and may even lead to a change of sign: in case of converting savannah to arable land for Jatropha cultivation, annualisation over 25 years would result in additional GHG emissions, whereas annualisation over 100+ years would result in GHG emission savings.

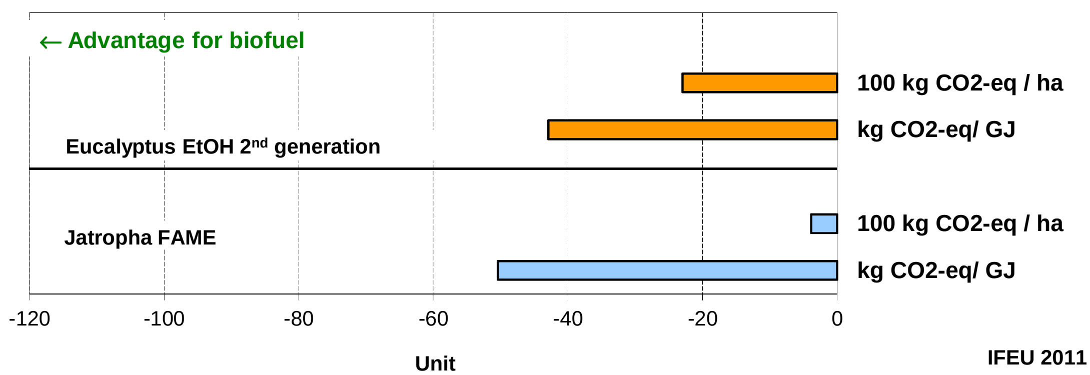


Figure 3-2 Results of the GHG balance for Jatropha FAME (Tanzania, smallholder, low input, marginal land) and Eucalyptus next EtOH (2nd generation, Mozambique, less suitable land).

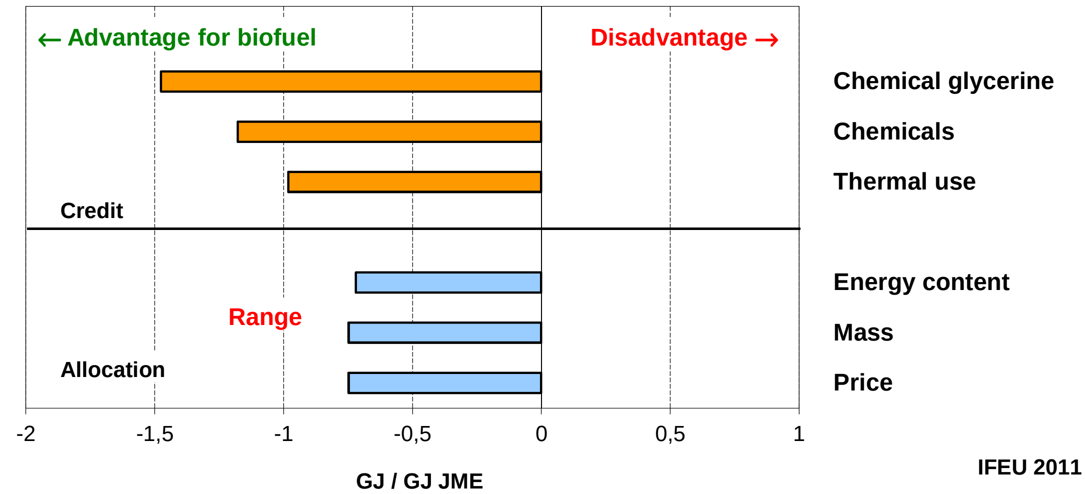


Figure 3-3 Results of the energy balance for Jatropha FAME for different options in terms of co-product (glycerine) handling.

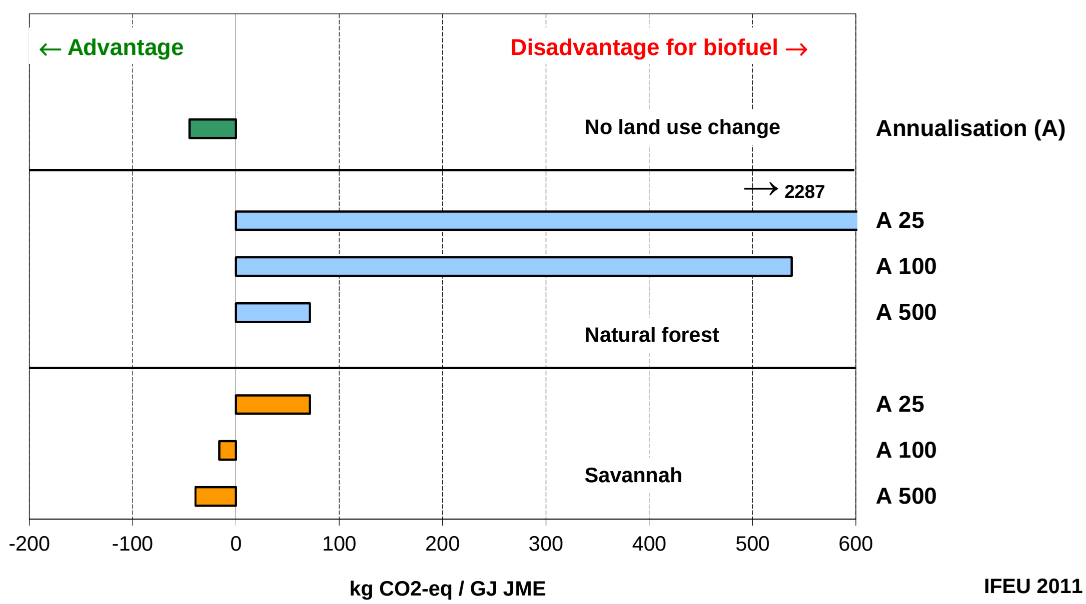


Figure 3-4 Results of the GHG balance for Jatropha FAME for different options in terms of land use change and annualisation

3.1.1.4 Recommendations

Life cycle energy and greenhouse gas balances using life cycle assessment (LCA) methodology are a suitable tool to assess important aspects of the environmental impact of biofuels, despite well-known (but mostly explicable) differences in results. However, as methodological choices may lead to major deviations in results, it is important to apply a tailor-made GEF calculation tool providing comparable and reliable results. Most importantly, the underlying methodology, assumptions and data should be clearly documented. When evaluating a proposed GEF project, it is crucial to identify the goal and scope of that project, in order to select the most suitable options in the GEF calculation tool.

3.1.2 Compliance with EU Renewable Energy Directive

The EU Renewable Energy Directive (RED) sets a mandatory target for the share of renewable energy in the transport sector (10% by 2020), most of which is expected to be met by biofuels. Increased environmental awareness has led to a number of safeguards in the form of sustainability criteria, which biofuels have to meet to be able to be accounted towards the target. One of these sustainability criteria is to achieve certain greenhouse gas emission savings.

The RED contains rules for calculating the greenhouse gas impact of biofuels as well as default values for some of the most common biofuels. Further information on RED calculation rules are given in Chapter 3.2.5 and Appendix B. The GEF tool for GHG balances can also be used to calculate balances in accordance with EU RED (cf. Chapter 3.5). Regarding the GEF case studies, only 5 out of the 12 biofuel pathways can be found in the current list of default values (Table 3-1). Currently, biofuels from crops such as jatropha, cassava and energy grass are not included in the list.

Table 3-1 Biofuel pathways covered by the GEF project and availability of RED default values

No	Feedstock	Origin	Liquid biofuel	RED default value
1	Soy	Argentina	FAME, SVO	FAME
2	Sugar Cane	Mozambique	1st and 2nd EtOH	1st EtOH
3	Jatropha	Mozambique	FAME, SVO	-
4	Cassava	Mozambique	EtOH	-
5	Energy grass	Argentina	2nd EtOH, BTL	-
6	SRC (eucalyptus)	Mozambique	BTL	BTL
7	SRC (poplar)	Ukraine	BTL	BTL
8	Residue (straw)	Ukraine	2nd EtOH, BTL	2nd EtOH

3.1.3 Compliance with UNFCCC

The UNFCCC provides methodologies for calculating GHG emission savings tradable within the international emission trading system based on the Kyoto protocol. For emission savings from the production and use of biofuels, there is currently only one approved methodology available: Methodology ACM0017 “Production from biodiesel for use as a fuel”. The applicability of this methodology is very limited. The development of new methodologies stalled because of the status of international negotiations on climate change. Therefore, certification under UNFCCC is currently not helpful within the GEF context.

Table 3-2 Main characteristics of UNFCCC ACM0017 methodology: Production from biodiesel for use as a fuel (UNFCCC, 2009)

Coverage	Biodiesel from seed oil grown on degraded or degrading land or within afforestation and reforestation projects
Land use change	DLUC addressed (baseline definition, but only soil carbon) ILUC considered not relevant (as only on degraded land)
Co-product handling	Four options: allocation by market price, substitution, allocation by energy content or attribution of all emissions to the main products
Uncertainty assessment	Detailed, parameter specific assessment needed
Data and defaults	Default values available for cultivation of Jatropha and oil palm. Individual data needed for all other plants and processes.

3.2 Setup of a spread sheet-based calculation tool for GHG balances

3.2.1 What is the purpose of the tool?

As part of the GEF project, the Excel-based 'GEF Biofuel Greenhouse Gas Calculator' was developed. This tool has different purposes:

1. **Increasing awareness on GHG emissions of biofuel pathways relevant for GEF eligible countries:** the tool generates life-cycle GHG emission results for all 74 biofuel settings defined in Chapter 2. Therewith it gives a comprehensive overview of GHG emissions related to biofuel production and use in developing countries. The results are summarised in a lookup table in Chapter 3.2.4.2. They can be used during biofuel project preparation phases (i.e. PIF submission) to gain an overview of the impact of that project in terms of GHG savings. Results can also be used indicatively for estimating the impacts of biofuel projects that are carried out in similar settings to those covered by the tool.
2. **Making GHG results transparent and replicable:** for users with a deeper interest in greenhouse gas balancing, the tool provides transparency with respect to the 74 greenhouse gas calculations. It lists all relevant input data for each life cycle step, emission and conversion factors as well as actual emission calculations. Thus results become replicable and the calculation methodology can be transferred to pathways not yet included in the tool.
3. **Customise GHG calculations:** the user can customise the pre-defined settings to his/her needs by using own input data (e.g. different yields). For this purpose every

calculation sheet (covering a certain feedstock / biofuel combination) contains a so-called ‘user-defined’ column where own input data can be entered. In the GEF context, user-defined calculations can be used to determine the exact GHG emissions or reductions of a specific project – either beforehand or in the context of an ex-post evaluation. The tool thus can supplement the ‘Manuals for calculating GHG benefits of GEF project’.

It has to be noted that all 74 GHG balances which are pre-calculated within the tool – and thus all ready-to-use results – only apply to the pre-defined settings. Furthermore, the given results do not present averages of the countries but are to be viewed as case study results that only apply to the specific circumstances listed for each setting. Thus, a transfer of results can only be done indicatively to feedstocks and biofuels that are produced under similar conditions. For a given feedstock / biofuel combination, results can be adjusted in the user-defined column by using own input data and select country-specific electricity and fuel mixes. However, if there is a need for new feedstock and / or biofuel pathways, new calculation sheets have to be set up in the tool.

In the user-defined columns of the tool, customisation possibilities are restricted to keep it simple and thus make it applicable to the widest possible group of users. It is possible to enter own input data while the transformation into greenhouse gas emissions is done automatically. The formulas cannot be changed by the user. However, a skilled user still could use the tool to make more elaborate calculations. For example, a detailed description is included in the tool on how to make the results conform to EU RED, i.e. to prove compliance with the GHG reduction thresholds stipulated in the EU RED (see Chapter 3.1.2 for explanations). The information on material and energy inputs could be used as a basis to add on alternative calculations. For example, references for co-product allocation could be changed or the substitution method could be added (see Chapter 3.1.1.2 for explanations on co-product handling).

3.2.2 A short introduction to the tool’s structure

How is the tool structured?

The tool includes several sheets:

- The ‘Directory’ sheet lists all pathways and settings and includes links to each pathway.
- The ‘About’ sheet explains abbreviations and the general mode of operation of the tool.
- The ‘Background data’ sheet lists all CO2 emission and other conversion factors (e.g. heating values, densities) that are necessary for calculating the GHG balances.
- The ‘Lookup table’ sheet summarises the GHG emission and savings results of all 74 biofuels in a condensed way.
- The ‘Diagrams’ sheet contains ready-to-use diagrams for all results. Results in the graphs are presented for two functional units: per MJ fuel and per hectare
- The ‘References’ sheet includes all references used in the tool.

The introductory sheets are followed by pathway calculation sheets where the GHG calculations of the 74 settings are presented in a most transparent way.

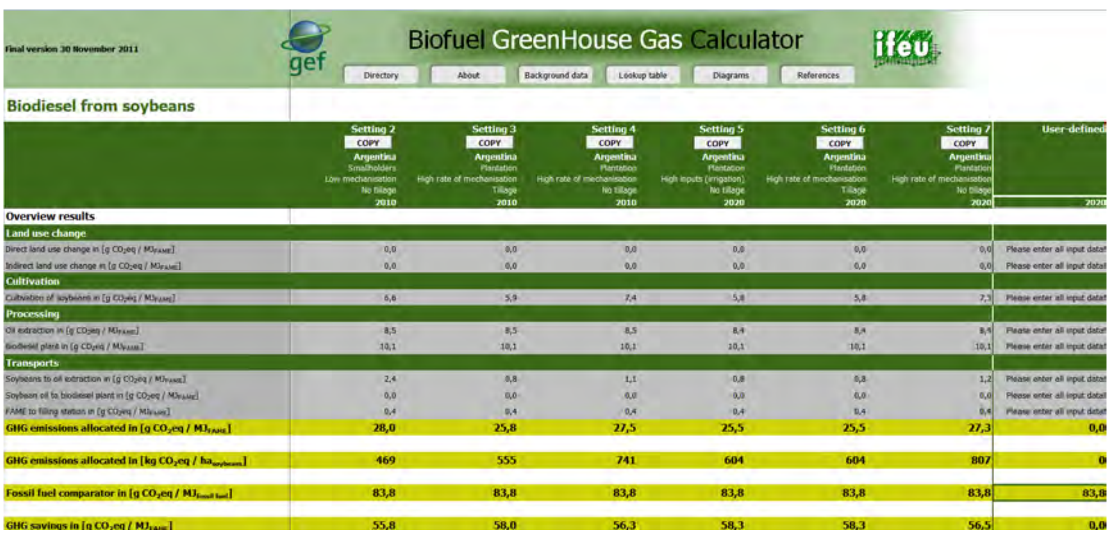
How are the pathway calculation sheets structured?

The pathway calculation sheets cover specific feedstock / fuel combinations (e.g. biodiesel from oil palm). Within the sheets calculations are made for several settings covering different countries and different cultivation conditions (e.g. plantations and smallholders, low input and high input; see Chapter 2). The key specifications of each setting are described at the top of the sheets. In addition to the pre-defined settings, every sheet includes a 'user-defined' column that allows customising the pre-calculated scenarios by entering one's own input data.

Each pathway calculation sheet is split vertically into three sections:

1. Overview results

The first part of the first section presents the GHG emissions that result from the individual life cycle steps, following the 'well-to-wheel' approach and presented per MJ fuel (see Figure 3-5). At the end of the section, overall results are presented for each setting: first, the total GHG emissions are presented, second the GHG savings that result from balancing the emissions with the fossil fuel comparator. The GHG savings refer to different functional units (per hectare, per MJ fuel, in %).


Final version 30 November 2011
Biofuel GreenHouse Gas Calculator
Directory | About | Background data | Lookup table | Diagrams | References

Biodiesel from soybeans

	Setting 2 COPY Argentina Smallholders Low mechanisation No tillage 2010	Setting 3 COPY Argentina Plantation High rate of mechanisation Tillage 2010	Setting 4 COPY Argentina Plantation High rate of mechanisation No tillage 2010	Setting 5 COPY Argentina Plantation High inputs (irrigation) No tillage 2020	Setting 6 COPY Argentina Plantation High rate of mechanisation Tillage 2020	Setting 7 COPY Argentina Plantation High rate of mechanisation No tillage 2020	User-defined 2020
Overview results							
Land use change							
Direct land use change in [g CO_2eq / MJ_{FAME}]	0,0	0,0	0,0	0,0	0,0	0,0	Please enter all input data
Indirect land use change in [g CO_2eq / MJ_{FAME}]	0,0	0,0	0,0	0,0	0,0	0,0	Please enter all input data
Cultivation							
Cultivation of soybeans in [g CO_2eq / MJ_{FAME}]	6,6	5,9	7,4	5,8	5,8	7,3	Please enter all input data
Processing							
Oil extraction in [g CO_2eq / MJ_{FAME}]	8,5	8,5	8,5	8,4	8,4	8,4	Please enter all input data
Biodiesel plant in [g CO_2eq / MJ_{FAME}]	10,1	10,1	10,1	10,1	10,1	10,1	Please enter all input data
Transports							
Soybeans to oil extraction in [g CO_2eq / MJ_{FAME}]	2,4	0,8	1,1	0,8	0,8	1,2	Please enter all input data
Soybean oil to biodiesel plant in [g CO_2eq / MJ_{FAME}]	0,0	0,0	0,0	0,0	0,0	0,0	Please enter all input data
FAME to filling station in [g CO_2eq / MJ_{FAME}]	0,4	0,4	0,4	0,4	0,4	0,4	Please enter all input data
GHG emissions allocated in [g CO_2eq / MJ_{FAME}]	**28,0**	**25,8**	**27,5**	**25,5**	**25,5**	**27,3**	**0,0**
GHG emissions allocated in [kg CO_2eq / $ha_{soybeans}$]	**469**	**555**	**741**	**604**	**604**	**807**	**0**
Fossil fuel comparator in [g CO_2eq / $MJ_{fossil\ fuel}$]	**83,8**	**83,8**	**83,8**	**83,8**	**83,8**	**83,8**	**83,8**
GHG savings in [g CO_2eq / MJ_{FAME}]	**55,8**	**58,0**	**56,3**	**58,3**	**58,3**	**56,5**	**0,0**

Figure 3-5 GEF Biofuel Greenhouse Gas Calculator: overview results

2. Input data per step

The second section presents all input data along the pathways on a step by step basis (see Figure 3-6). The first columns contain the pre-defined settings with default data, the last column ('user-defined') allows for entering one's own values. All default data used in the settings are referenced in the sheets.

For each life cycle step the following information is given: yields of the main products and co-products, energy inputs (e.g. steam or electricity) and other material inputs (e.g. fertiliser, chemicals, etc.).

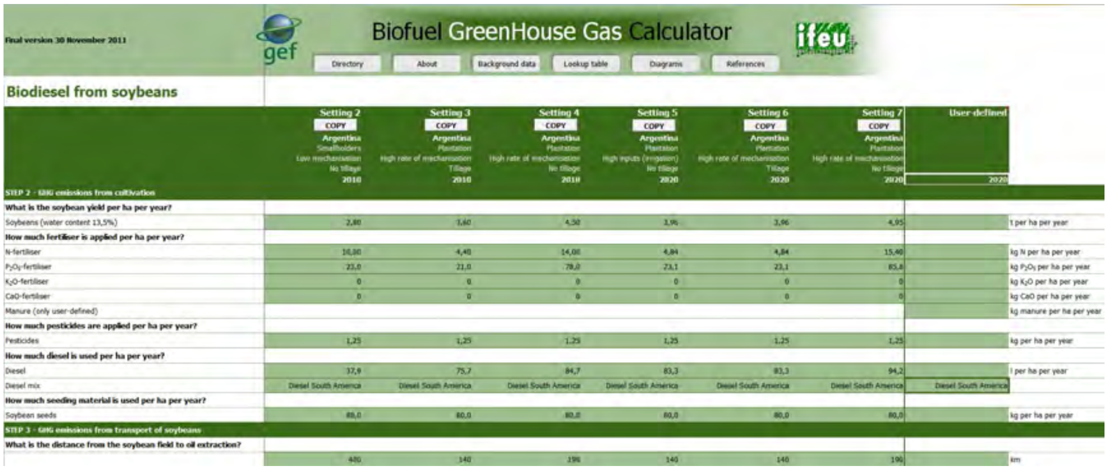


Figure 3-6 GEF Biofuel Greenhouse Gas Calculator: input data

3. Calculation of GHG emissions

The last section contains the actual conversion of input data into GHG emissions, again stepwise (see Figure 3-7). The calculation uses all input data from the second section as well as conversion and emission factors listed in the 'Background data' sheet. Also 'user-defined' column contains fixed formulas which calculate emissions automatically. It is not possible to change any formula here.

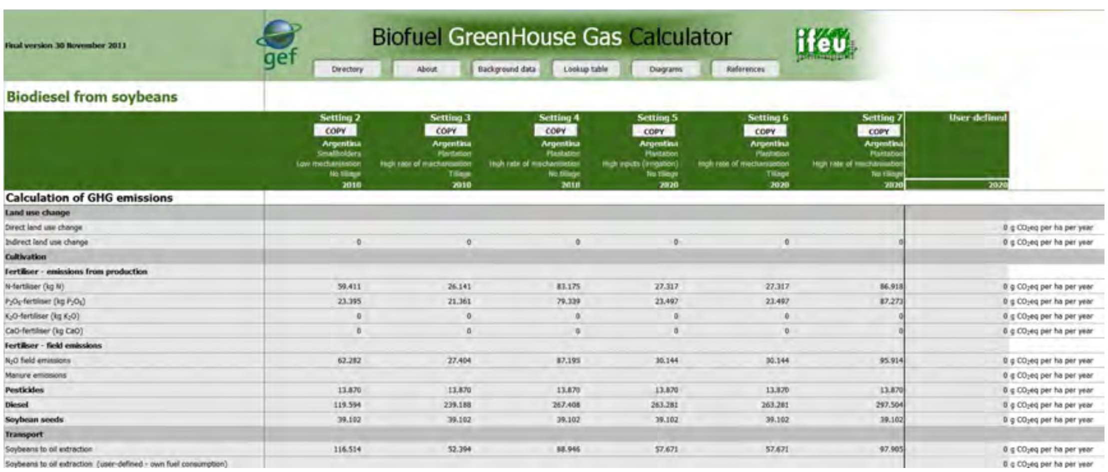


Figure 3-7 GEF Biofuel Greenhouse Gas Calculator: calculation of GHG emissions

Which data sources are used for the background data?

All greenhouse gas emission factors and conversion data (e.g. lower heating values, densities etc.) required for the calculations are listed in the 'Background data' sheet. A large part of this data has been compiled in the course of the BioGrace project[8]. One objective of this EU-funded project is to harmonise data necessary for greenhouse gas balancing on a European level. Where necessary, data has been complemented with data compiled and evaluated by IFEU. All data is referenced.

[8] http://www.biograce.net/

3.2.3 How GHG calculations are done within the tool

What are the specifications?

As Chapter 3.1 has shown, certain parameters have a strong impact on the greenhouse gas emission results. Therefore, it is crucial to clearly specify and define such parameters. The following specifications apply in the tool:

- **Overall system boundaries:** the calculations in the tool follow a “well-to-wheel” approach, i.e. the whole life cycle of the biofuels is included starting from cultivation (including both direct and indirect land use changes), covering biofuel processing and including transports and distribution. All inputs into and outputs from the system are taken into account such as fertilisers, fuels, co-products and emissions. Infrastructure, i.e. emissions from the manufacturing of buildings and machinery, is not included. The use phase GHG emissions of biofuels are set to zero since the CO_2 emitted is biogenic.
- **Functional unit:** different functional units may be subject to different goal and scope definitions. The results in the tool are given for different functional units to meet the needs of different users:
    - kg CO_2 eq per hectare
    - g CO_2 eq per MJ fuel
    - Percent of GHG emissions saved (relative to fossil fuel comparator)
    - For the input data along the life cycles, different units are used to increase practicality and data transparency.
- **Co-product handling:** along the biofuels’ life cycles several co-products are obtained which can be dealt with in different ways (see Chapter 3.1). In the tool, allocation is applied on the basis of the energy content (lower heating values).
- **Fossil reference product:** the fossil reference product (in the tool referred to as ‘fossil fuel comparator’) is the product that is replaced by the biofuel. In the tool, a default fossil fuel comparator is included (83.8 g CO2 eq / MJ). It can be replaced by another value in the user defined column.
- **Land use change:** the tool offers the possibility to include GHG emissions from direct and indirect land use changes (see Chapter 3.1 and appendix A-1.2.2 for definitions). Emissions from direct land use changes are not included in the calculations from the outset since it strongly depends on the specific project settings whether land use changes occur or not. If necessary, emissions can be calculated on an extra sheet and included in the user-defined column. For indirect effects, a clear and straightforward quantification is not possible (see appendix A-1.2.2). There is a worldwide debate on the extent of such GHG emissions and on how to deal with this issue. Many studies focus on the quantification of indirect land use change effects, generally using two approaches: global agro-economic equilibrium models are used that predict market responses and related changes in land allocation to additional biofuel demand (CARB, 2009; EPA, 2010; Al-Riffai et al., 2010; Fonseca et al., 2010, Hiederer et al., 2010). Others use a simpler causal-descriptive approach (Overmars et al., 2011; Bowyer, 2010; Nassar et al., 2010; Arima et al., 2011; Bauen et al., 2010). Regardless of the approach used, very

different results are obtained from the studies (see Dehue et al., 2011; DG Energy, 2010 and Edwards et al., 2010; for an overview).

In October 2012, the European Commission published a proposal for the amendment of the RED and the FQD (EC 2012) that lists factors for estimated emissions from indirect land use changes. The factors apply to cereals / other starch rich crops (12 g CO_{2eq}/MJ); sugar crops (13 g CO_{2eq}/MJ and oil crops (55 g CO_{2eq}/MJ). Where applicable, these factors are implemented in the GEF calculator.

The GEF tool and the RED

In the recent past, many greenhouse gas calculation tools were developed – among others tools that enable calculations that prove compliance with the RED GHG emission thresholds. The GEF tool, however, is not intended to perform such calculations, i.e. in its standard configuration it is not suitable to prove whether a certain biofuel will meet the RED thresholds. However, in the user-defined column calculations can be adjusted in a way that they are in line with the RED methodology. It has to be noted, however, that compliance can only be indicatively checked but not proven with the tool. This has to be done via a third party certification scheme that has been approved by the European Commission.

One main principle of RED compliant calculation is already included in the tool: co-product allocation is done based on the lower heating values of the products. Also the default fossil fuel comparator is the same as is used in the RED. To make the calculation even more in line with RED, the following major changes have to be applied:

- **Co-product allocation:** in the tool, all co-products (excluding wastes) are allocated whereas the RED excludes certain co-products from allocation: agricultural crop residues (including straw, bagasse, husks, cobs and nut shells) and process residues (including crude glycerine) shall not been taken into account for allocation (Annex V C(18)) in (EU, 2009). To some co-products the special allocation rule for refineries may apply (for definitions, see Annex II in (EU, 2009). To check RED conformity, the amounts of co-products to which these definitions apply must be set to zero.
- **Indirect land use changes:** in the RED only GHG emissions from direct land use changes have to be included. Regarding indirect land use changes, there is no agreement so far on which method should be applied. Therefore, emissions from indirect land use changes should be excluded by choosing ‘No’ for 'Indirect land use changes'.[9]
- **Straw:** In the RED approach, agricultural residues that are used for biofuel production are counted with 'zero' life cycle emissions. In the pre-defined rice and wheat straw settings, however, fertilizers are included, as they compensate for the nutrient losses resulting from the straw's removal. Change these inputs to 'zero' in order to check RED-conformity.

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9 The European Commission published a proposal on 17 October 2012 considering iLUC when assessing the greenhouse gas performance of biofuels, EC (2012).

How is the actual calculation done?

For each input value from section 2 (e.g. fertiliser, diesel fuel, electricity etc.), the emissions of the three main greenhouse gases for liquid biofuels (CO_2, N_2O, CH_4) are calculated. The gases are transferred into CO_2 equivalents (CO_2 eq) based on their global warming potentials (GWPs, included in the 'Background data' sheet). All CO_2 emission factors required are listed in the 'Background data' sheet. These values cannot be changed by users. Details on the calculation formula applied can be seen by clicking on the respective cells in the third section of each sheet. Please note that formula cannot be changed!

For transparency reasons, the calculation of GHG emissions is done individually for each life cycle step. The emissions are summed up to total GHG emissions per hectare and transferred into different functional units. Energy-based allocation between main products and co-products is applied at each life cycle step where a relevant co-product is obtained. For doing so, all emissions that occur up to this separation point are summed up and divided between the products based on their lower heating values. The lower heating values are listed in the 'Background data' sheet.

3.2.4 Overview on GHG results from the tool

The following sections depict selected results from the GHG calculation tool. First, some greenhouse gas emission results are visualised with diagrams, and second, a lookup table is included in section 3.2.4.2 that contains the GHG results of all 74 biofuel settings.

3.2.4.1 Selected diagrams

The diagrams presented in the following section aim at giving an overview on the diversity of biofuel GHG results covered by the GEF calculator. Some meaningful settings were chosen to show the possibilities of how to compare and interpret results. Diagrams for all settings that refer to different functional units are included in the GHG calculator.

Greenhouse gas emissions from direct land use changes can have a major effect on the results (see also section 3.1.1.2). Despite their large influence, they are not included in the calculations from the outset. It strongly depends on the specific project circumstances whether land use changes occur and how large emissions are. Therefore, there is no valid reason for generally adding land use change emissions to, for example, Indonesian palm oil. If necessary, emissions from land use changes can be calculated on an extra sheet and added in the user-defined columns.

The same applies to greenhouse gas emissions from indirect land use changes (iLUC) (for a definition of indirect land use change, see Chapter 3.1.1 and Appendix A-1.2.2). The relevance of indirect land use changes (iLUC) is still strongly issued at expert level. As explained in Chapter 3.1.1 a number of assessments conclude that iLUC is likely to have a strong effect on the GHG performance of 1st generation biofuel. The tool allows expressing the specific iLUC results applying the approach of Fritsche et al. 2010. However, since this is not a commonly agreed methodology the standard configuration of the tool excludes iLUC. Also in the lookup Table 2 3 emissions from iLUC are not included.

Having said that, emissions from indirect effects are displayed in all of the following diagrams in order to show their potential impact on the overall results. They are added as grey bars at the outer right hand side so that they can be deducted easily from overall emissions. All diagrams display GHG emissions per MJ fuel. The fossil fuel comparator (83.8 g CO_2 eq / MJ_{fuel}) is plotted with a vertical red line in every diagram.

Biodiesel (FAME) from palm oil

Figure 3-8 shows the GHG emissions of all palm oil biodiesel (FAME) settings.

- All settings emit far less greenhouse gases than the fossil fuel comparator provided that there are no indirect land use change effects. If such effects occur, settings 19 to 22 emit more greenhouse gases than fossil fuel, meaning that there are no net GHG savings from using palm oil biodiesel.
- Differences between settings are due to different cultivation practices (e.g. smallholders with intermediate inputs vs. plantations with high inputs in settings 19 and 20) and due to different production conditions in individual countries (e.g. Indonesia in setting 20 and Colombia in setting 21).
- The large emission reduction in 2020 compared to 2010 is due to improvements in the oil mill's production process: whereas in 2010 oil mill effluents are assumed to be stored in open ponds, in 2020 these ponds are supposed to be covered. In open ponds very high methane emissions arise which can be avoided by covering the ponds. Additionally, the captured methane can be used for biogas production and thus for allocation. Emissions in 2020 are further reduced by increases in oil yields.

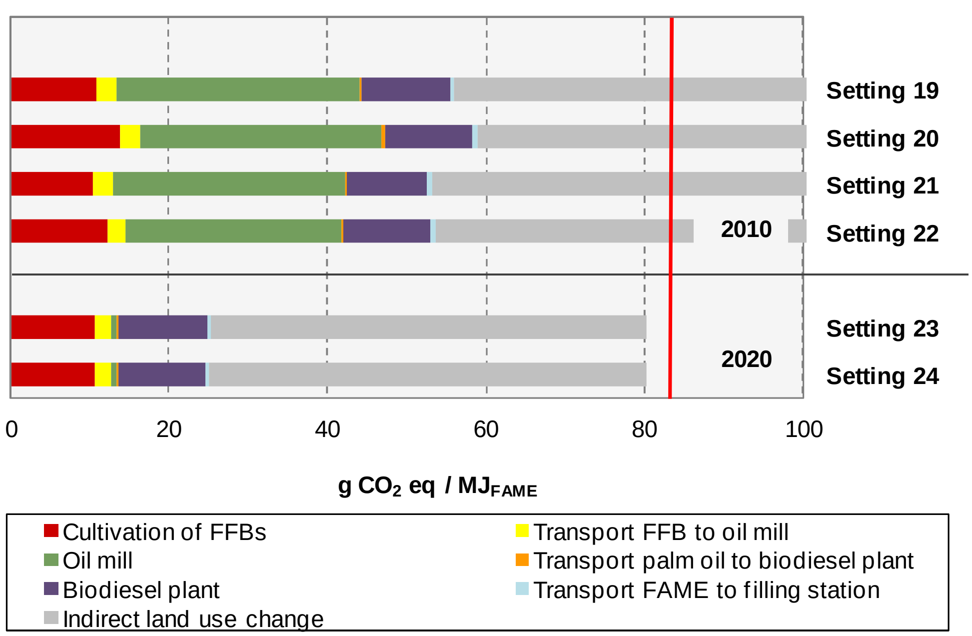

Figure 3-8 GHG emissions for biodiesel (FAME) from palm oil; vertical red line marks fossil fuel comparator; right-most bars display emissions from indirect land use changes

Biodiesel (FAME) from jatropha

Figure 3-9 shows the GHG emissions of biodiesel (FAME) produced from jatropha.

- Differences between the settings are caused in the cultivation phase and are due to differences in cultivation practices and logistics. In settings 28 to 31 (34 to 39 for 2020), husks remain at the field to be used as fertiliser resulting in a reduced need for mineral fertiliser. In the two smallholder settings (28, 30), it is assumed that no fertiliser at all is applied. In contrast, in setting 26 and 27 husks are used in the oil extraction plant for process energy generation thus higher amounts of mineral fertiliser are needed. Additionally, in these scenarios high amounts of diesel fuel are used for field work.

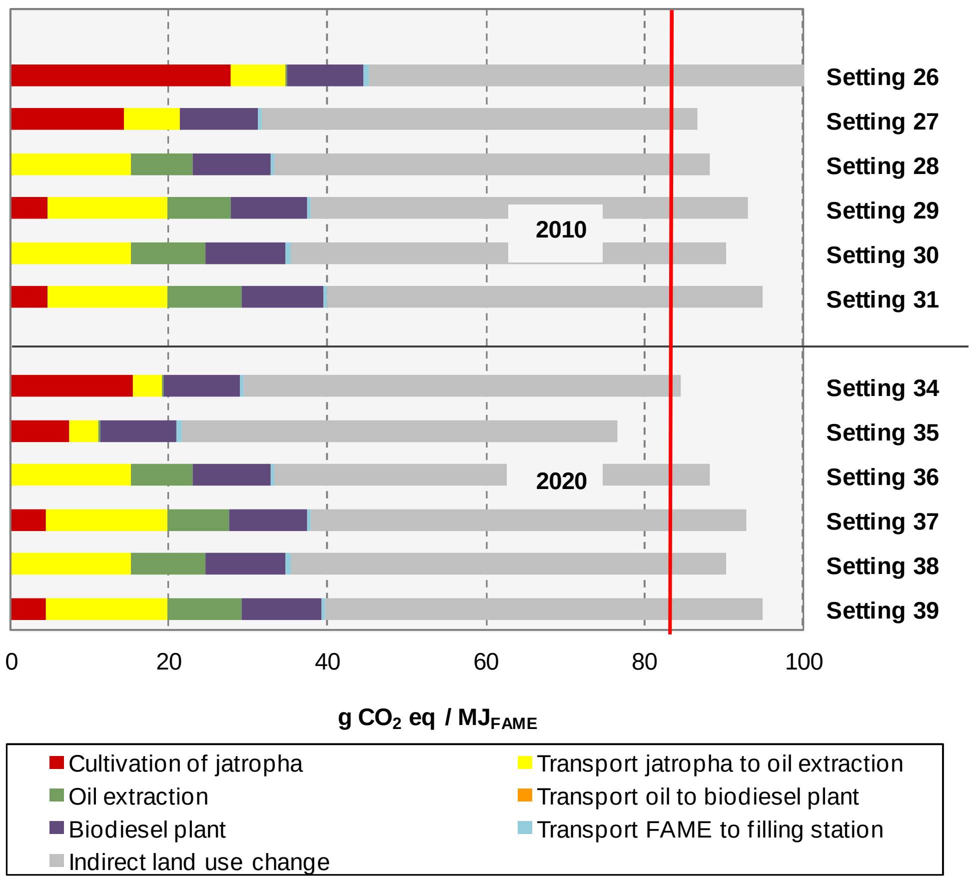

Figure 3-9 GHG emissions for FAME from jatropha; vertical red line marks fossil fuel comparator; overall emissions are up to 491 g CO_2 eq / MJ_{FAME}; right-most bars display emissions from indirect land use changes

- The four settings 26 / 27 and 34 / 35 visualise the great influence co-product allocation has on the overall results (for explanation, see Chapter 3.1.1.2 and Appendix A-1.2). Whereas all other scenarios hardly show any difference between 2010 and 2020, settings 34 and 35 clearly emit less than their counterparts 26 and

27. In the four settings, husks are combusted in the oil extraction plant for process energy generation. But only in the 2020 settings is surplus electricity fed into the grid which means that the corresponding amount of husks can be used for allocation. As a result, a considerable share of the greenhouse gas emissions is allocated to the husks leading to an emission reduction for the biofuel.

First generation ethanol from sugarcane and cassava

Figure 3-10 shows the impact feedstock choices can have on the GHG performance of a biofuel. First generation ethanol from sugarcane and cassava is used as an example.

- The great influence of the feedstock chosen is obvious – sugarcane ethanol production causes far less GHG emissions than cassava ethanol production leading to higher savings compared to the fossil fuel. There are two reasons.
- First, the cassava pathway includes an additional, energy consuming, processing step as well as an additional transport step: cassava roots are chipped and dried before being transported to the ethanol plant.

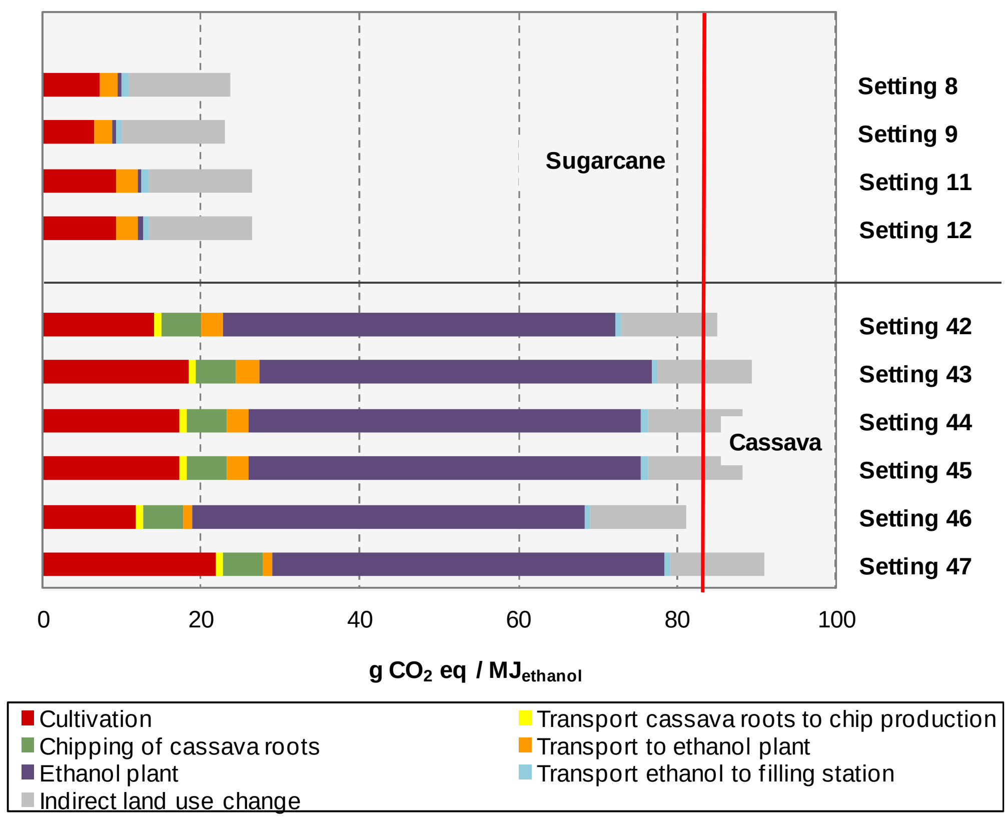

Figure 3-10 GHG emissions for ethanol from sugarcane and cassava (for 2010 only); vertical red line marks fossil fuel comparator; for cassava, overall emissions are up to 341 g CO_2 eq / $MJ_{ethanol}$; right-most bars display emissions from indirect land use changes

- The largest difference between both feedstocks, however, is due to the fact that ethanol production itself requires much more energy for cassava than for sugarcane. Whereas sugarcane contains an easily fermentable juice, cassava chips need some further preparation before fermentation.

First generation ethanol from sugarcane

Figure 3-11 again displays the GHG emissions from sugarcane ethanol, however, this time referring to two different functional units: results are shown per MJ fuel and per hectare sugarcane.

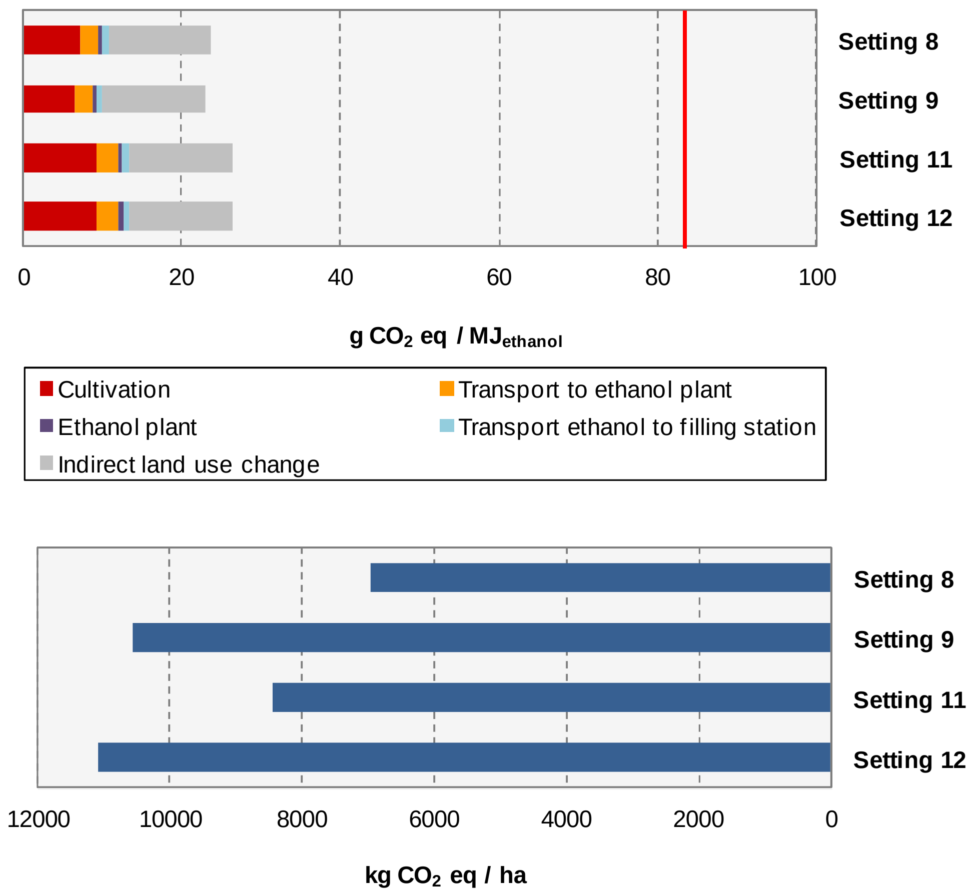

Figure 3-11 GHG emissions for ethanol from sugarcane and cassava (for 2010 only); vertical red line marks fossil fuel comparator; right-most bars in the upper diagram display emissions from indirect land use changes

- The diagram clearly shows that the choice of the functional unit influences the outcomes of results and their interpretation. In the upper graph, there are only small differences between the settings, especially if effects from land use changes are ignored. However, in the lower graph differences become clearly visible. The reason is that differences between settings are only during the cultivation phase. Since most inputs depend on the yield, the respective emissions change proportionally to the yield results refer to MJ_{fuel}. If results refer to one hectare, effects from yield changes have a much stronger impact. Please also refer to Chapter 3.1 for some more examples on the influence of the functional unit.

Second generation ethanol and BtL from switchgrass

Figure 3-12 shows the GHG emissions of two different fuels that can be produced from a feedstock, namely second generation ethanol and BtL from switchgrass.

- Since the same feedstock is used, all emissions that occur up to the fuel processing plant (i.e. from cultivation and switchgrass transport) are equal. Emissions occurring during fuel production, however, are very different. Both processes run energy autonomously with process energy being gained from co-product combustion. Thus, variations are due to different chemical inputs. Ethanol production requires a much higher material input compared to BtL resulting in higher greenhouse gas emissions.
- The diagram displays settings for 2020 and 2030 which are equal both for ethanol and BtL. The reason is that during this period no profound improvements in production processes are assumed to occur. Since no external energy carriers are used in the process, also changes in electricity mixes do not influence the results. Differences only occur from differences in transport fuel emissions. However, influences are marginal as transports contribute only little to overall emissions.

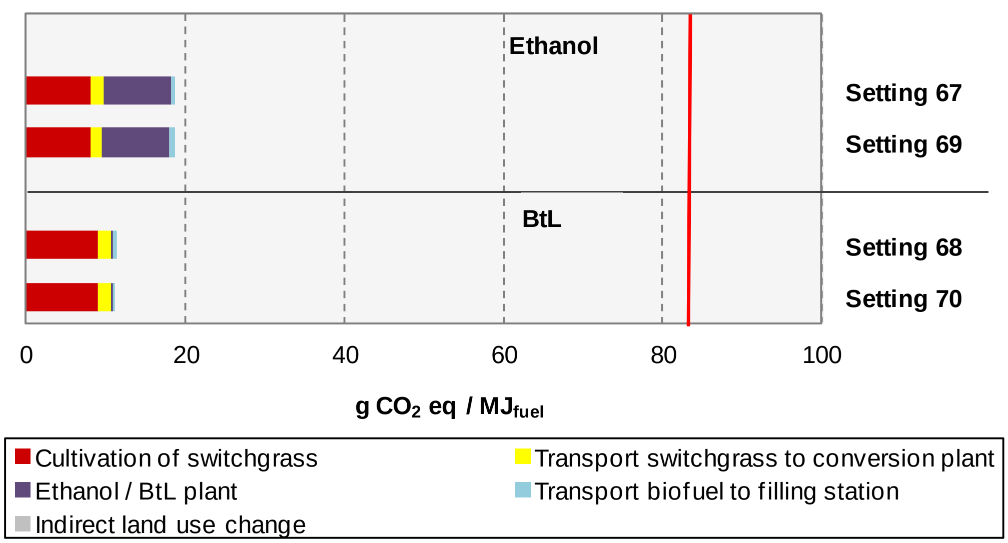

Figure 3-12 GHG emissions for second generation ethanol and BtL from switchgrass; vertical red line marks fossil fuel comparator

3.2.4.2 Lookup table

Table 3-3 lists the greenhouse gas results of all 74 biofuel settings. Results are given as disaggregated greenhouse gas emissions per life cycle step as well as overall savings referring to two functional units. Emissions from direct and indirect land use changes (LUC) are not included in the table. However, they can be added in the calculator.

Table 3-3 Lookup table with greenhouse gas emissions and savings for all 74 biofuel settings; results without direct and indirect land use change (LUC) effects; for abbreviations see 'Abbreviation' section

Pathway	N°	g CO_2eq per MJ fuel						kg CO_2eq per ha
		LUC	Cultivation	Pro-cessing	Trans-port	Fossil fuel comparator	Overall savings	Overall savings
Soybean SVO	1	0.0	6.8	9.6	2.9	83.8	64.5	1123
Soybean FAME	2	0.0	6.6	18.6	2.8	83.8	55.8	933
	3	0.0	5.9	18.6	1.3	83.8	58.0	1248
	4	0.0	7.4	18.6	1.6	83.8	56.3	1513
	5	0.0	5.8	18.4	1.3	83.8	58.3	1380
	6	0.0	5.8	18.4	1.3	83.8	58.3	1380
	7	0.0	7.3	18.4	1.6	83.8	56.5	1672
Sugarcane EtOH1	8	0.0	7.3	0.5	3.0	83.8	73.0	8457
	9	0.0	6.5	0.5	3.0	83.8	73.8	12824
	11	0.0	9.2	0.6	3.5	83.8	70.5	10339
	12	0.0	9.3	0.6	3.5	83.8	70.4	13583
	13	0.0	7.2	0.5	3.0	83.8	73.2	8894
	14	0.0	7.2	0.5	3.0	83.8	73.1	13330
	16	0.0	7.5	0.5	3.0	83.8	72.7	8422
	17	0.0	7.2	0.5	3.0	83.8	73.1	14809
Sugarcane EtOH1 & 2	10	0.0	7.6	1.7	3.1	83.8	71.4	14577
	15	0.0	7.5	1.7	3.1	83.8	71.5	15332
Oil palm SVO	18	0.0	11.3	32.7	1.1	83.8	38.7	4543
Oil palm FAME	19	0.0	10.9	41.7	3.4	83.8	27.8	3117
	20	0.0	13.8	41.7	3.4	83.8	24.9	2964
	21	0.0	10.4	39.5	3.3	83.8	30.7	4034
	22	0.0	12.2	38.2	3.1	83.8	30.2	4190
	23	0.0	10.7	11.7	2.9	83.8	58.5	8687
	24	0.0	10.7	11.5	2.9	83.8	58.7	8713
Jatropha SVO	25	0.0	0.0	9.3	17.2	83.8	57.3	440

Pathway	N°	g CO_2eq per MJ fuel						kg CO_2eq per ha
		LUC	Cultivation	Processing	Transport	Fossil fuel comparator	Overall savings	Overall savings
Jatropha FAME	26	0.0	27.8	9.9	7.5	83.8	38.7	811
	27	0.0	14.3	9.9	7.5	83.8	52.1	925
	28	0.0	0.0	17.6	15.7	83.8	50.5	387
	29	0.0	4.7	17.6	15.7	83.8	45.8	629
	30	0.0	0.0	19.5	15.7	83.8	48.5	337
	31	0.0	4.7	19.5	15.7	83.8	43.9	461
	32	0.0	0.0	21.2	15.7	83.8	46.9	530
	33	0.0	4.7	21.2	15.7	83.8	42.3	717
	34	0.0	15.3	9.9	4.3	83.8	54.3	1311
	35	0.0	7.3	9.9	4.3	83.8	62.3	1272
	36	0.0	0.0	17.6	15.7	83.8	50.5	445
	37	0.0	4.6	17.6	15.7	83.8	45.9	725
	38	0.0	0.0	19.5	15.7	83.8	48.5	387
	39	0.0	4.6	19.5	15.7	83.8	44.0	531
	40	0.0	0.0	21.2	15.7	83.8	46.9	610
	41	0.0	4.6	21.2	15.7	83.8	42.4	826
Cassava EtOH1	42	0.0	19.0	49.5	4.5	83.8	10.8	137
	43	0.0	23.5	49.5	4.5	83.8	6.3	120
	44	0.0	22.3	49.5	4.5	83.8	7.5	142
	45	0.0	22.2	49.5	4.5	83.8	7.6	288
	46	0.0	16.8	49.5	2.8	83.8	14.7	935
	47	0.0	26.8	49.5	2.8	83.8	4.7	329
	48	0.0	22.0	49.5	4.5	83.8	7.8	149
	49	0.0	21.9	49.5	4.5	83.8	7.9	301
	50	0.0	28.9	49.5	3.9	83.8	1.5	74
	51	0.0	14.0	49.5	4.5	83.8	15.8	1002
	52	0.0	21.3	49.5	4.5	83.8	8.5	592
	53	0.0	28.4	49.5	3.9	83.8	2.0	175
	54	0.0	16.1	49.5	2.8	83.8	15.4	1560
	55	0.0	26.2	49.5	2.8	83.8	5.3	570
	56	0.0	28.2	49.5	3.9	83.8	2.2	308
Eucalyptus EtOH2	57	0.0	24.6	8.5	4.3	83.8	46.4	2482
	58	0.0	24.0	8.5	4.9	83.8	46.4	3653
	59	0.0	23.5	8.5	4.9	83.8	46.9	8126

Pathway	N°	g CO_2eq per MJ fuel						kg CO_2eq per ha
		LUC	Cultivation	Processing	Transport	Fossil fuel comparator	Overall savings	Overall savings
Eucalyptus EtOH2	60	0.0	23.9	8.5	4.3	83.8	47.1	3856
	61	0.0	23.6	8.5	4.9	83.8	46.8	4416
	62	0.0	23.1	8.5	4.9	83.8	47.3	8927
Poplar BtL	63	0.0	16.4	0.2	1.7	83.8	65.6	143
	64	0.0	7.0	0.2	1.7	83.8	74.9	8379
	65	0.0	16.4	0.2	1.7	83.8	65.6	3143
	66	0.0	7.0	0.2	1.7	83.8	74.9	8379
Switchgrass EtOH2	67	0.0	8.2	8.5	2.0	83.8	65.1	2562
	69	0.0	8.1	8.5	2.0	83.8	65.2	2566
Switchgrass BtL	68	0.0	9.1	0.2	2.0	83.8	72.5	2694
	70	0.0	9.0	0.2	2.0	83.8	72.6	2698
Rice straw EtOH2	71	0.0	12.3	8.5	2.2	83.8	60.7	406
	73	0.0	12.1	8.5	2.2	83.8	60.9	408
Wheat straw EtOH2	72	0.0	11.7	8.5	1.6	83.8	62.1	415
	74	0.0	11.5	8.5	1.6	83.8	62.2	416

3.2.5 Conclusions

The Excel-based GHG calculation tool offers two general ways to get informed on the GHG performance of a specific biofuel. First, a readily calculated value can be selected from the 74 settings representing a wide range of possible pathways. If none of the settings should match with the respective case, the user can define settings alternatively.

The results show that all 74 biofuel settings are connected with lower GHG emission than the replaced fossil fuel, supposed no land use change is given, neither direct nor indirect.

In cases where direct land use change (dLUC) is given, the actual change in carbon stock between the previous status and the implemented farming system is the crucial factor. Particularly where forested area is replaced by cropland an overall saving of GHG emissions will not be realised anymore. Replacing fragmented wooded areas or grasslands by permanent croplands might still allow a net saving. After all, the result is depending on actual conditions which have to be assessed case by case. The tool offers a separate worksheet to figure single cases out.

Regarding the crop types it can be concluded that there are some crops with generally better results than other crops. Best results show ethanol from sugar cane, and 2nd generation ethanol or BtL from poplar and switchgrass, given that the energy demand of the processing steps are fuelled with non-fossil fuels.

Medial results are provided by FAME from soybean and jatropha. Smallholders on marginal land and plantations on good land with higher input do not differ strongly within the overall balance. As for jatropha the efficiency of the use of co-products (residues) is a key factor. Agricultural options like no-till render some improvement but not very significantly. As for FAME from palm oil the use of POME is the key factor. Uncaptured methane emissions lead to a low final saving rate while methane capture and use as biogas will enhance the benefit of this type of biofuel significantly.

Within the analysed pathways ethanol from cassava turns out to provide the highest GHG emission rates which are marginally lower than fossil fuel comparators. The major reason is the high demand of process energy (steam) which is based on the use of fossil fuels according to the settings here. These scenarios might improve in case biogas should be used in future as the study by Nguyen and Gheewala, 2008 can show.

Analysing these 74 settings can support the choice of a crop beneficial for the GHG balance. Perennial crops tend to provide higher saving potentials than annual crops. Good practice in process efficiency and use of co-products and residues will always help to improve the overall performance.

3.3 Evaluation of GHG calculation in certification schemes in the context of GEF activities

3.3.1 Goal and scope

In recent years, greenhouse gas balancing has found its way into the political context as a means to assess the environmental sustainability of bioenergy. Many certification schemes introduced GHG emission thresholds and require the performance of greenhouse gas calculations for proving compliance with those thresholds. This Chapter provides guidance on these methodologies. Although the focus is on certification schemes, a broader context is provided by including international agreements such as the Global Bioenergy Partnership (GBEP) and regulatory frameworks such as the European Renewable Energy Directive (RED). Especially the latter significantly influences the design of GHG calculation methodologies in certification schemes.

From the many existing certification schemes the only ones assessed are those that operate in the field of biofuels and include a clear methodology for greenhouse gas calculations.

3.3.2 Overview on GHG calculation in the systems

The following sections provide a summary of the most relevant features of included GHG calculation methods and the differences between the systems. Table 3-4 lists the selected systems and their scope of applications. A more extended table can be found in Appendix B. Also in the appendix are detailed descriptions of all systems, of the role of GHG calculation within the systems as well as characterisation tables describing the most important elements of GHG calculation.

Table 3-4 System selected for assessment

Name	Website	Scope
International agreements and standards		
UNFCCC - United Nations Framework Convention on Climate Change	http://cdm.unfccc.int/methodologies/DB/Z6UFHXTRQJ2PSZ1EOD21IT8FEF4AE7	Only biodiesel[10]
GBEP – Global Bioenergy Partnership	http://www.globalbioenergy.org	All biomass for energy
ISO 13065 Sustainability criteria for bioenergy	http://www.iso.org/iso/iso_technical_committee.html?commid=598379	All biomass for energy
EU standard prEN 16214-4: Sustainability criteria for the production of biofuels and bioliquids for energy applications	http://www.cen.eu/cen/Sectors/Sectors/UtilitiesAndEnergy/Fuels/Pages/Sustainability.aspx	Biofuels and other bioliquids
Regulatory frameworks		
LCFS – Low Carbon Fuel Standard (California)	http://www.energy.ca.gov/low_carbon_fuel_standard/index.html	Most common biofuels in California
RFS2 – Renewable Fuel Standard (USA)	http://www.epa.gov/otaq/fuels/renewablefuels/index.htm	Most common biofuels in US
RED – European Renewable Energy Directive	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF	All liquid biofuels / bioliquids
Voluntary certification schemes		
BioGrace (GHG calculation tool)[11]	http://www.biograce.net/	25 biofuel / bioliquid pathways
BSI – Bonsucro	http://www.bonsucro.com/welcome.html	Sugarcane
GGL – Green Gold Label	http://www.greengoldcertified.org/index.php?id=5	All biomass for fuel, power and material use
ISCC – International Sustainable and Carbon Certification	http://www.iscc-system.org/index_eng.html	All biomass for energy uses (material use under development)
NTA 8080	http://www.sustainable-biomass.org/publicaties/3892	All biomass for energy uses
RSB – Roundtable on Sustainable Biofuel	http://rsb.epfl.ch/	All liquid biofuels
RTRS – Roundtable on Sustainable Soy	http://www.responsiblesoy.org/	Soy

[10] CDM provides guidelines on various project scopes. However, with respect to biofuels, there is only one methodology that applies to biodiesel from waste oils and oil seeds produced on degraded land.

[11] BioGrace is a GHG calculation tool currently under development for performing calculations that conform to RED. As soon as it is finalised, the application as a certification scheme will follow.

The systems are assessed with respect to two aspects:

1. The detail level of greenhouse gas calculations within the systems
2. Methodological differences between the systems with regard to greenhouse gas calculation

3.3.2.1 Level of detail

International agreements and standards

Subject to their different scopes and fields of application, greenhouse gas calculation within the systems differs with regard to its level of detail. The GBEP framework and the standards (ISO 13065 and prEN 16214-4, both in process) are guidelines that have been agreed (or are assumed to be agreed) upon on an international level. All three do not describe specific GHG calculation methodologies but rather give guidance on how to perform such calculations. GBEP has been initiated by governments and international organisations and therefore takes a policymaker's perspective. The framework in the form of a checklist shall enable decision makers to identify the character and completeness of specific GHG calculation methodologies. Within the ISO standardisation process industry is strongly represented and therefore, the ISO 13065 (under development) will address the market actors' viewpoint. The standard shall define good GHG calculation practice in compliance with other standards but will not determine a specific methodology.

The European standards prEN 16214 (draft standard) strongly follows the principles and rules stipulated in the RED (see below). The purpose of the standard is to give appropriate clarifications, explanations and further elaborations concerning the rules given in the RED and any additional interpretation of the legislative text published by the EU.

Regulatory frameworks

Two fundamentally different approaches can be distinguished: under the US laws LCFS and RFS2 ex ante greenhouse gas calculations are performed. These calculations are done for most common biofuels in order to a) assess whether they meet certain GHG emission thresholds and thus are allowed to be counted towards a biofuel goal (RFS2) or b) in order to generate default greenhouse gas emission values (LCFS). Under both laws, individual calculations by market operators are not required. Since the calculations are performed by scientific institutions within a larger time frame, they can be realised in great scientific depth. The calculations are model-based and include global direct and indirect land use change effects.

In contrast, the European Renewable Energy Directive (RED) sets a greenhouse gas emission threshold for biofuels that has to be met by every economic operator on the European market. Compliance with the threshold has to be proven individually. Although default emission values are provided for many biofuel pathways, ones own calculations are often necessary. These calculations have to generate transparent, replicable and clear results. Therefore, the RED provides a clear methodology with energy-based allocation of co-products as the most important feature.

Voluntary certification schemes

Many voluntary certification schemes introduced GHG emission thresholds that have to be met by parties that want to get certified. Individual greenhouse gas calculations are also here required to prove compliance with the thresholds. The respective calculation methodology is provided by the certification schemes focusing again on generating results that are as clear and unambiguous as possible.

3.3.2.2 Methodological differences

International agreements

As explained above neither the GBEP framework nor the ISO standard determines specific methodological rules. The European standard prEN 16214-4 recaptures the RED rules which are analysed below.

Regulatory frameworks

The two US laws and the RED use profoundly different calculation methodologies subject to their different fields of application. Under the RFS2 and the LCFS biofuel GHG emissions are modelled. RFS2 uses a partial equilibrium model covering the whole agricultural sector. It determines the overall response of economic sectors to a certain volume change of biofuels. The responses are expressed as changes in total GHG emissions. Two separate partial equilibrium models (FASOM and CAPRI) are added to assess effects from global direct and indirect land use changes.

LCFS uses a simpler approach with the multi-dimensional spread-sheet based GREET model covering more than 100 fuel pathways (fossil and biogenic). It was adapted to Californian conditions and a partial equilibrium model (GTAP) was added to include land use change effects.

In contrast, the RED provides a simpler methodology that can be used for individual greenhouse gas calculations. The verification of compliance with the GHG emission thresholds is realised by third-party certification schemes that also have to put into practice the GHG calculation methodology. As a result, the RED influenced the worldwide design of certification schemes in the field of biofuels. Existing certification schemes created add-on standards to enable EU market access. Other recently developed schemes adopted the RED calculation methodology from the onset.

Voluntary certification schemes

Among the certification schemes assessed, only RSB and BSI require GHG calculations independently from the RED and therefore provide their own methodologies. Both schemes, together with RTRS which did not require GHG calculation, developed add-on standards to prove RED compliance. GGL, NTA, ISCC and the BioGrace tool included the RED methodology from the onset. This strong influence of the RED results in a low variability of greenhouse gas methodologies in certification schemes.

Differences between methodologies are due to two facts: first, GHG calculation is part of the main scheme independently from the RED (only in RSB and BSI). Second, there are differences between RED-compliant schemes and add-on standards since the RED leaves certain room for interpretation and does not always give exact guidance.

Table 3-5 lists the certification schemes and the RED for comparison. All schemes including add-on standards are differentiated – the original one for global application is referred to as ‘main’ and the add-on standard for granting an EU compliant certificate is referred to as ‘EU’. The table lists only those methodological specifications that are known to have a major influence on GHG calculation results (see also Chapter 3.1). For exact details on all schemes, please refer to the characterisation tables in Appendix B. Generally, all schemes follow a “well-to wheel” calculation approach with the same functional unit (results are referred to MJ fuel).

In the ‘main’ standards of RSB and BSI and in NTA, additional major deviations from the RED methodology can be found. In order to not overload the table they are listed separately:

GHG thresholds (RSB), GWPs and greenhouse gases taken into account (RSB), infrastructure (RSB), LUC methodology (RSB), cut-off date for land use change (NTA), emissions from sugarcane trash burning (RSB, BSI), indirect field N_2O emissions (RSB), surplus electricity (RSB, BSI).

Besides methodological specifications, the database used is a further reason for deviations between the schemes. Even the RED does not give any obligatory guidance on background data to be used such as emission or conversion factors. As a result, the certification schemes refer to existing data bases such as ecoinvent[12] or GEMIS[13] or include reference values from different sources in their appendices. The tool developed in the Bio-Grace project includes a separate sheet with all relevant background data.

[12] www.ecoinvent.ch

[13] http://www.gemis.de

Table 3-5 Overview on greenhouse gas balancing in certification systems

Name	Overall methodology	Data used	Land use change	Co-products	Fossil reference system
RED	Well-to-Wheel calculation	Default values provided; operator-specific values can be used	Direct LUC according to Decision 2010/335/EU based on IPCC 2006 Tier 1	Allocation based on LHV except agricultural residues	Default provided
RSB – main	Same as RED; some minor variations	Operator-specific values shall be used	Same as RED with some additional features	Economic allocation, all co-products	Different from RED
RSB – EU	Same as RED	Same as RED	Same as RED	Same as RED	Same as RED
BSI – main	Well-to-Wheel	Only operator-specific values can be used	Same as RED	Substitution and allocation (different references), all co-products	Different from RED
BSI – EU	Same as RED	Only default values can be used	Same as RED	Same as RED	Same as RED
GGL	Same as RED	Operator-specific values should be used	Same as RED	Same as RED	Same as RED
ISCC	Same as RED	Same as RED	Same as RED	Same as RED	Same as RED
NTA	Same as RED	Same as RED		Same as RED	Same as RED
RTRS – main	No GHG balancing				
RTRS – EU	Same as RED	Same as RED	Same as RED	Same as RED	Same as RED
BioGrace tool	Same as RED	Default values provided; operator-specific values can be included	Same as RED	Same as RED	Same as RED

3.3.3 Conclusions

Different scopes and fields of application for the systems assessed lead to differences regarding levels of detail and methodological aspects in greenhouse gas calculation methodologies. GBEP and the international and European standards only want to guide greenhouse gas calculation and thus do not provide exact methodologies. RFS2 and

LCFS perform ex ante GHG calculations in great scientific depth. Only the RED and the voluntary certification schemes provide calculation methodologies for individual market players. Since most certification schemes included such methodologies only after the adoption of the RED, they do not show great diversity. In addition, when methodologies are provided independently, methodological deviations are rather marginal. The need for a clear, transparent methodology that leads to unambiguous results limits eligible specifications.

If a respective scheme or methodology is to be introduced in the GEF context, the certification schemes presented in this section can serve as appropriate examples since they focus on clearness and an easy application of greenhouse gas calculation. It should be noted, though, that no matter how detailed guidance may be, it can still leave space for interpretation and thus could lead to differences in results. Furthermore, if background data is not predefined, the same methodology could still lead to diverging results.

Regarding aspects such as applicability and accurateness of the presented schemes, in-depth experiences are still missing. Greenhouse gas calculation in the context of regulatory frameworks is a rather new topic compared to life cycle assessments in general which have been applied since the 1990's. Certification of biofuels is only about to start and is therefore still subject to changes and adaptations.

The same applies to experiences regarding the effectiveness of such systems when it comes to their contribution to greenhouse gas savings. It is already obvious that, among the three regulatory frameworks, the RED provides most possibilities to introduce further incentives to reduce greenhouse gas emissions. Since each economic operator is asked to calculate his/her emissions, savings that go beyond the thresholds could easily be linked to financial incentives. In contrast, under the US laws no results on actual greenhouse gas emissions from single economic operators are available. Furthermore, the inclusion of GHG calculations for new pathways is quite time-consuming which could slow down the implementation of new solutions.

3.4 Screening tool for life cycle energy and greenhouse gas (GHG) assessment aspects

The following screening tool contains a summary of life cycle energy and greenhouse gas (GHG) assessment and builds on the traffic light concept that is explained earlier in this document.

Table 3-6 Screening tool for greenhouse gas assessment

Factors to consider	**GO**	**CHECK**	**STOP**
Net CO_{2eq} savings relative to fossil reference system	More than 50%	Less than 50%	No greenhouse gas savings

3.5 Summary: Life cycle energy and greenhouse gas (GHG) assessment

A thorough life cycle energy and greenhouse gas assessment is a major step in determining the sustainability of biofuels. This report gives an overview on how energy and greenhouse gas balances are calculated and on the key parameters influencing the results. It presents GHG emission results for 74 biofuel pathways and gives an overview on GHG calculation methodologies implemented in certification schemes. The main work task was the development of an Excel-based spread sheet tool, the so called 'GEF Biofuel Greenhouse Gas Calculator' that is publicly available for free. The tool contains pre-calculated GHG results for 74 biofuel settings covering the full life cycles up to their provision ("from cradle to tank"). The focus was put on developing a tool that is simplified and justified but still complex enough to assure accuracy. The ready-to-use result values can serve as basic references for biofuel projects in the respective countries. Beside the pre-calculated biofuel pathways, the calculation tool allows operators, stakeholders or decision makers to adopt the determined settings to actual case situations or to calculate own pathways by using user specific input data[14]. Such adoptions require some relevant pathway information like fertiliser consumption, harvest levels, energy input and efficiency factors. In many cases these types of information are not easily available. However this data is essential if a biofuel project intends to improve its performance.

The calculation of the 74 biofuel settings showed that all biofuels emit less GHG than the replaced fossil fuels, provided that direct and indirect land use changes are avoided. In cases where direct land use change is given, emissions depend on the actual change in carbon stock between the previous status and the implemented farming system. Within the pathways, high yielding crops such as sugarcane or palm oil show best results on a per hectare basis. Also certain second generation biofuels from perennial woody crops show high potentials of reducing GHG emissions. Besides yields, results are strongly influenced by the co-product use (best is an energetic use) and the production management. For example in palm oil production, the capture of methane from the oil mill's effluent (POME) has a much larger influence on results than yields. In contrast, transports and the type of management system have minor influences.

When it comes to GHG calculations within sustainability schemes, there still is a low degree of standardization despite the long-term and widespread experiences and practices of GHG assessments for biofuels. Different approaches are in place that lead to quite different GHG results depending on scope, methodical settings and applied background data. Unfortunately biofuel pathways tend to be rather complex. Essentially GHG figures need a maximum of transparency to be acceptable for policy purposes. With regard to the complexity of supporting calculation tools it will be inevitable to foster both: applying GHG assessments at large and making it transparent and reproducible.

[14] Please note: as the tool includes a limited number of biofuel pathways (raw material and conversion to 1st or 2nd generation biofuel) a user can calculate only such biofuel pathways with user specific data.

4 Economic viability of the production of liquid biofuels

The economic viability of the 1st generation bioenergy crops: soy, sugarcane, palm, jatropha and cassava will be presented in US-$ per GJ. The cost figures have been collected or reviewed by local experts to make sure they represent realistic values. The economic viability varies greatly with the agricultural intensity of the cultivating stage, therefore the management settings will be described together with more background information on the specific settings in section 4.2.

4.1 Methodology

Feedstock costs are calculated by taking an economic lifetime of 24 or 25 years (depending on the crop cycle), and discounting all expenses (labour and other inputs) over the years. The NPV is calculated to show the profitability of the crop for the farmers. The revenues for a farmer are a multiplication of the yield and the market price for the fresh product, see Appendix D with all data input. The NPV is calculated using the following formula (I):

$$NPV = \sum_{i=0}^{n} \frac{B_i - C_i}{(1+r)^i} \qquad \text{(I)}$$

where

NPV	Net Present Value [US-$]
Bi	benefits in year i [US-$]
Ci	costs in year i [US-$]
r	discount rate [%]
n	lifetime of project [years]

If yields are increased or costs reduced, the NPV will increase. In the following results section, figures with stacked columns also show the breakdown of the largest contributors to costs (for example labour expenses or fertilisers). To be able to compare the different end products of the feedstocks, the final costs are given in US-$$_{2010}$/GJ. The final costs represents: feedstock costs (including labour, fertilizers etc.), transport costs (from field to conversion plant), conversion costs (in $/l), if applicable transesterification or further refining costs and finally distribution to the end consumer (filling station). The transport expenses are linked to the GHG balance data by using the same transport distances, also the yields are equal. The final cost is calculated by dividing the total discounted costs by the total discounted yields, using the following formula (II):

$$C = \frac{\sum_{i=1}^{i_t} \left(ecc_i \sum_{y=1}^{n} \frac{f_i(y)}{(1+r)^y} \right)}{yld \sum_{y=1}^{n} \frac{f_{yld}(y)}{(1+r)^y}} \qquad \text{(II)}$$

where

C	Cost of biomass [$ kg^{-1} or $ t^{-1} or $ m^{-3}]
i_t	number of cost items with different time pattern
ecc_i	cost of energy crop cost item [$ ha^{-1}]
n	number of years of plantation lifetime [yr]

$f_i(y)$ number of times that cost item i is applied on the plantation in year y [dimensionless]
r discount rate [dimensionless]
yld yield of the energy crop [kg ha^{-1} yr^{-1} or t ha^{-1} yr^{-1} or m^3 ha^{-1} yr^{-1}]
$f_{yld}(y)$ binary number, harvest (1) or not (0) in year y [dimensionless]

All $ are US$ $_{2010}$, the lifetime is 24 or 25 years for all crops (perennial and annual crops) and the discount factor is 8.2 (van Eijck et al. 2012). This rate, which applies to Tanzania, Mozambique, Mali and Thailand, is assumed to be equal for the other regions in our settings.

First the input data that is used in the calculations is described and in the second section the results are given that show the total prices per GJ and the NPV or agricultural input breakdown. Finally, the cost ranges of the liquid biofuels per region and per feedstock are given.

4.2 Description of input data

The different feedstocks are described separately, the most important input parameters are given and a discussion on the sensitivity of some of the data. Tables with all input data are available in Appendix D.

4.3 Soy

All 7 settings that concern soy are situated in Argentina. The management systems that are varied are the rate of mechanisation and the practice of tillage. Furthermore smallholders and plantations are incorporated as well as two timeframes: 2010 and 2020, see Table 4-1.

Table 4-1 Seven settings for soy taken into account in the cost calculations

Setting No	Smallholder/ plantation	Management system	End product	Timeframe
1	smallholders	low mechanisation, no tillage	SVO	2010
2	smallholders	no mechanisation, no tillage	FAME	2010
3	plantation	high rate of mechanisation, tillage	FAME	2010
4	plantation	high rate of mechanisation, no tillage	FAME	2010
5	plantation	high inputs (irrigation), no tillage	FAME	2020
6	plantation	high rate of mechanisation, tillage	FAME	2020
7	plantation	high rate of mechanisation, no tillage	FAME	2020

All settings are situated in Argentina, a country that has a lot of experience with soy cultivation. Over the last decades, soybean cultivation has grown substantially representing 37,000 hectares in the 1970/71 campaign to more than 17 million at present (INTA 2011a). The main product of the cultivation of soy is animal feed while the oil that is obtained from processing is considered a by-product. Therefore, the cost of feedstock production is only allocated to soy biodiesel by 20% (by mass). Soy cultivation in Argentina takes place on large scale plantations with high rates of mechanisation.
The use of no tillage is the most common practice in the country, which leads to better environmental performance through lower carbon and water footprint. Zero-tillage technology allows the farmer to lay seed in the ground at the required depth with a

minimal disturbance of the soil structure. Specially designed farm machinery eliminates the need for ploughing and minimizes the tillage required for planting. . In Figure 4-1 the average soybean yield development of national averages is shown.

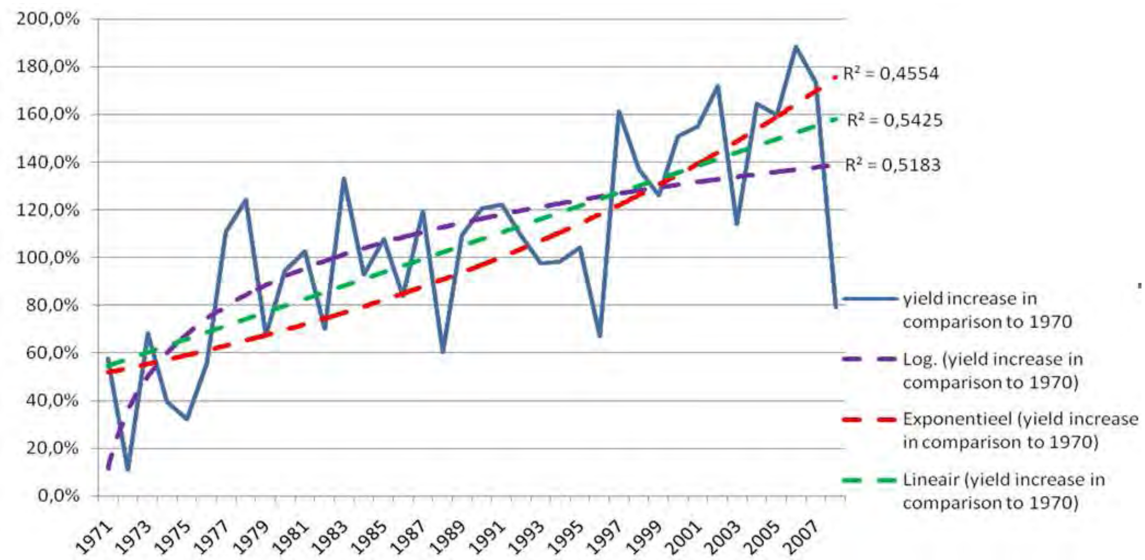

Figure 4-1 Average historic soy yield development – Argentina country level

Yields -- There are large differences between the individual provinces, with Cordoba reaching an average yield gain of around 300% in the last 10 years whereas Corrientes and La Pampa reached an average yield gain of around 60% in the same period. Increased yields are explained by a conjunction of factors including: agronomic, genetic, farm machinery and general management. There are good perspectives for this tendency to continue in the near future. Soybean BTRR2 specifically developed for the southern hemisphere could generate an increase between 10 and 15% in yields (INTA 2011a). See Table 4-2 for the yields used in the calculations, they are based on specific provinces in Argentina.

Table 4-2 Yield estimates used in the calculations with their respective regions source: (INTA 2011b)

Setting number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
	smallholders	smallholders	plantation	plantation	plantation	plantation	plantation
Year	2010	2010	2010	2010	2020	2020	2020
average yield [t/ha]	2.8	2.8	3.6	4.5	4	4	5
Province	South of Cordoba (rio Cuarto)	South of Cordoba (rio Cuarto)	Pergamino and Pehuajo (North and West of BA)	South of Santa Fe (Venado Tuerto)			

Costs -- Prices for inputs and soy beans change over time. The production costs of soy have increased since 2002, but dropped between 1991 and 2002, current costs are at a similar level as 1991, see Appendix D. Therefore the same prices for inputs in 2010 and

2020 were used. Wages are expected to increase from 3.18 $/hr in 2010 to 8.29 $/hr in 2020. See Figure 4-2 with a breakdown of all inputs for soybean production that are taken into account.

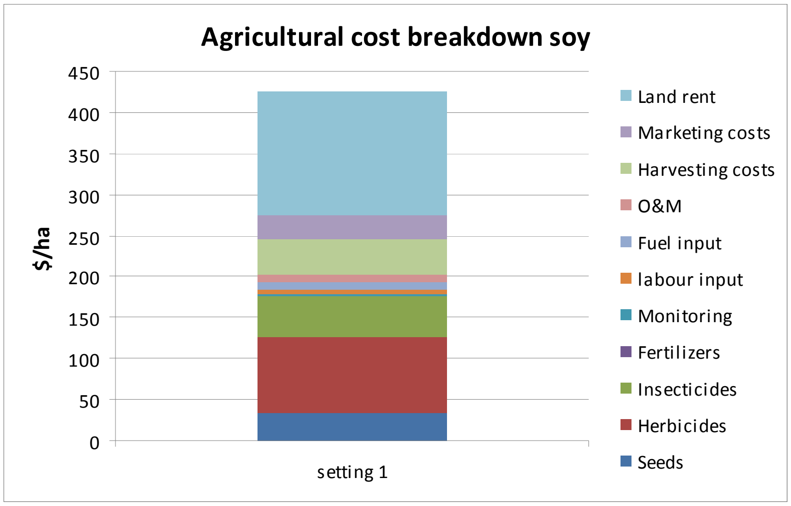

Figure 4-2 Cost breakdown for setting 1, Argentina

Transport distances vary greatly, since Argentina is a large country. For setting 1 and 2 an average of 400 km between field and conversion plant is taken, based on the production regions described above (INTA 2011b). The transport costs are 0.06 $/ton km (van Dam et al. 2009). The market price of soybeans is taken as 168.8 $/ton, this price can vary between 152-185 $/ton (INTA 2011b). All input data that is used in the calculations can be found in Appendix D.

4.4 Sugarcane

The settings that relate to sugarcane are located in Brazil and Mozambique. Both countries currently produce sugarcane and sugar, but only Brazil produces ethanol. In Brazil two production systems exist; large scale plantations and outgrowers who deliver to a central processing unit. The latter is used in our calculations. The production system is placed in North East Brazil (NE), a region which has higher production costs compared to the Central South region of Brazil (CS) (where sugarcane ethanol prices are globally the most competitive), but there is also quite a lot of room for improvement. Cultivation practices have not changed much in the last decade and are not optimal. Mechanised harvest is not practised at a very large scale in the NE, but policies in Brazil require a gradual implementation, which will potentially drive other improvements. Furthermore the NE has the advantage of having several large harbours that are relatively close to the production facilities.

Both production systems also exist in Mozambique. Outgrowers often obtain almost all inputs from the central processing mill, while their only input is labour. There is a large difference between very suitable soils and less suitable soils, (see Chapter 10 on Scale up and integration). Xhinavane is a production region close to Maputo that has been selected for irrigated production, while the Dombo region (more in the Central region) with more suitable soils is selected for non-irrigated production. Sugarcane is cultivated in 5-yrs ratoon cultivation, the crop is planted in year 0, harvested every subsequent year and is replanted in year 6.

Table 4-3 Setting specification for Sugarcane

Nr.	Country	smallhol/pl	Management system	End product	Time-frame
8	Brazil	centralised system (with outgrowers)	Mechanised harvesting, no irrigation (intermediate inputs)	EtOH	2010
9	Brazil	centralised system (with outgrowers)	Manual harvesting, irrigation (high inputs)	EtOH	2010
10	Brazil	centralised system (with outgrowers)	Mechanised harvesting, irrigation	Next EtOH	2020
11	Mozambique	centralised system (with outgrowers)	No irrigation (intermediate inputs)	EtOH	2010
12	Mozambique	centralised system (with outgrowers)	Irrigation (high inputs)	EtOH	2010
13	Brazil	centralised system (with outgrowers)	Mechanised harvesting, no irrigation (intermediate inputs)	EtOH	2020
14	Brazil	centralised system (with outgrowers)	Mechanised harvesting, irrigation (high inputs, high rate mechanisation)	EtOH	2020
15	Brazil	centralised system (with outgrowers)	Mechanised harvesting, irrigation (high inputs, high rate mechanisation)	Next EtOH	2030
16	Mozambique	centralised system (with outgrowers)	No irrigation (intermediate inputs)	EtOH	2020
17	Mozambique	centralised system (with outgrowers)	Irrigation (high inputs)	EtOH	2020

Two settings (10 and 15) consider both 1st and 2nd generation ethanol, ethanol produced from the juice (1st generation) and from the bagasse (2nd generation). Every ton of bagasse produces 88.3 l ethanol (CGEE 2009).

Yields -- The yield for the NE is based on (Herreras 2011) and is 60 ton cane/ha/yr for non-irrigated cane and 90 ton ha/yr for irrigated cane. The yields in Mozambique (76 t/ha/yr non-irrigated and 100 t/ha/yr irrigated) are based on (De Vries et al. 2011) and (van der Hilst, submitted). The higher yields in Mozambique are explained by the high climate suitability of sugarcane. Per ratoon year the yield is expected to decrease to respectively 96, 92, 88, 83 and 79% of the maximum yield. Yields are projected to increase with 5% in 2020 compared to 2010.

Other costs and inputs -- Transport costs in Mozambique are quite high; 0.096 $/ton km, for Beira region, while for Brazil they are 0.06 $/ton km (CEPAGRI et al. 2011). Land rent in Mozambique is assumed to be 22.05 $/ha/yr. Depending on the type of land (bare land, agricultural etc.) this price can vary, for example agricultural land that is leased from the Government has only a tax fee of around 0.5 $/ha/yr (MZM 15/ha/yr) (Investment

Promotion Center 2009). See Figure 4-3 for a detailed cost breakdown. In Appendix D all other input data is shown.

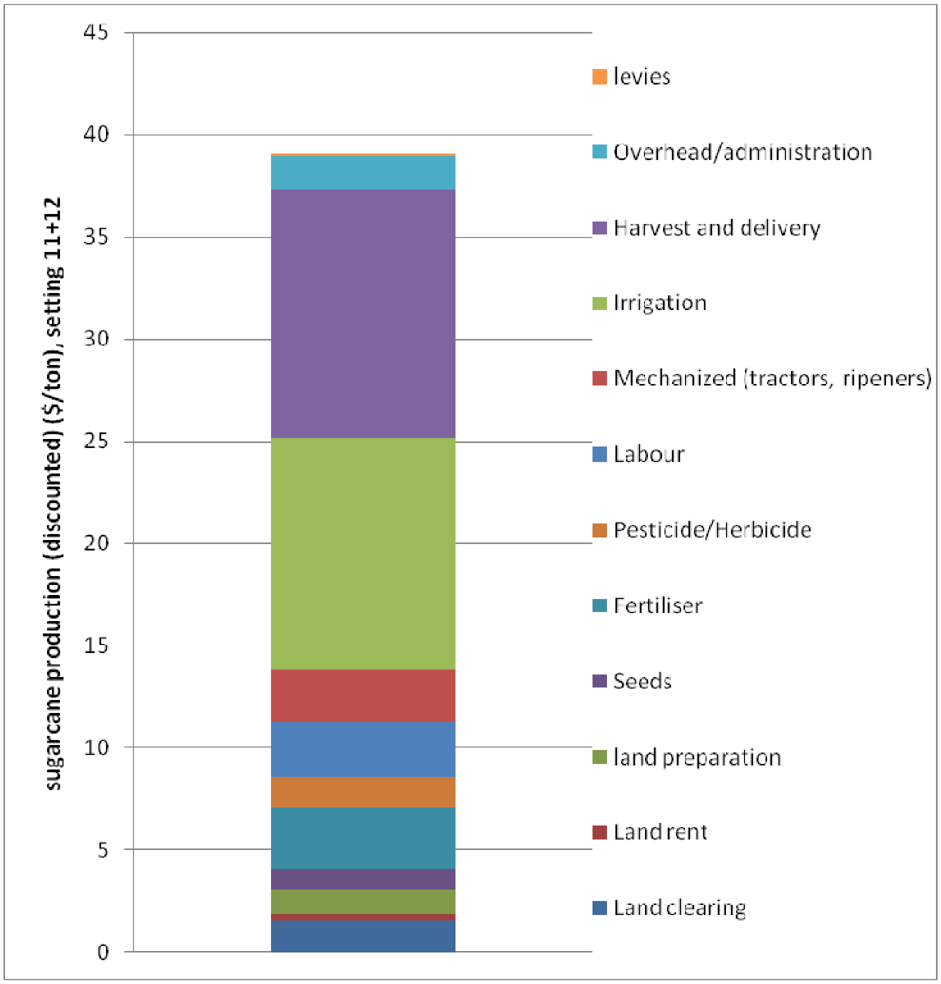

Figure 4-3 Breakdown of discounted costs for Mozambique ($/ton cane)

4.5 Palm oil

The palm oil settings that we selected refer to production in Colombia, Indonesia and Malaysia. Malaysia is the largest exporter of palm oil and is considered to operate on a best-practice base. Colombia currently has >400,000 ha of oil palm plantations and is the worlds' fifth producer (Fedepalma 2010a). See Table 4-4 for more details on the settings, for this cost calculation section we have added a setting for palm oil production 2020 in Colombia, setting 21b.

For Indonesia the setting is located in Jambi (Harapan Makmur village) on Sumatra. Outgrowers are mainly small-scale farmers, who on average each own a 2 ha farm. They obtain a relatively low yield, which appears to result from a range of factors related to sub-optimal management practices. Farmers farm their own land using family labour. Fertiliser application, the largest cost component of farmers' operating costs, is variable. Farmers currently apply a mix of inorganic fertilizers (Global Biopact 2011).

Table 4-4 Settings selected for palm oil production

Nr	Country	Smallholder/ plantation	Management system	End product	Timeframe	By-products
18	Indonesia	smallholders	intermediate inputs	SVO	2010	no pome use
19	Indonesia	smallholders	intermediate inputs	FAME	2010	no pome use
20	Indonesia	plantation	high inputs	FAME	2010	no pome use
21	Colombia	smallholders	intermediate inputs	FAME	2010	no pome use
22	Malaysia	plantation	high inputs	FAME	2010	no pome use
23	Indonesia	plantation	high inputs	FAME	2020	pome use
24	Malaysia	plantation	high inputs	FAME	2020	pome use
21b	Colombia	smallholders	Intermediate inputs	FAME	2020	

(POME=Palm Oil Mill Effluent, or waste water)

In Colombia production systems are present with small, medium and large scale oil palm growers. Especially for outgrowers, improvements in yield and the amount of hectares planted are expected to increase in the future. Cost data is derived from CENIPALMA (Investigación e Innovación Tecnológica en Palma de Aceite) and (Fedepalma 2010b). Data from Malaysia is obtained from (Ismail et al. 2003). The breakdown of the agricultural inputs is shown in Figure 4-4 and Figure 4-5, the costs structure is slightly different.

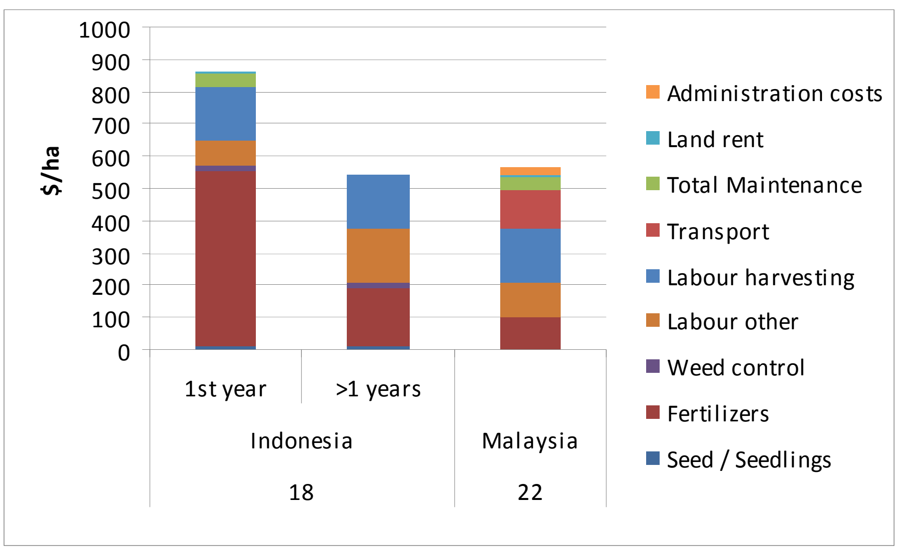

Figure 4-4 Breakdown of feedstock production costs Indonesia and Malaysia for setting 18 and 22

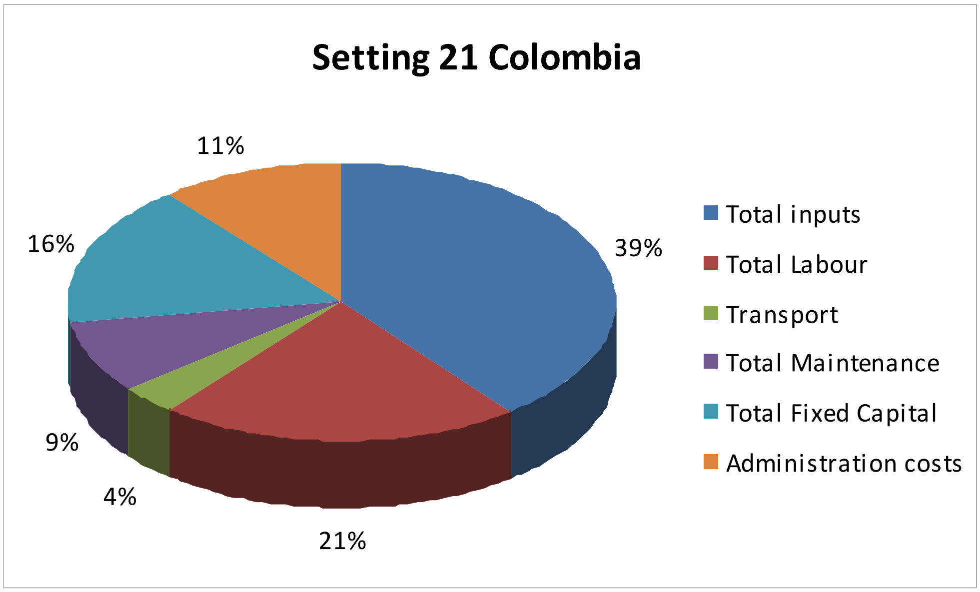

Figure 4-5 Cost breakdown of feedstock production for Colombia, setting 21

The major cost item for total inputs is fertiliser, followed by labour required particularly for harvesting.

Yield – Yield is expressed in Fresh Fruit Bunches (FFB). It is estimated that Indonesia (16 ton FFB/ha/yr) reaches the yield level of Malaysia (19 ton FFB/ha/yr) by 2020. This is relatively conservative since a case study plantation in Malaysia, analysed by Wicke et al. (2008), yielded 25 ton FFB/ha/yr. Better genetic varieties can increase yields. Also for Colombia the expectation is that yield levels will reach Malaysia. Although Bud rot disease can seriously affect yields and has done so in Colombia, hybrid materials have been developed but it takes some time before they are in production (Fedepalma 2010a).

Other input data can be found in Appendix D.

4.6 Jatropha

There are 17 settings that relate to Jatropha. Three countries are included: Tanzania, Mali and India as well as three different management settings: low inputs, intermediate inputs and high inputs. A production system with smallholders and a plantation is also considered (see Table 4-5).

Smallholders produce for a processor, either under a contract or independently. They often use family labour to cultivate their fields. Jatropha is planted as hedges around their farming plots, or planted with other crops on their fields. The seeds that are produced can be sold to the processor via a collector. Collection centers are located near strategic places, farmers bring their seeds in bags and company employees organise transport to a central place and then on to the central processing unit. The processor provides the farmers and collectors with extension services such as knowledge on cultivation practices and the initial planting material. A typical size for a smallholder plot is 0.5 to 2.0 ha (Mitchell 2008). Jatropha seeds are harvested from year 2-24, harvest periods in Tanzania are end of November (depending on the rainy period) and July-august. In India the harvest period is July-August and October-November in Karnataka (Estrin 2009).

Table 4-5 Different settings (17) considered for Jatropha

Nr	Country	Smallholder/ Plantation	Management system	End product	Timeframe
25	Tanzania	smallholders	low inputs, marginal land, no irrigation	SVO	2010
26	Tanzania	plantation	high inputs, good land, no irrigation	FAME	2010
27	Tanzania	plantation	intermediate inputs, marginal land, no irrigation	FAME	2010
28	Tanzania	smallholders	low inputs, marginal land, no irrigation	FAME	2010
29	Tanzania	smallholders	smallholder, intermediate inputs, marginal land	FAME	2010
30	Mali	smallholders	low inputs	FAME	2010
31	Mali	smallholders	intermediate inputs	FAME	2010
32	India	smallholders	low inputs	FAME	2010
33	India	smallholders	intermediate inputs	FAME	2010
34	Tanzania	plantation	high inputs, good land, no irrigation	FAME	2020
35	Tanzania	plantation	intermediate, marginal land, no irrigation	FAME	2020
36	Tanzania	smallholders	low inputs, marginal land	FAME	2020
37	Tanzania	smallholders	intermediate inputs, marginal land	FAME	2020
38	Mali	smallholders	low inputs	FAME	2020
39	Mali	smallholders	intermediate inputs	FAME	2020
40	India	smallholders	low inputs	FAME	2020
41	India	smallholders	intermediate inputs	FAME	2020

In a plantation system the land is cultivated by employees of the company, often with much higher rates of mechanisation. The land can be cultivated in patches of, for example, 200 ha each. Each patch is then managed by a block-manager/field officer. Employees of the company pick the seeds which are then processed. The fruit shells (capsules) are obtained when opening them to obtain the jatropha seeds. It is assumed that smallholders leave these on the field, while in a plantation system they are used as fuel.

All three countries produce jatropha, however experiences on commercial levels are limited. The amount of oil produced is relatively low, so therefore most cost data is derived from small-medium sized extraction plants or is estimated. Large investments have been made in jatropha research so efficiency improvements are expected; on the other hand some large scale operations halted their activities.

Feedstock production -- The cost factors are different for smallholders and a plantation system. The feedstock costs factors for the smallholder settings are shown per country.

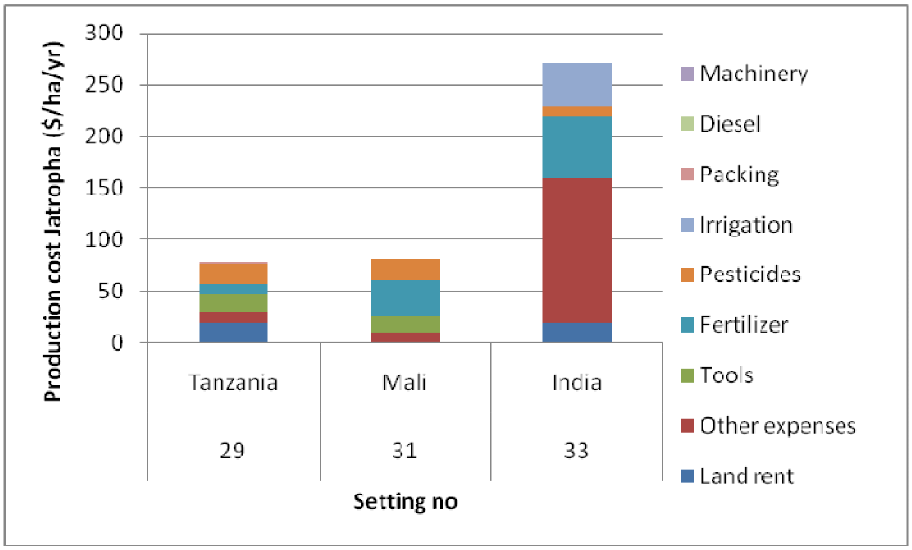

Figure 4-6 Feedstock production cost breakdown ($/ha)

A difference between the countries is that for Tanzania it is assumed that farmers have to pay for packaging, 0.45$ per bag of 60 kg, these expenses are not accounted for in Mali and India. Since bags are often re-used these expenses are not always accounted for by the farmers (also not in Tanzania (Van Eijck 2009)), this shows the difference in costs.

The plantation setting is situated in Tanzania, the low input setting (no 27) represents a plantation based with manual labour, while the intermediate input setting (26) represents mechanised harvesting. Since this is not currently applied globally, experimental data of the BEI-harvester has been used to estimate these costs. See Figure 4-7 and Figure 4-8 that visually illustrate the difference in cost structure of the two plantation settings.

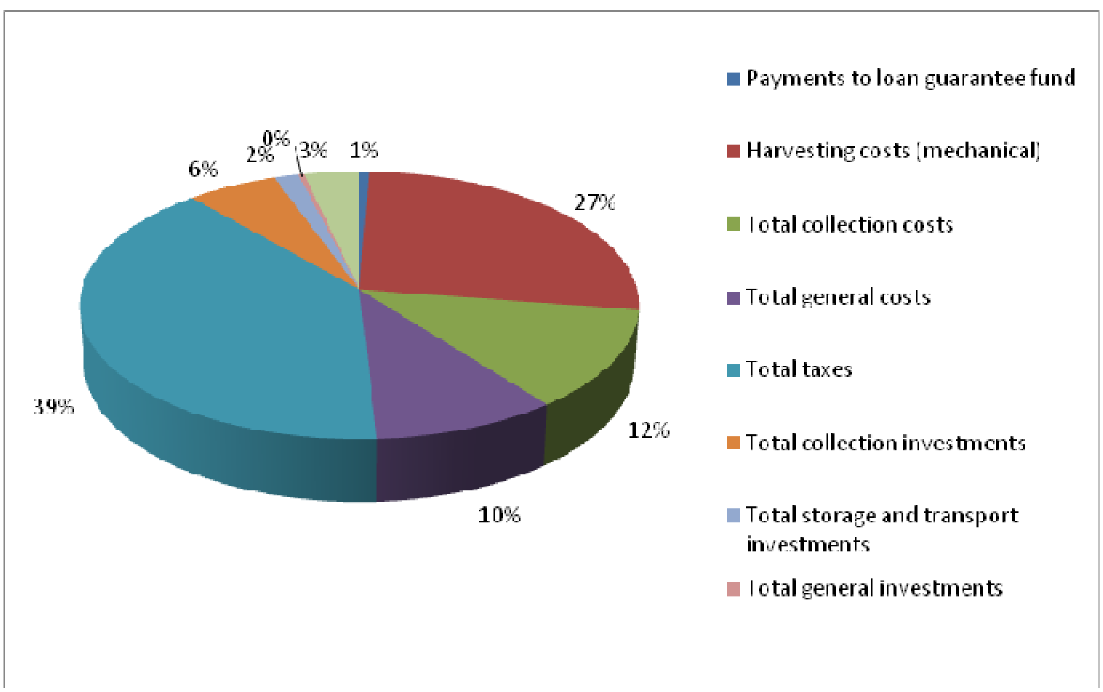

Figure 4-7 Cost structure setting 26, mechanised harvest

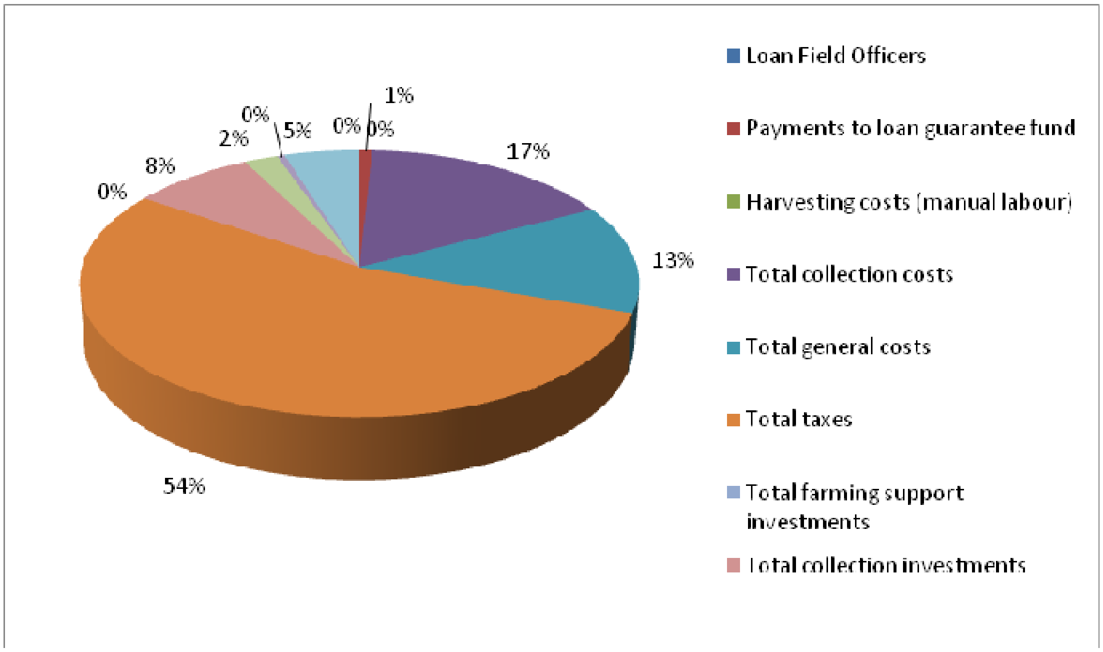

Figure 4-8 Cost structure setting 27, manual labour

In the 2020 settings, the parameters for the mechanised harvester are changed, the price is decreased by 60% (from 180,000$ per harvester to 60,000$) and the harvesting speed is increased from 1.5 ha/hour to 3 ha/hour. For both production systems the costs are linked to the yield. Wage rates are relatively low in the countries, and only low skilled labour is required for cultivation. Smallholders often do not count their labour hours, so this can also be seen as opportunity costs. For all three regions the labour requirements have been kept constant, total labour requirements for jatropha depend on harvest and vary between 30-120 days/ha/year. In Appendix D the range in labour days is given.

Wage rates are varied per country. India has the lowest wages with 1.29$/day (Rs 60/day), this is the minimum wage) (Altenburg et al. 2009), Tanzania has wages rates of 2$/day (van Eijck et al. 2012) and Mali 2.47 $day (API Mali 2010).

Yields -- Jatropha is a perennial crop with a productive lifetime of >30 years. For this study, an economic lifetime of 24 years has been used. The plant matures in 6 years' time; the first year 0% of the mature yield is expected. In the second year 10% of the yield is expected and 25%, 40% and 80% in the subsequent years until year 6, see Table 4-6. Furthermore, for 2020 the yields are expected to increase by 15% considering large efforts in Jatropha breeding programs (Hawkings and Chen 2011).

Conversion -- Since Jatropha production has not reached commercial levels, costs of conversion to SVO and biodiesel are relatively high; 0.20 $/l and 0.28 $/l respectively (van Eijck et al. 2012). In India there is a well-established oilseed sector, therefore the conversion costs to SVO are lower (0,14 $/l (Estrin 2009). Conversion and transesterification costs for 2020 are based on US biodiesel conversion plants that are also used by (Mulugetta 2009). Large efficiency improvements are expected.

All input data can be found in Appendix D.

Table 4-6 Maximum yield values for jatropha in 2010 and 2020

Setting number	**Country**	**Yield (kg/ha/yr)**
25	Tanzania	1,100
26	Tanzania	3,000
27	Tanzania	1,400
28	Tanzania	1,100
29	Tanzania	1,980
30	Mali	1,000
31	Mali	1,500
32	India	2,000
33	India	2,500
34	Tanzania	3,450
35	Tanzania	2,875

4.7 Cassava

Cassava is currently cultivated in large parts of the world, often by subsistence farmers as source for food. Cassava roots can be stored in the soil for two years, serving as food storage (Elbersen and Oyen 2009). Small scale farmers cultivate cassava as an additional crop on their land, and in between other crops. These cultivation management techniques are often far from best practice. In Thailand, more commercial farming of cassava exists and the first (pilot) cassava to ethanol conversion plants have already been established. In Mozambique and Tanzania such facilities do not exist yet. Data on cassava cultivation is obtained from (van Eijck et al. 2012), IIAM Mozambique, (Nguyen et al. 2008), (Silalertruksa and Gheewala 2009) and through personal communication with Prof. Gheewala (The Joint Graduate School of Energy and Environment King Mongkut's University of Technology Thonburi, Bangkok, Thailand), Thea Shayo in Tanzania (Shayo feb. 2010) and Sicco Colijn in Mozambique (2010). There are 16 settings related to cassava feedstock, see Table 4-7.

Input costs – The labour days required for cultivation in Mali and Tanzania are expected to reduce in 2020 to only half of the amount of 2010. This is due to increased mechanisation that enables labour rates more equal to Thailand. The labour requirements for Mozambique and Tanzania are based on (van Eijck et al. 2012). 142 labour days per year are required for the low input system and 165 days/ha/yr for the intermediate input systems. The difference is due to the labour days required for additional management such as fertiliser, pesticide and herbicide application and pruning. Since there are currently no large scale plantations for cassava cultivation, these are only included for 2020, when it is expected that commercial plantations will start up.

Yields -- Cassava is harvested every year, but for comparison reasons a system lifetime of 24 years is taken. In the low input system in Mozambique and Tanzania it is assumed that due to a lack of suitable levels of fertiliser applied, the yields decline by 2% per year. In Thailand, current practice is to apply fertiliser, therefore yields are assumed to be stable over the years. For the settings that relate to 2020, it is assumed that Mozambique reaches yield levels of Tanzania, and Tanzania reaches yield levels of Thailand, see Table 4-8.

Input costs – The labour days required for cultivation in Mali and Tanzania are expected to reduce in 2020 to only half of the amount of 2010. This is due to increased mechanisation that enables labour rates more equal to Thailand. The labour requirements for Mozambique and Tanzania are based on (van Eijck et al. 2012). 142 labour days per year are required for the low input system and 165 days/ha/yr for the intermediate input systems. The difference is due to the labour days required for additional management such as fertiliser, pesticide and herbicide application and pruning.

Table 4-7 Definition of settings related to cassava

No	Country	smallhol/pl	Management system	End product	Time-frame	Byproducts
42	Mozambique	smallholders	low inputs	EtOH	2010	Cake as fertilizer
43	Mozambique	smallholders	intermediate inputs	EtOH	2010	Cake as fertilizer
44	Tanzania	smallholders	low inputs	EtOH	2010	Cake as fertilizer
45	Tanzania	smallholders	intermediate inputs	EtOH	2010	Cake as fertilizer
46	Thailand	smallholders	low inputs	EtOH	2010	Cake as fertilizer
47	Thailand	smallholders	intermediate inputs	EtOH	2010	Cake as fertilizer
48	Mozambique	smallholders	low inputs	EtOH	2020	Cake as fertilizer
49	Mozambique	smallholders	intermediate inputs	EtOH	2020	Cake as fertilizer
50	Mozambique	plantation	high inputs	EtOH	2020	Cake as fertilizer
51	Tanzania	smallholders	low inputs	EtOH	2020	Cake as fertilizer
52	Tanzania	smallholders	intermediate inputs	EtOH	2020	Cake as fertilizer
53	Tanzania	plantation	high inputs	EtOH	2020	Cake as fertilizer
54	Thailand	smallholders	low inputs	EtOH	2020	Cake as fertilizer
55	Thailand	smallholders	intermediate inputs	EtOH	2020	Cake as fertilizer
56	Thailand	plantation	high inputs	EtOH	2020	Cake as fertilizer

Table 4-8 Yield levels for cassava

Setting number	Input system	Yield (t/ha)	Region	Literature source
42	Low inputs	4	Mozambique	FAO average
43	Intermediate inputs	6	Mozambique	FAO average
44	Low inputs	6	Tanzania	(van Eijck et al. 2012)
45	Intermediate inputs	12	Tanzania	(van Eijck et al. 2012)
46	Low inputs	20	Thailand	(Office of Agricultural Economics (OAE) 2009)*
47	Intermediate	22	Thailand	(Office of Agricultural Economics (OAE) 2009)* average of country averages 2007-2009
54	Low	32	Thailand	(Silalertruksa and Gheewala 2010)*
55	Intermediate	34	Thailand	(Silalertruksa and Gheewala 2010)*
56	High	44	Thailand	Estimate IFEU/UU

* also based on personal communication Prof. Gheewala, Bangkok, Thailand

The amount of labour days for Thailand is much lower (around 44 days/ha/yr (Nguyen et al. 2008)) but the use of agricultural equipment is higher. The labour costs for Thailand are based on averages from 2005-2008 (Office of Agricultural Economics (OAE) 2009). There are no costs for fertiliser included in the low input settings for Mozambique and Tanzania, this is done because the fertiliser applied (e.g. 13.6 k N per ha for setting 42, see GHG calculations) is expected to be derived from manure that is freely available. The input costs for Thailand are averages from 2005-2008 (Office of Agricultural Economics (OAE) 2009). The average farm gate price of fresh cassava roots in Thailand (2006-2008) is 1400 THB/t or 45 $\$_{2010}$/t. See Figure 4-9 for a breakdown of input costs. All input data can be found in Appendix D.

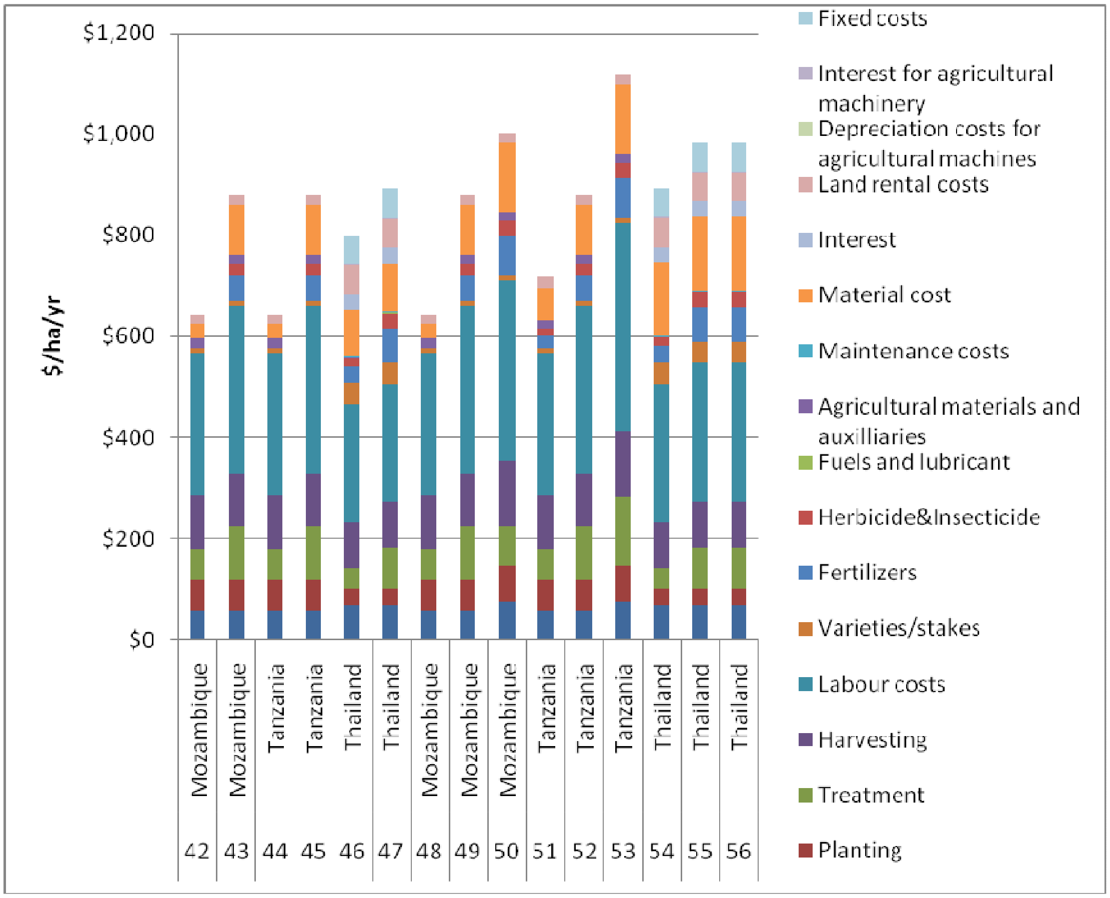

Figure 4-9 Input costs for cassava settings ($/ha)

4.8 Costs of liquid biofuels production

The results of the total production costs per feedstock are presented in this chapter.

4.8.1 Soy biodiesel

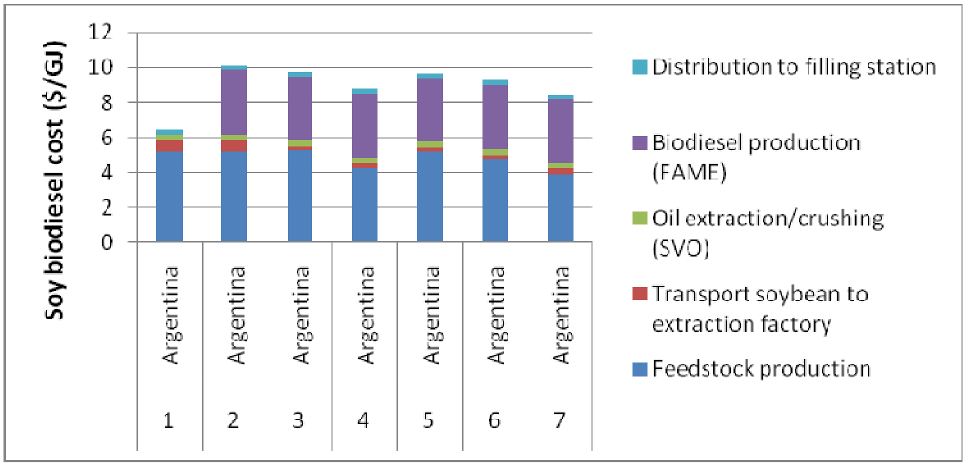

Figure 4-10 Cost price $/GJ for settings 1-7; (energy content 32.9 MJ/l)

The price per GJ for soy biodiesel in Argentina is relatively low, this is due to the high value of the (main) product; soy meal. Of the feedstock costs 20% is allocated to soy biodiesel (by mass). The breakdown of discounted expenses for soy production (Figure 4-11) shows that land rent is a relatively high contributor. The value of land rent that is used in the calculations is 150 $/ha/yr. This value is actually quite low, considering other sources that mention prices of 200 $/ha/yr (INTA 2011b) or even higher (commercial) rates of almost 520 $/ha/yr.

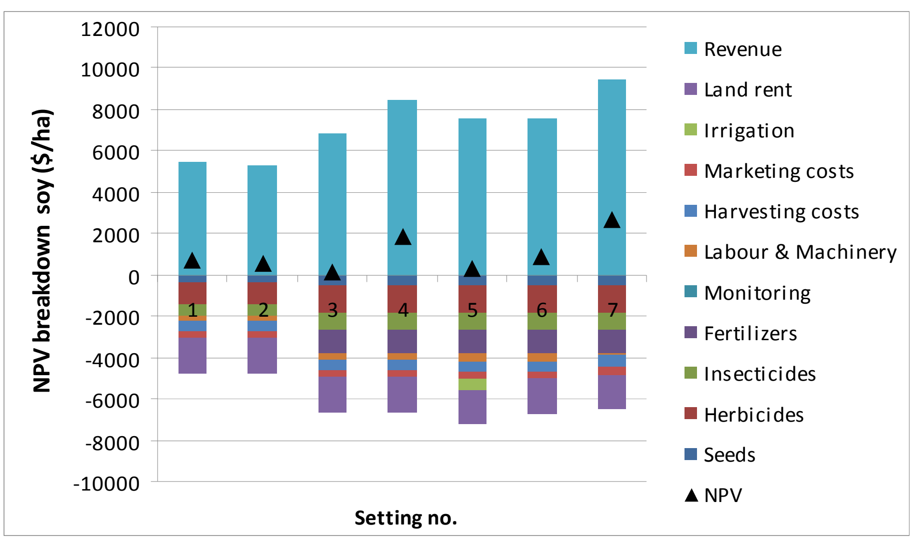

Figure 4-11 NPV per ha for soy settings

4.8.2 Sugarcane ethanol

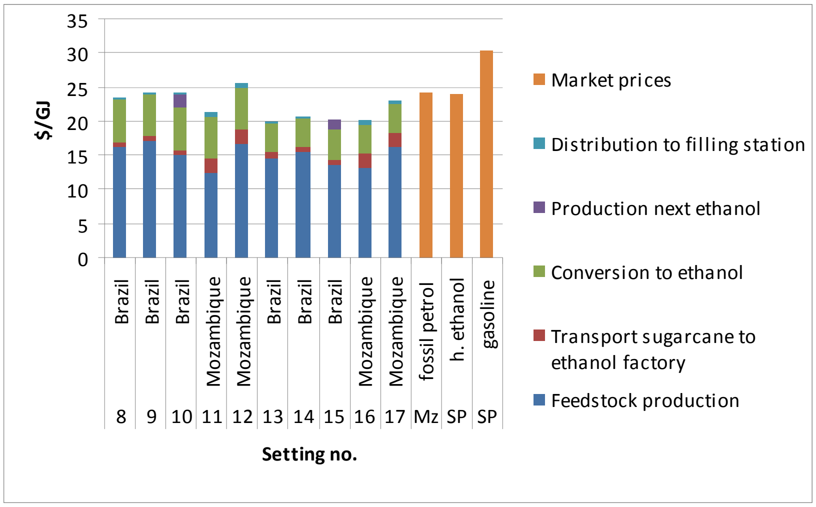

Figure 4-12 Cost price per GJ for setting 8-17 (SP is Sao Paulo, market price of hydrated ethanol and gasoline: (van den Wall Bake et al. 2009), Mz is price of petrol in Mozambique in 2009 (excluding taxes), ethanol energy content 26.4 MJ/l

Information on the market prices for sugarcane (26.4 MJ/l) has to be included for NPV calculations. These prices fluctuate with the global sugar prices and therefore are very volatile.

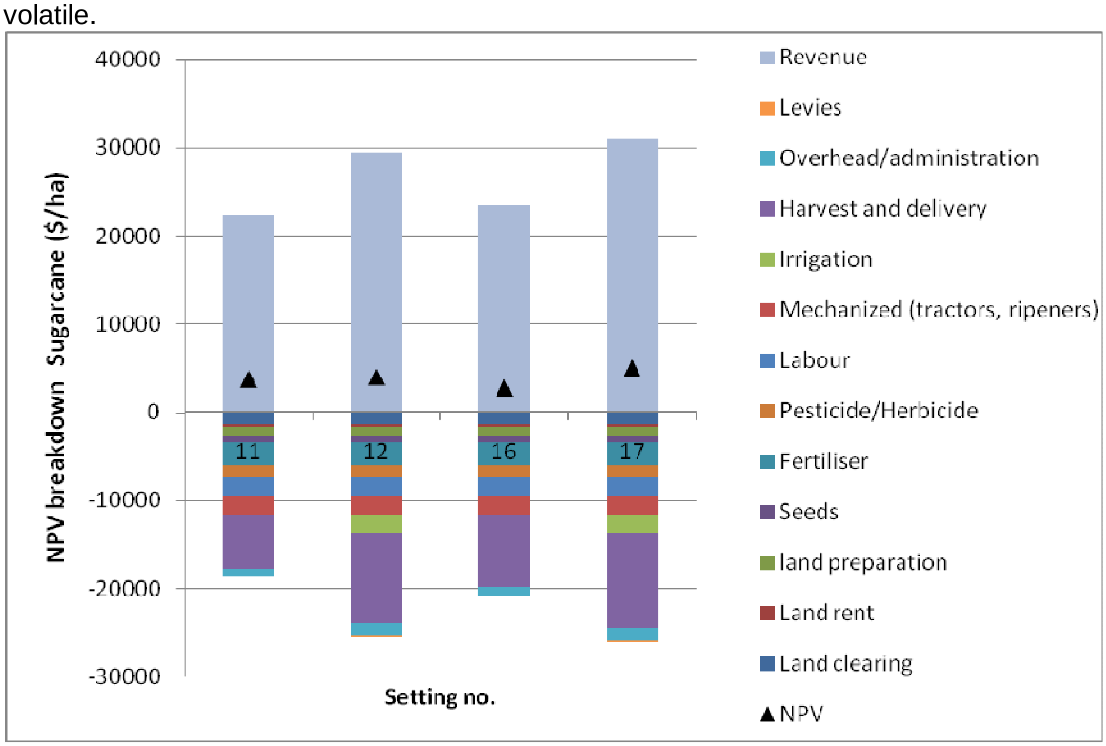

Figure 4-13 NPV per ha for sugarcane Mozambique settings

All NPVs for Mozambique are positive. Note that in setting 12 and 17, it is assumed that the instalment costs for irrigation are accounted for by the central producer; the outgrower has to account for the labour that is associated with irrigation.

4.8.3 Palm oil (CPO and FAME, Indonesia-Colombia-Malaysia)

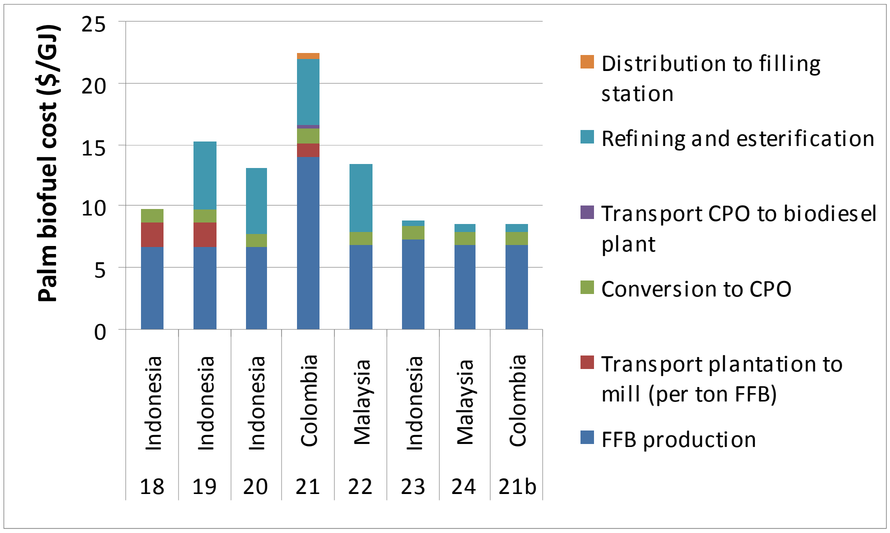

Figure 4-14 Cost of Palm oil production (CPO and biodiesel) in Indonesia, Colombia and Malaysia; energy content 36.92 MJ/l (Yáñez Angarita et al. 2009)

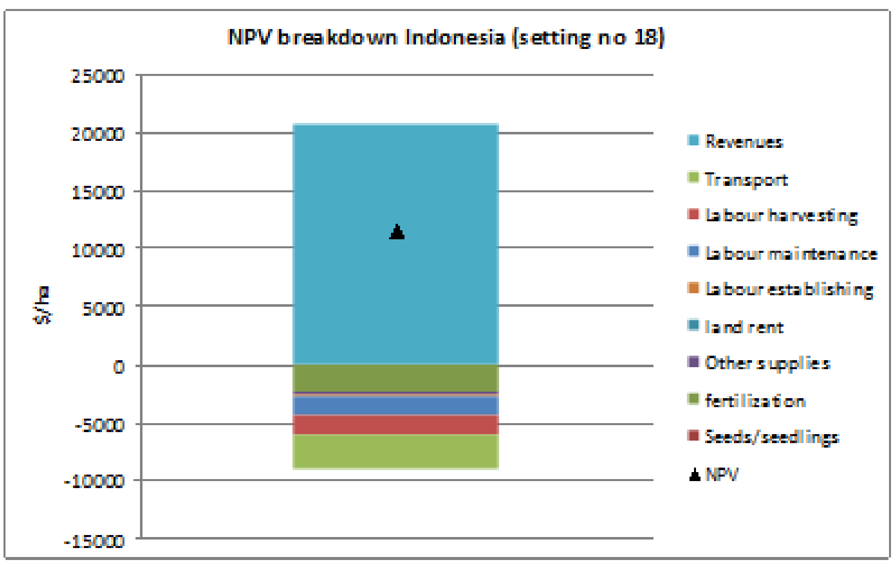

Figure 4-15 NPV for Setting 18

The NPV for Indonesian farmers is very high. This is due to the relatively high yields we have incorporated in our calculations. Smallholders also have to pay for transport expenses to the mill which is included in the calculations. FFB prices are volatile and since they have to be processed within a short time frame, farmers often do not have a choice but to sell them for a (set) price to the mill.

4.8.4 Jatropha oil and biodiesel

In Figure 4-16 the costs of Jatropha SVO and biodiesel in Tanzania, Mali and India are shown.

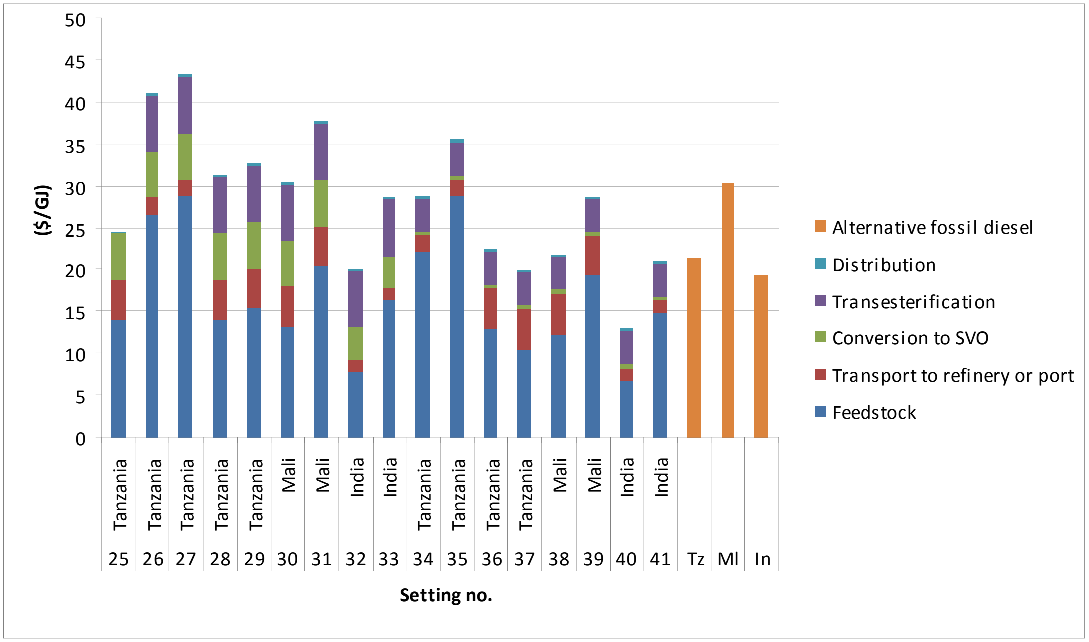

Figure 4-16 Costs per GJ for Jatropha SVO and Biodiesel for setting 25-41, compared to the price per GJ of the locally available fossil diesel (36.2 MJ/l)

The cultivation of Jatropha is very labour intensive. That is why wage rates have a large influence on feedstock production costs. The wage rate of India is relatively low (60rs/day or 1.29 $/day), compared to Tanzania (2$/day). The wage rate of Mali is (slightly) higher with 2.46 $/day. Intermediate inputs in India also includes irrigation which is why this setting (33 and 41) has higher costs than cultivation without irrigation (32 and 40). Transport expenses are quite low in India compared to the African countries. If infrastructure improves these costs can be lowered but this has not been taken into account in the analysis. The NPV is shown in Figure 4-17.

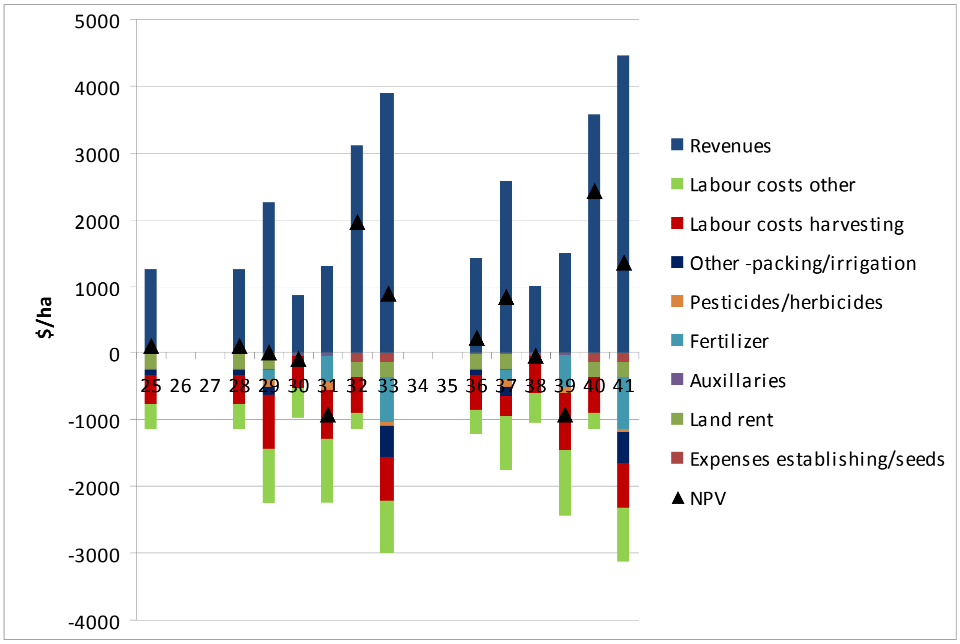

Figure 4-17 NPV for Jatropha settings (excluding plantation settings)

For quite a number of settings the NPV is negative. The profitability for farmers mainly depends on the yield that can be obtained. Intermediate inputs do not lead to higher NPV's. With relatively low labour costs (or family labour when there are limited other options) and an average yield the NPV can be high; 2,437 $ (India, setting 40).

The two plantation settings are different in their production system and cost structure, in setting 26 (mechanized labour) production costs per kg are 0.24 $/kg seeds, while in setting 27 (manual labour) these costs are 0.26 $/kg seeds. The difference is due to the relatively high price of the harvester, which is expected to decreases in the future.

4.8.5 Cassava ethanol

Figure 4-18 shows the costs of cassava ethanol production for the different settings in Tanzania, Mozambique and Thailand. In 2010 prices, none of the settings can obtain cassava ethanol for a price below current fossil petrol prices. However, with anticipated increase in yields (see data input section) and a reduction of conversion costs from 0.23 $/l to costs equal to corn ethanol conversion costs (0.14 $/l (Hettinga et al. 2009)), all 2020 settings could be competitive to current fossil petrol prices. The price of 0.23 $/l is derived from a pilot factory in Thailand where efficiency improvements and cost reductions are likely. Prices of inputs are assumed to remain the same over the decade. Several factors influence these prices. Inflation could increase prices and revenues, while more efficient management techniques, better varieties etc. could reduce prices. Also, fertiliser prices are linked to fossil prices that are highly volatile. More research is required to quantify these effects. The NPV for producing cassava feedstock in the different settings is shown in Figure 4-19.

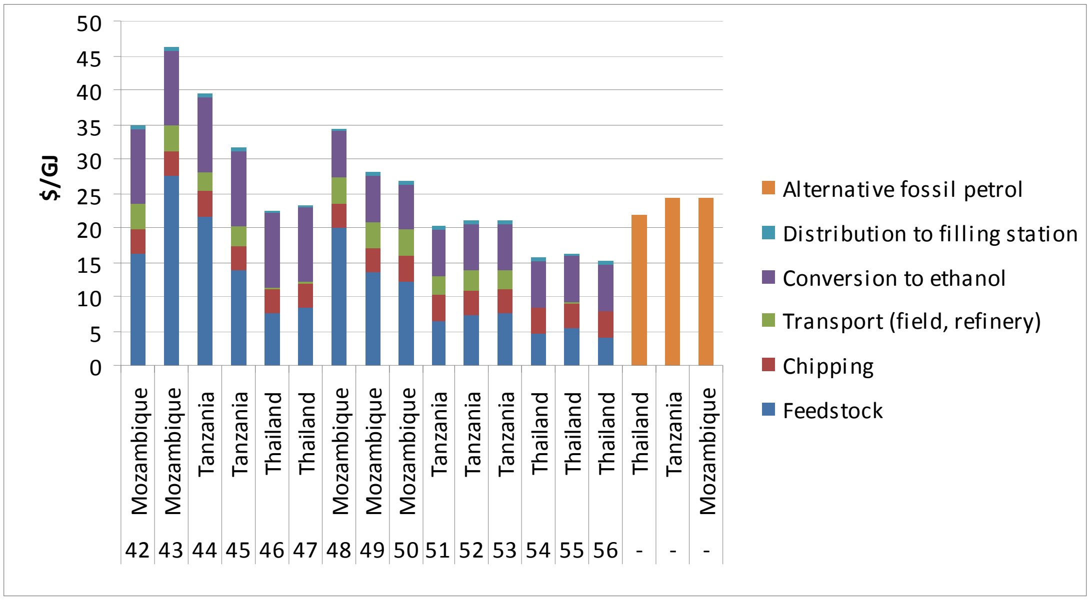

Figure 4-18 Life cycle cost calculations for cassava ethanol (20.88 MJ/L)

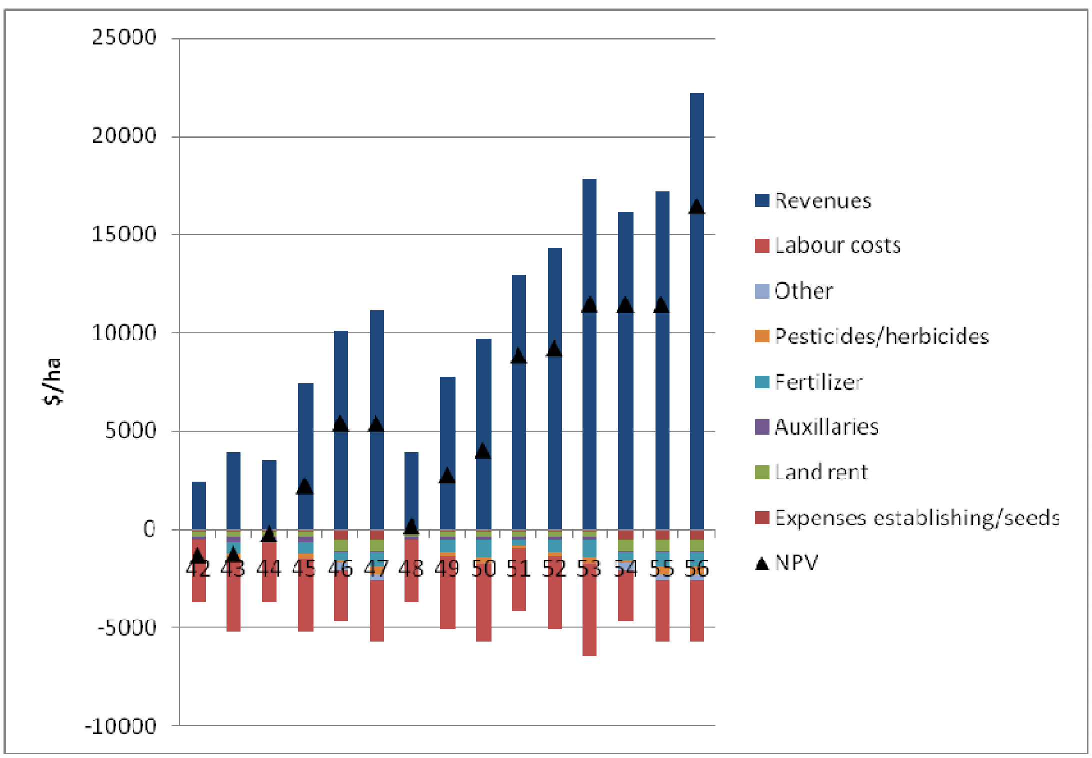

Figure 4-19 Costs, revenues and NPV for cassava in different settings ($/ha)

Setting 42, 43 and 44 do not have positive NPVs, which means that at current market prices for fresh cassava roots, and current (low) yields, cassava cultivation is not profitable in these regions (Mozambique and Tanzania). Settings 45, 46 and 47, however, (all 2010 settings) are quite profitable (Tanzania and Thailand). This is due to the higher yields that make up for additional expenses on fertiliser and other inputs.

All settings that relate to 2020 (setting 48-56) have positive NPVs (from 180-16,000 $/ha). Labour costs are the major cost contributor, while for Thailand land rent is also a relatively large contributor.

4.9 Competitiveness of liquid biofuels and improvement strategies

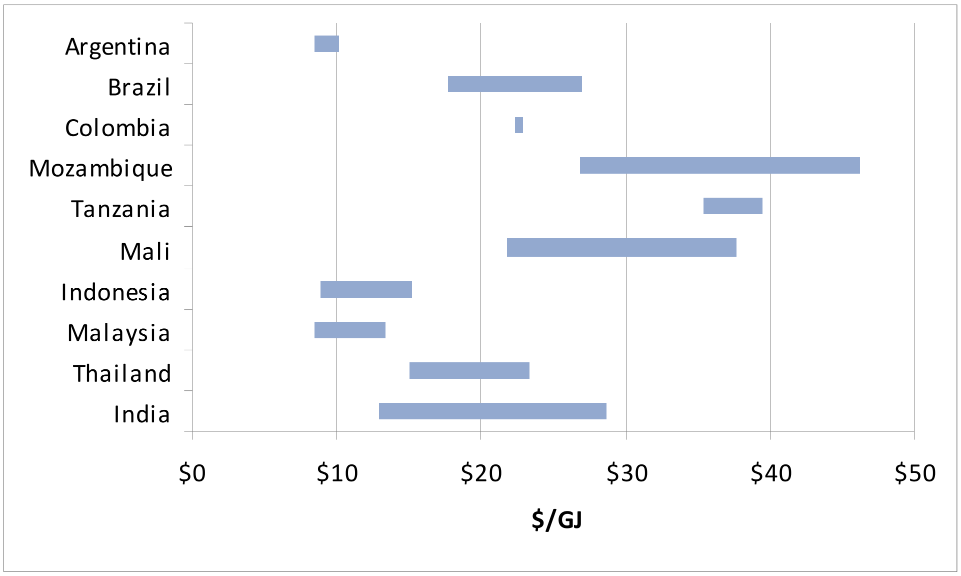

Figure 4-20 Ranges of biofuel cost prices ($/GJ) per region

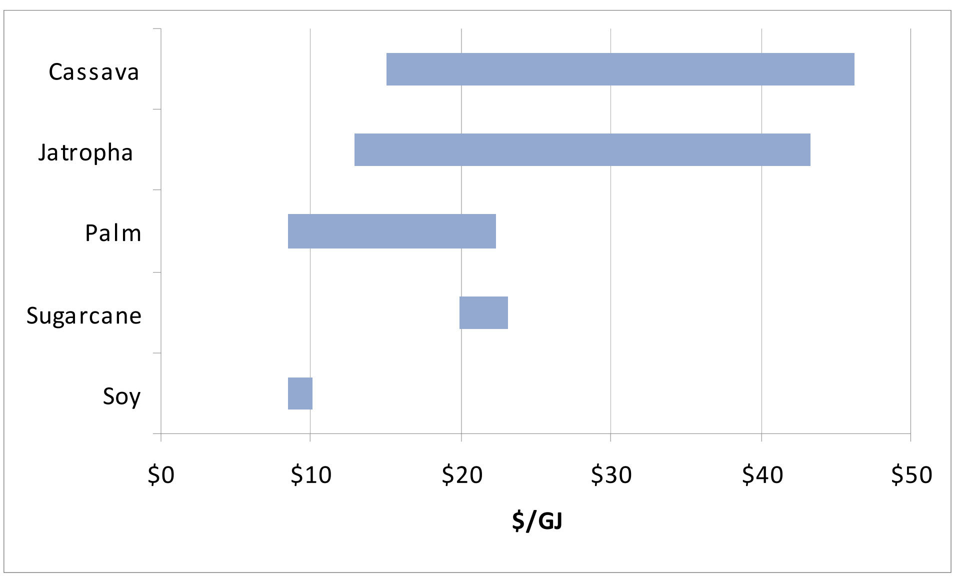

Figure 4-21 Ranges of biofuel production costs ($/GJ) per feedstock

4.10 Sensitivity analysis

Discount rates are varied from the original 8.2% to 6% and 15%, see Figure 4-22. This only influences the costs of the perennial crops.

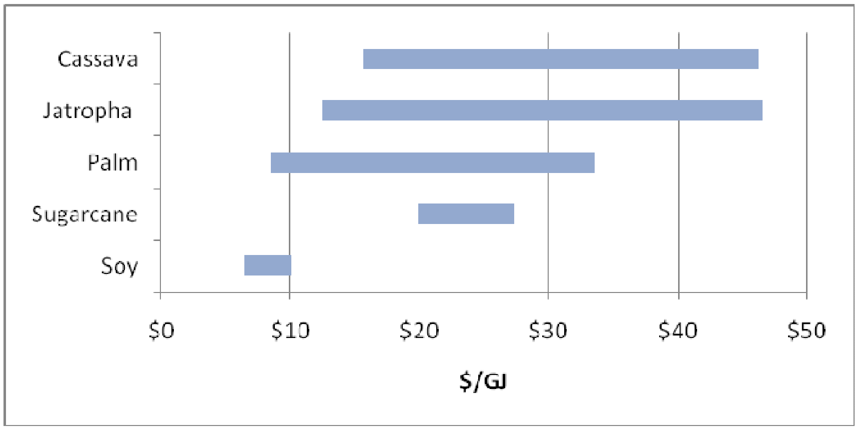

Figure 4-22 New ranges for variation in discount rates, 6%-15%

Wages/labour costs

Wage rates for Argentina used in calculations are 3.18 $/h in 2010 and 8.29 $/h in 2020. For this sensitivity analysis they are varied from 1$/h to 15 $/h. Sugarcane labour costs are varied from zero to double. Palm lacks specific data on labour. Jatropha labour rates are varied from 0 to 7.5 $/day. The zero labour costs represent family labour. And finally for cassava the wage rates are varied from 0 to 8 $/day (8 is the double rate of the 4 $/day that is used for 2020 Moz.).

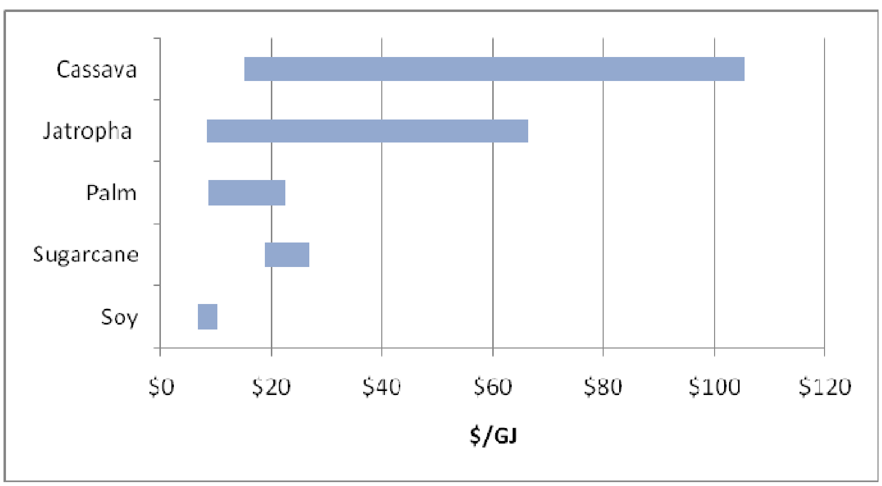

Figure 4-23 New ranges for variation in wage rates

The influence of wages is large especially for cassava ethanol, jatropha SVO and biodiesel. The influence on soy is minimal. The price of inputs has been considered constant.

4.11 Screening tool for economic aspects

The following screening tool contains a summary of issues from the economic analyses; it builds on the traffic light concept that is explained earlier in this document.

Table 4-9 Screening tool for economic aspects

Factors to consider	**GO**	**CHECK**	**STOP**
NPV	The NPV is positive and compares well to other feedstocks in the region or the same feedstocks in other regions.	The NPV is close to zero.	The NPV is negative.
Life cycle costs	The life cycle costs compare favorably to other feedstocks or countries.	The life cycle costs are neutral compared to other feedstocks or countries.	The life cycle costs do not compare favorably to other feedstocks or countries.
Data quality	Specific regional setting data on costs, yields etc.	Specific cost data is lacking or only generic literature available	Not applicable
Sensitivity (i.e. a measure of whether NPV and life cycle costs remain stable under varying market conditions, such as yield, discount rate, wages, land rent, cost of other inputs such as fertilizers, packaging, market price of feedstock)	Robust performance, NPV and life cycle costs remain positive/competitive under varying market conditions	No robust performance of NPV and life cycle costs: they are only marginally positive or slightly negative under varying market conditions.	Highly negative performance of NPV and life cycle costs, therefore high risk of project negatively affected by varying market conditions.
Technological complexity and maturity	Technical and industrial capabilities available	Relies on new, (whether proven or not) technology and/or new infrastructure	Not applicable

4.12 Summary: Economic viability of the production of liquid biofuels

Net present value (NPV) and life cycle cost calculations are made for the 1st generation feedstock settings (setting 1-54). A positive NPV indicates profitability. Two timeframes are included, 2010 and 2020; cost of inputs for 2020 has been considered a constant. Yields are expected to increase due to better management and improved varieties.

High NPVs are calculated for cassava and palm. But cassava can also have a negative NPV which indicates that the project investment is not robust. The calculated NPVs for jatropha also range from negative to positive, while for sugarcane and soy the NPV is more robust (always positive). Total life cycle cost in 2010 is estimated to vary between below 10 \$/GJ to above 40\$/GJ for 1st generation feedstocks in the chosen settings and from below 10 to above 20 \$/GJ in 2020, see specifics per crop below;

- *Soy* - Costs for soy SVO and biodiesel are calculated to be the lowest with 6.4-10.1 \$/GJ, only 20% of the production costs are allocated to soy biodiesel since the crop is used mainly for animal feed. The NPV is positive in all cases, ranging from 180 \$/ha/year to above 2,900 \$/ha/year in 2020 assuming a yield of 5 ton/ha/yr.
- *Sugarcane* - Sugarcane ethanol (incl. 2nd generation next ethanol) can be produced for 21-26 \$/GJ in 2010 and 20-23 \$/GJ in 2020 in our study. The NPV for farmers in Mozambique is positive, however only if the installation costs of an irrigation system do not have to be paid for by the farmers.
- *Palm oil* - Palm oil can be produced between 12-22 \$/GJ in 2010 and between 8.5-12 \$/GJ in 2020 in our study. The NPV is positive, although for Malaysia and Colombia more specific data is required to calculate NPVs.
- *Jatropha* - Jatropha can be produced for 20-42 \$/GJ in 2010 and 13-25 \$/GJ in 2020. The wage rate has a large influence on the costs. Yields are currently quite low since this is a relatively new commercial crop, but there is quite a lot of room for improvement. The NPV is high when low amounts of inputs are used, high amounts of expensive fertilizer decreases profitability up to a point where farmers can make a loss. With low wage rates (e.g. family labour) profitability is reasonable.
- *Cassava* - Cassava ethanol can be produced in our study between 22-46 \$/GJ in 2010 and between 15-21 \$/GJ in 2020. Except for the 2010 settings with low yields in Mozambique, all NPVs are positive.

Data quality is crucial, local conditions can have a major influence. Main factors that influence the outcome of the NPV calculations are; yield, labour requirements, labour costs, costs of other inputs (land costs etc.) and the value of the by-products that are produced. More local data is required to be able to make more detailed calculations and to take site specific conditions into account. The ranges in this report can be used as benchmark if there is a lack of sufficient data, life cycle costs of the same feedstocks and/or in the same region can be compared.

5 Global non-GHG environmental impacts of biofuels

5.1 Environmental standards, criteria and indicators for biofuels

This section provides a compilation of science-based criteria and indicators relevant for the non-GHG environmental impacts of biofuels. It should be noted that the compilation was **not** restricted to criteria and indicators compatible with international trade law[15]. Since the beginning of the international discussion on the environmental sustainability of biofuels in the early 2000's[16], a variety of studies were prepared on the issue so that this study can rely on a substantial body of work[17]. The FAO BEFSCI Project compiled an overview table (see below) of regulatory and voluntary schemes for biofuels and their respective "coverage" of environmental issues.

Figure 5-1 Environmental Sustainability Aspects/Issues Addressed under the Initiatives reviewed by BEFSCI

	REGULATORY FRAMEWORKS	Biofuels Life Cycle Assessment Ordinance (BLCAO) - Swiss Confederation	Biomass Sustainability Order (BioNachV) - Germany	EU Renewable Energy Directive (RED)	Low Carbon Fuel Standard (LCFS) - California (USA)	Renewable Fuel Standard (RFS2) - USA	Renewable Transport Fuel Obligation (RTFO) - UK	Social Fuel Seal - Brazil	Testing Framework for Sustainable Biomass ("Cramer Criteria") - The Netherlands	VOLUNTARY STANDARDS / CERTIFICATION SCHEMES	Basel Criteria for Responsible Soy Production	Bonsucro (BSI)	Council on Sustainable Biomass Production (CSBP)	Forest Stewardship Council (FSC)	Global Bioenergy Partnership (GBEP)	Green Gold Label 2: Agriculture Source Criteria (GGLS2)	International Sustainability & Carbon Certification (ISCC)	Nordic Ecolabelling of Fuels	Roundtable on Responsible Soy (RTRS)	Roundtable on Sustainable Biofuels (RSB)	Roundtable on Sustainable Palm Oil (RSPO)	SEKAB Verified Sustainable Ethanol Initiative	Sustainable Biodiesel Alliance (SBA)	SCORECARDS	IDB Biofuels Sustainability Scorecard	WB/WWF Biofuels Environmental Sustainability Scorecard
1. ENVIRONMENTAL																										
1.1 Land-use changes (both direct and indirect)		√		√		√			√			√	√	√	√	√	√	√	√		√	√	√		√	√
1.2 Biodiversity and ecosystem services		√	√	√		√	√		√		√	√	√	√	√	√	√	√	√	√	√	√	√		√	√
1.3 Productive capacity of land		√	√	√		√	√	√	√		√	√	√	√	√	√	√		√	√	√	√	√		√	√
1.4 Crop management and agrochemical use		√	√				√		√		√	√	√	√	√	√	√		√	√	√		√		√	√
1.5 Water availability and quality		√	√	√			√		√		√	√	√	√	√	√	√		√	√	√	√	√		√	√
1.6 GHG emissions		√	√	√	√	√	√		√			√	√		√		√	√	√	√	√	√	√			√
1.7 Air quality		√	√	√	√	√	√		√		√	√			√		√	√	√	√	√		√		√	√
1.8 Waste management		√		√		√	√		√		√	√	√	√		√	√		√	√	√		√		√	√
1.9 Environmental sustainability (cross-cutting)		√		√				√	√		√	√	√	√		√	√		√	√	√	√	√		√	

Source: FAO (2011a), edited by Oeko-Institut

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[15] GEF funding considerations for biofuel projects are not subject to trade law. This is in contrast to **mandatory** sustainability schemes such as the EU RED which restrict their scope of criteria to those which are in compliance with WTO rules, e.g. focussing on the "global commons" for which UN Conventions exist, e.g., biodiversity and climate change (ICTSD 2009). Thus, GEF rules for the sustainability of biofuel projects can – similar to voluntary approaches - be stricter than mandatory certification schemes.

[16] There is no "real" beginning of this debate, as there were already critical discussions on liquid biofuels in the 1980's. Still, the OECD workshop on biomass and agriculture in 2003 (OECD (2004) can be seen as an "official" beginning.

[17] Relevant studies are e.g. Lewandowski/Faaij (2004; 2006), CIFOR (2010), Dam (2009, 2010), FAO (2011a), IFEU (2008), OEKO/IFEU (2010), OEKO/IFEU/CI (2010), SLU (2010A), UNEP (2009), UNEP/DC/MNRA (2007), Winrock (2010)

The compilations of the BEFSCI screening are in accordance with key findings of other studies[18]: which agree that the most relevant non-GHG environmental impacts of biofuel projects are

- air emissions (section 5.4)
- biodiversity impacts (section 5.5)
- soil (section 5.6)
- water (section 5.7)

In following up on a recent study which considered the specific resource restrictions of biomass as a relevant sustainability issue (OEKO 2011), **resource use efficiency** is added as a further category (section 5.3).

5.2 Methodological approach

During the environmental sustainability analysis of biofuel projects, the type of biomass feedstock is evidentially of significance, while the downstream processes within the supply chain typically show lower relevance[19]. A key distinction is between biomass feedstock cultivation which can have high environmental risks at the field level and the collecting of organic residues and wastes which has very low risks[20].

Environmental risks vary strongly with the biomass origin and their downstream processing between different environmental areas of concern, such as biodiversity, soil, and water. For example, excessive collection of agricultural residues can decrease soil fertility and functioning, but agro-biodiversity and water availability may be less affected[21].

Due to these differences and in order to structure sustainability requirements accordingly, the following categories of biomass feedstock type and downstream processing were developed:

- Cultivating feedstocks and co-products, and their conversion
- Collection of primary residues, waste and secondary residues

As 67 of the 71 settings analysed in this study refer to dedicated biofuel feedstock cultivation and only four concern organic wastes as input for advanced biofuel production, the main focus of the analysis is on the **cultivation systems** and, where relevant, the respective downstream processing.

[18] see IFEU (2008), OEKO/IFEU (2010), OEKO/IFEU/CI (2010), SLU (2010A), UNEP (2009), UNEP/DC/MNRA (2007), Winrock (2010)

[19] An exception of this “rule of thumb“ is possible water contamination from feedstock conversion.

[20] Handling and converting organic wastes may show higher environmental risks than agricultural and forestry residues if wastes are contaminated. This is excluded in the settings defined for this study.

[21] Similarly, non-routine operation of conversion plants bears risks for biodiversity (downstream ecosystems) and water (contamination of water bodies), but soils are very unlikely affect in this context. This study only concerns routine operations.

The methodology used to identify, define and quantify (where possible) the main environmental criteria regarding air, biodiversity, soil and water suggest **thresholds** for the overall traffic light system which was developed here to be used for analyzing the sustainability of biofuel projects (see Chapter 1).

For **each** environmental category, this approach allows identifying project conditions with

- **high risks** which cannot be mitigated (**STOP**)
- **potential risks** which could be mitigated by specific project designs (**CHECK**)
- **no relevant risks** or designs adequately mitigating such risks (**GO**).

The traffic light approach was presented in an earlier phase of this study, and is compatible with the logic of the UN Energy Decision Support Tool for Bioenergy (2010).

5.3 Optional category: sustainable resource use

The biomass feedstocks used for biofuels are a renewable resource, but two specific features distinguish it from all other renewable energy sources:

- The conversion efficiency of solar energy into chemical energy in plants is only 1-2% which implies significantly more land needed to indirectly harvest solar energy through terrestrial biomass cultivation than through more concentrated hydro, direct solar or wind energy systems[22].
- Any changes in natural biomass production, e.g. replacing natural vegetation with cultivated plant varieties or improving crop yields, could have positive or negative impacts on ecosystem services and, through food/feed chains, human livelihoods.

Therefore, land is a **fundamental** issue closely related to biofuels and the sustainability of biofuels depends on the productivity of the land use[23]. As biofuels can also be derived from biogenic residues and wastes which stem from "earlier" biomass production or are co-products from agriculture or forestry, the efficiency of converting such secondary resources into biofuels is another aspect of sustainable resource use to be addressed.

5.3.1 Indicator: land use efficiency

The efficiency of converting cultivated bioenergy feedstocks into biofuels should be considered in terms of useful biofuel energy per hectare of land used for feedstock production. Land is a finite and increasingly scarce resource around the world and non-biofuel uses such as food/feed, and fibre production as well as nature protection, ecosystem services, and recreation are competing with land use for biofuels.

During the calculation of the land use efficiency, by- and co-products along the biofuel life cycles should be taken into account. With regard to the settings under consideration in this study, the following tables give the results of such a calculation[24].

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22 see Fritsche/Sims/Monti (2010), and Graebig/Bringezu/Fenner (2010)

23 Possible effects of land use changes associated with the incremental production of bioenergy are discussed with regard to GHG emissions in Section 3.

24 The calculation use GEMIS (www.gemis.de) which was calibrated for the settings of this study.

Table 5-1 Biofuels life-cycle land use efficiency for cassava-EtOH settings

				$GJ_{biofuel}$/ha	
Country	**setting**	**input level**	**cultivation**	**2010**	**2020**
MZ	42	low	smallholders	13	
MZ	43	intermediate	smallholders	19	
TZ	44	low	smallholders	19	
TZ	45	intermediate	smallholders	38	
TH	46	low	smallholders	64	
TH	47	intermediate	smallholders	70	
MZ	48	low	smallholders		19
MZ	49	intermediate	smallholders		38
MZ	50	high	plantation		48
TZ	51	low	smallholders		64
TZ	52	intermediate	smallholders		70
TZ	53	high	plantation		87
TH	54	low	smallholders		102
TH	55	intermediate	smallholders		108
TH	56	high	plantation		140

Source: own computation with GEMIS 4.8

Table 5-2 Biofuels life-cycle land use efficiency for Jatropha FAME settings

				$GJ_{biofuel}$/ha	
Country	**setting**	**input level**	**cultivation**	**2010**	**2020**
TZ	26	high	plantation	22	
TZ	27	intermediate	plantation	19	
TZ	28	low	smallholder	8	
TZ	29	intermediate	smallholder	14	
ML	30	low	smallholder	7	
ML	31	intermediate	smallholder	11	
IN	32	low	smallholder	12	
IN	33	intermediate	smallholder	18	
TZ	34	high	plantation		36
TZ	35	intermediate	plantation		31
TZ	36	low	smallholder		9
TZ	37	intermediate	smallholder		17
ML	38	low	smallholder		8
ML	39	intermediate	smallholder		13
IN	40	low	smallholder		14
IN	41	intermediate	smallholder		20

Source: own computation with GEMIS 4.8

The bandwidth of land use efficiency for cassava-based EtOH is about a factor of 10, with low and intermediate inputs in smallholder settings differing between 13 and 102, and 19 and 108 $GJ_{biofuel}$/ha, depending on the country.
For high input plantations, the range between countries is 87 to 140 $GJ_{biofuel}$/ha.

Reasons for the large bandwidths are differences in cultivation practices, soil conditions, and climatic conditions, especially water availability.

For Jatropha- and Palm-based FAME, the differences in land use efficiency are smaller, as shown in Table 5-3. For sugarcane-based EtOH, the range between settings is again more significant:

Table 5-3 Biofuels life-cycle land use efficiency for palmoil FAME settings in 2010

				$GJ_{biofuel}$/ha	
Country	**setting**	**input level**	**cultivation**	**2010**	**2020**
ID	19	intermediate	smallholder	113	
ID	20	high	plantation	120	
CO	21	intermediate	smallholder	133	
MY	22	high	plantation	140	
ID	23	high	plantation		150
MY	24	high	plantation		150

Source: own computation with GEMIS 4.8

Table 5-4 Biofuels life-cycle land use efficiency for sugarcane EtOH settings

				$GJ_{biofuel}$/ha	
Country	**setting**	**input level**	**harvest**	**2010**	**2020**
BR	8	intermediate	mechanised	131	
BR	9	high	manual	197	
MZ	11	intermediate	manual	147	
MZ	12	high	manual	193	
BR	13	intermediate	mechanised		138
BR	14	high	mechanised		207
MZ	16	intermediate	mechanised		131
MZ	17	high	mechanised		230

Source: own computation with GEMIS 4.8

Based on these results, the suggested traffic light thresholds are given in Table 5-5.

Table 5-5 Screening tool for biofuel land use efficiency

Setting	GO	CHECK	STOP	Unit
Low input, marginal land	>25	10-25	< 10	$GJ_{biofuel}$/ha
Intermediate input, marginal land	>50	25-50	< 25	$GJ_{biofuel}$/ha
High input, good land	>100	50-100	< 50	$GJ_{biofuel}$/ha

Source: compilation by Oeko-Institut

5.3.2 Indicator: secondary resource Use efficiency

For advanced biofuels stemming from the conversion of secondary resources such as residues and wastes, a minimum value for the resource use efficiency should be considered, expressed in terms of the heating value of the biofuel output divided by the heating value of the secondary resource input.

In calculating the resource efficiency, by- and co-products along the biofuel life cycles should be taken into account.

With regard to the settings under consideration in this study, Table 5-6 gives the results of such a calculation.

Table 5-6 Advanced EtOH biofuels life-cycle secondary resource use efficiency

Feedstock	own	setting	year	$GJ_{biofuel}/GJ_{residue}$
rice straw	CN	71	2020	89%
rice straw	CN	73	2030	89%
wheat straw	UA	72	2020	63%
wheat straw	UA	74	2030	63%

Source: own calculation with GEMIS 4.8

Based on these results, the suggested traffic light thresholds are given in Table 5-7.

Table 5-7 Screening tool for secondary resource use efficiency

GO	CHECK	STOP	unit
>60	50-60	< 50	%

Source: compilation by Oeko-Institut

5.4 Category: air emissions

Some biofuels can help improve air quality during the **use phase**, depending on feedstocks and combustion methods. A 20% blend of biodiesel, for example, can reduce particulate matter by 30% and SO_2 by nearly 100%. This is due to the significantly higher sulphur content of fossil transport fuels in developing countries – especially diesel[25].

However, during the feedstock production for biofuels, air pollution can be significant, e.g. due to burning of crop wastes. Furthermore, ammonia emissions from fertiliser application can increase local air pollution. Thus, the evaluation of airborne life-cycle emissions of non-GHG pollutants[26] from bioenergy should be limited to those of competing fossil fuels, and possibly perform better.

5.4.1 Indicator: emissions of SO_2 equivalents

Air pollutants causing acidification are SO_2, NOx and NH_3 and can occur along biofuel life-cycles. They should be limited to the life-cycle emissions of the fossil fuel comparator, expressed in terms of SO_2 equivalents. The emissions should be calculated in accordance to the life cycle emission methodology for GHG (see section 0), i.e. by- and co-products

25 For a discussion of air emissions from biofuels used for cooking and electricity generation, see section 8.8.

26 The GBEP Sustainability Task Force proposes to also include air toxics (e.g. heavy metals, volatile organic compounds) in this indicator, see GBEP (2011). Due to restrictions of available data and severe data uncertainties and variability, we refrain from doing so here.

along the biofuel life cycles should be taken into account. With regard to the settings under consideration in this study, Table 5-8 gives the results of such a calculation[27].

Table 5-8 Biofuel life-cycle SO_2-eq emissions for all settings

fuel	setting	country	year	SO_2eq	SO_2	NO_x	NH_3
Soybean SVO	1	AR	2010	0.159	0.049	0.111	0.017
Soybean FAME	2	AR	2010	0.154	0.046	0.110	0.016
	3	AR	2010	0.113	0.036	0.096	0.006
	4	AR	2010	0.148	0.046	0.107	0.014
	5	AR	2020	0.149	0.047	0.125	0.008
	6	AR	2020	0.149	0.047	0.125	0.008
	7	AR	2020	0.197	0.062	0.141	0.019
Sugarcane EtOH	8	BR	2010	0.192	0.051	0.143	0.022
	9	BR	2010	0.238	0.048	0.214	0.022
	10	BR - 2G	2020	0.203	0.054	0.155	0.022
	11	MZ	2010	0.247	0.051	0.223	0.022
	12	MZ	2010	0.247	0.051	0.223	0.022
	13	BR	2020	0.202	0.051	0.146	0.026
	14	BR	2020	0.194	0.052	0.145	0.022
	15	BR - 2G	2030	0.213	0.054	0.158	0.026
	16	MZ	2020	0.197	0.053	0.147	0.022
	17	MZ	2020	0.194	0.052	0.145	0.022
Oil palm SVO	18	ID	2010	0.087	0.021	0.081	0.004
Oil palm FAME	19	ID	2010	0.093	0.027	0.082	0.004
	20	ID	2010	0.144	0.044	0.131	0.004
	21	CO	2010	0.092	0.026	0.083	0.004
	22	MY	2010	0.131	0.040	0.119	0.004
	23	ID	2020	0.123	0.039	0.110	0.003
	24	MY	2020	0.121	0.038	0.109	0.003
Jatropha SVO	25	TZ	2010	0.245	0.113	0.189	0.000
Jatropha FAME	26	TZ	2010	0.476	0.140	0.315	0.062
	27	TZ	2010	0.309	0.083	0.158	0.062
	28	TZ	2010	0.254	0.120	0.191	0.000
	29	TZ	2010	0.311	0.124	0.204	0.024
	30	ML	2010	0.259	0.123	0.194	0.000
	31	ML	2010	0.316	0.127	0.207	0.024
	32	IN	2010	0.258	0.127	0.187	0.000
	33	IN	2010	0.325	0.135	0.209	0.024
	34	TZ	2020	0.477	0.140	0.316	0.062
	35	TZ	2020	0.305	0.081	0.154	0.062
	36	TZ	2020	0.255	0.120	0.192	0.000
	37	TZ	2020	0.312	0.124	0.205	0.024
	38	ML	2020	0.259	0.123	0.194	0.000
	39	ML	2020	0.316	0.127	0.207	0.024
	40	IN	2020	0.258	0.127	0.187	0.000

27 The calculation was based on the GEMIS model (version 4.7) which was calibrated for the settings of this study. The model and database is freely available at www.gemis.de

fuel	setting	country	year	SO_2eq	SO_2	NO_x	NH_3
	41	IN	2020	0.325	0.135	0.209	0.024
Cassava EtOH1	42	MZ	2010	0.361	0.101	0.218	0.057
	43	MZ	2010	0.410	0.106	0.231	0.076
	44	TZ	2010	0.410	0.106	0.230	0.076
	45	TZ	2010	0.410	0.106	0.230	0.076
	46	TH	2010	0.349	0.105	0.237	0.042
	47	TH	2010	0.466	0.122	0.287	0.076
	48	MZ	2020	0.406	0.103	0.229	0.076
	49	MZ	2020	0.406	0.103	0.229	0.076
	50	MZ	2020	0.556	0.158	0.365	0.076
	51	TZ	2020	0.318	0.095	0.207	0.042
	52	TZ	2020	0.405	0.102	0.228	0.076
	53	TZ	2020	0.554	0.158	0.363	0.076
	54	TH	2020	0.345	0.104	0.236	0.041
	55	TH	2020	0.465	0.121	0.287	0.076
	56	TH	2020	0.550	0.154	0.363	0.076
SRC Eucalyptus EtOH2	57	MZ	2020	0.681	0.212	0.354	0.118
	58	BR	2020	0.673	0.209	0.347	0.118
	59	BR	2020	0.667	0.207	0.341	0.118
	60	MZ	2030	0.678	0.211	0.352	0.118
	61	BR	2030	0.675	0.210	0.349	0.118
	62	BR	2030	0.669	0.207	0.343	0.118
SRC Poplar BtL	63	UA	2020	2.243	0.033	0.369	1.038
	64	UA	2020	0.994	0.020	0.194	0.446
	65	UA	2030	2.243	0.033	0.369	1.038
	66	UA	2030	0.994	0.020	0.194	0.446
Switchgrass EtOH2	67	AR	2020	0.593	0.245	0.438	0.023
Switchgrass BtL	68	AR	2020	0.394	0.125	0.289	0.025
Switchgrass EtOH2	69	AR	2030	0.593	0.245	0.438	0.023
Switchgrass BtL	70	AR	2030	0.394	0.125	0.289	0.025
Rice straw EtOH2	71	CN	2020	0.521	0.203	0.318	0.051
Wheat straw EtOH2	72	UA	2020	0.448	0.193	0.291	0.028
Rice straw EtOH2	73	CN	2030	0.521	0.203	0.318	0.051
Wheat straw EtOH2	74	UA	2030	0.448	0.193	0.290	0.028
fossil fuel comparators (upstream only)							
diesel, EU		DE	2010	0.048	0.030	0.025	0.000
diesel, generic		**IN**	**2010**	**0.282**	**0.204**	**0.112**	**0.000**
diesel, syncrude		DE	2010	0.359	0.290	0.099	0.000
gasoline, EU		DE	2010	0.057	0.036	0.030	0.000
gasoline, generic		IN	2010	0.104	0.056	0.068	0.000

Based on these results, the thresholds to be used in the evaluation of SO_2 equivalent emissions from biofuel projects are given in Table 5-9.

Table 5-9 Screening Tool for Biofuel Life-Cycle Air Emissions (SO_2 equivalents)

GO	CHECK	STOP	unit
< 100	100-250	> 250	% of generic fossil fuel comparator

Source: compilation by Oeko-Institut

5.4.2 Indictor: emissions of PM_{10} and use of non-renewable primary energy

Besides air pollutants causing acidification, the emission of fine particles (PM_{10}) is a key health issue in many countries, and these emissions can also occur along the biofuel life-cycles. Similar to other air emissions, PM_{10} should be limited to the life-cycle emissions of the fossil fuel comparator. The emissions should be calculated in accordance to the life cycle emission methodology for GHG (see section 0), i.e. by- and co-products along the biofuel life cycles should be taken into account. Furthermore, the **non-renewable** primary energy use for biofuel feedstock production is an issue.

With regard to the settings under consideration in this study, Table 5-10 gives the results of the calculation for PM_{10}, and non-renewable primary energy use[28].

Table 5-10 Biofuel life-cycle PM_{10} emissions for all settings

Name	no.	country	year	PM_{10} g/$MJ_{biofuel}$	non-renewable primary energy MJ/$MJ_{biofuel}$
Soybean SVO	1	AR	2010	0.017	0.24
Soybean FAME	2	AR	2010	0.016	0.26
	3	AR	2010	0.010	0.23
	4	AR	2010	0.013	0.25
	5	AR	2020	0.014	0.28
	6	AR	2020	0.014	0.28
	7	AR	2020	0.017	0.31
Sugarcane EtOH	8	BR	2010	0.036	0.14
	9	BR	2010	0.167	0.13
	10	BR - 2G	2020	0.039	0.14
	11	MZ	2010	0.168	0.14
	12	MZ	2010	0.168	0.14
	13	BR	2020	0.036	0.14
	14	BR	2020	0.036	0.14
	15	BR - 2G	2030	0.039	0.14
	16	MZ	2020	0.036	0.14
	17	MZ	2020	0.036	0.14
Oil palm SVO	18	ID	2010	0.083	0.12
Oil palm FAME	19	ID	2010	0.080	0.13
	20	ID	2010	0.083	0.20
	21	CO	2010	0.072	0.14
	22	MY	2010	0.073	0.19
	23	ID	2020	0.067	0.17

[28] see footnote 27

Name	no.	country	year	PM_{10} g/$MJ_{biofuel}$	non-renewable primary energy MJ/$MJ_{biofuel}$
	24	MY	2020	0.066	0.17
Jatropha SVO	25	TZ	2010	0.065	0.34
Jatropha FAME	26	TZ	2010	0.058	0.58
	27	TZ	2010	0.044	0.39
	28	TZ	2010	0.064	0.43
	29	TZ	2010	0.065	0.46
	30	ML	2010	0.065	0.44
	31	ML	2010	0.066	0.46
	32	IN	2010	0.067	0.44
	33	IN	2010	0.071	0.47
	34	TZ	2020	0.058	0.58
	35	TZ	2020	0.043	0.39
	36	TZ	2020	0.064	0.44
	37	TZ	2020	0.065	0.46
	38	ML	2020	0.065	0.44
	39	ML	2020	0.066	0.46
	40	IN	2020	0.067	0.44
	41	IN	2020	0.071	0.47
Cassava EtOH1	42	MZ	2010	0.059	0.17
	43	MZ	2010	0.061	0.21
	44	TZ	2010	0.061	0.21
	45	TZ	2010	0.061	0.21
	46	TH	2010	0.060	0.16
	47	TH	2010	0.065	0.25
	48	MZ	2020	0.060	0.19
	49	MZ	2020	0.060	0.19
	50	MZ	2020	0.079	0.38
	51	TZ	2020	0.057	0.13
	52	TZ	2020	0.060	0.18
	53	TZ	2020	0.079	0.37
	54	TH	2020	0.059	0.15
	55	TH	2020	0.065	0.24
	56	TH	2020	0.078	0.35
SRC Eucalyptus EtOH2	57	MZ	2020	0.045	0.22
	58	BR	2020	0.045	0.21
	59	BR	2020	0.044	0.21
	60	MZ	2030	0.045	0.22
	61	BR	2030	0.045	0.22
	62	BR	2030	0.044	0.21
SRC Poplar BtL	63	UA	2020	0.011	0.11
	64	UA	2020	0.008	0.06
	65	UA	2030	0.011	0.11
	66	UA	2030	0.008	0.06
Switchgrass EtOH2	67	AR	2020	0.049	0.31
Switchgrass BtL	68	AR	2020	0.030	0.33
Switchgrass EtOH2	69	AR	2030	0.049	0.31
Switchgrass BtL	70	AR	2030	0.030	0.33

Name	no.	country	year	PM_{10} $g/MJ_{biofuel}$	non-renewable primary energy $MJ/MJ_{biofuel}$
Rice straw EtOH2	71	CN	2020	0.039	0.17
Wheat straw EtOH2	72	UA	2020	0.034	0.11
Rice straw EtOH2	73	CN	2030	0.039	0.17
Wheat straw EtOH2	74	UA	2030	0.034	0.11
fossil fuel comparators (upstream only)					
diesel, EU		DE	2010	0.004	1.14
diesel, generic		**IN**	**2010**	**0.043**	**1.30**
diesel, syncrude		DE	2010	0.015	1.60
gasoline, EU		DE	2010	0.004	1.20
gasoline, generic		**IN**	**2010**	**0.021**	**1.19**

Source: own calculation with GEMIS 4.8

Based on these results, the thresholds to be used in the evaluation of PM_{10} emissions from biofuel projects are given in Table 5-11.

Table 5-11 Screening tool for Biofuel Life-Cycle PM_{10} Emissions

GO	CHECK	STOP	unit
<100	100-250	> 250	% of generic fossil fuel comparator

Source: compilation by Oeko-Institut

For non-renewable primary energy use, the performance of biofuels is quite well, i.e. the non-renewable primary energy requirement for biofuel production is typically less than 50% of the energy content of the biofuels so that no specific threshold is needed.

5.5 Category: biodiversity and land use

Due to the land use associated with biofuel feedstock cultivation, the protection of biodiversity is a core global benefit concern and as such a key issue for possible biofuel projects. Effects can be positive or negative, strongly depending on location, agricultural and forestry practices, previous and indirect land-use, and the conversion systems used in the downstream chain (processing, distribution and consumption).

During the 9th meeting of the Conference of the Parties at the CBD, parties emphasised the challenge of promoting the positive impacts of biofuel production on biodiversity while minimizing negative effects. The international literature on protecting biodiversity as well as the indicators recently agreed on by the GBEP focus on the following two key issues for risk-mitigation strategies:

- Conservation of **areas of significant biodiversity** value, and
- **promotion** of agricultural and forestry **practices with low negative impacts** on biodiversity.

As the land use is quantitatively far more relevant for the cultivation stage of biofuel life-cycles, the risks related to routine operations of downstream processes (conversion, distribution) are usually much smaller.

Conservation of areas of significant biodiversity value

Habitat loss as a result of direct and indirect land-use changes is the major threat to biodiversity, with over 80% of globally threatened birds, mammals and amphibians affected wholly or in part by habitat loss. Areas of significant biodiversity value are qualified through

- the presence of threatened or endemic species, and
- rare and threatened ecosystems.

These areas are particularly concentrated in the Tropics. Prominent factors causing the decline of biodiversity are deforestation, conversion of wetlands, habitat fragmentation and isolation, land-use intensification and overexploitation, invasive species and adverse climate-change impacts.

Key for biodiversity conservation is to identify and conserve those areas harbouring relevant portions of biodiversity (i.e., areas of significant biodiversity value). Protected areas (PAs), areas with public or private conservation status, provide the cornerstones of national and regional conservation strategies and often represent the minimum threshold for areas of significant biodiversity value because of their legal recognition. One objective of a PA network is to represent the biodiversity of each region and to protect this biodiversity from threats. Yet, existing PAs throughout the world are still far from fulfilling either global biodiversity commitments or the needs of species and ecosystems. Thus, existing PAs alone do not guarantee a sufficient protection of biodiversity.

To avoid risks for biodiversity from biofuel production, an assessment is needed of areas of significant biodiversity value, whether protected or unprotected. Several processes were developed and tested to guide identification and mapping of such areas at a level of resolution practical for planning and management purposes. Prominent examples are the mapping of

- Key Biodiversity Areas (KBA),
- Important Bird Areas (IBA),
- Important Plant Areas (IPA),
- Alliance for Zero Extinction sites (AZE), and
- World Intact Forest Landscapes.

Existing mapping tools can assist land managers in meeting requirements to identify and protect biodiversity on a project level (e.g., High Conservation Value Network)[29].

Box: Biodiversity mapping for marginal and degraded land

Marginal and degraded lands are often seen offering important potential for biomass feedstock cultivation without land use competition, thus possibly avoiding indirect effects (see Chapter 1). There is considerable land worldwide not currently used for agriculture or forestry, but biodiversity may be an issue (besides social effects) if that land would be used for biofuel feedstocks.

However, there is still significant uncertainty about the actual biofuel potential from these lands and about costs and environmental and socio-economic impacts of such land into production. The extent of this land has not yet been quantified in detail, but is anticipated to be in the range of 0.5 to 2 billion ha worldwide, and only some parts of this land could potentially be suitable for sustainable and economically viable biofuel feedstock production. The biofuel potential from degraded land has been estimated for a range of 10-100 EJ (OEKO/IFEU 2010; OEKO/UNEP 2009; Schweers (2010, Wicke 2011).

Part of this land is actually too degraded to be converted to biomass cultivation, while in other cases it would simply be too expensive. In addition, making this land productive will not always be a sustainable action: this land may actually have biodiverse vegetation on it and could provide habitats for endangered species (Hennenberg et al. 2009).

On the other hand, some portion of these currently uncultivated lands as well as the local communities is likely to benefit from bioenergy cultivation, as it may improve the overall quality of the soil by, for example, increasing nutrient and carbon content, reducing erosion and retaining (rain) water, and thereby stimulate the local economy.

There is still quite some debate and significant uncertainty about the current extent of these types of land, on their sustainable biofuel potential and on the investments required to develop them accordingly.

As part of a recent global study (OEKO/IFEU 2010), country studies were carried out in Brazil, China and South Africa to identify degraded lands potentially suitable for biofuel feedstock cultivation. Local ground truthing was used at selected degraded land areas. From theses country studies the following key conclusions were drawn:

Combining top-down and bottom-up analysis to identify suitable degraded areas for bioenergy production is feasible and can make use of globally available data. If more appropriate national data is available, global and national data can be combined. However, the hit-rate of suitable areas depends on the quality of the top-down data. It also became very clear that the bottom-up analysis is evidentially needed. Information from top-down data is sometimes incorrect (e.g. degraded land and carbon stock) or

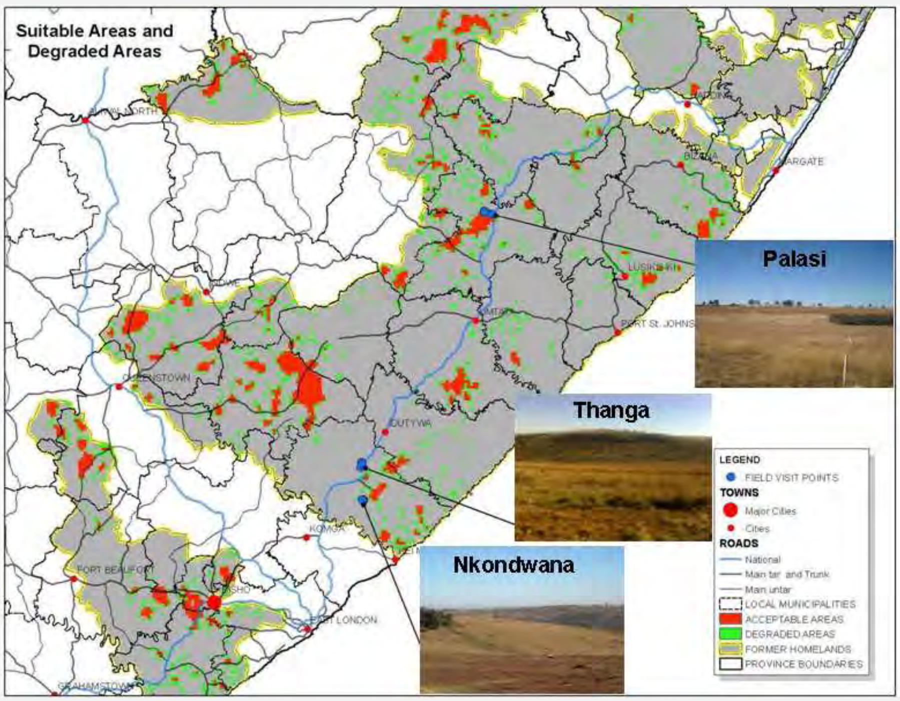
[29] Appendix G gives an overview of such tools.

incomplete (e.g. biodiversity) and important aspects are inadequately covered by available data (e.g. land use).

The amount of degraded land potentially available for sustainable biofuel feedstock cultivation appears to be 5-10 times lower than earlier estimated, but further ground truthing is needed to derive better data.

The country studies showed that there is certainly potential for producing biofuel feedstocks on unused degraded lands. If managed well, this production can achieve the promised positive impacts, viz. reduction of GHG emissions, rehabilitation of degraded areas and opportunities for rural development, including access to modern energy.

In the following figure, degraded land identified as being potentially suitable for biomass cultivation in the South African Eastern Cape is shown together with the location of test sites. These “acceptable areas” and “degraded areas” show no concerns regarding biodiversity and carbon stocks.



Cultivation is likely to impact the biodiversity value of the area if the cultivation of feedstocks and co-products and the collection of primary residues are located in an area of significant biodiversity value (e.g. primary forest).

Such risk exists especially for high input systems, but they cannot be excluded for intermediate and low input systems. Thus, proof is needed that the cultivation area is not located in an area of significant biodiversity value.

As a starting point, the proof should consider existing GIS data listed in Table 5-12.

Table 5-12 Datasets to be considered for proofing the location of areas of significant biodiversity value

Data Source	Content / area types
IBAT	Information on national and international protected areas (PA), Key Biodiversity Areas (KBA), Important Bird Areas (IBA), Important Plant Areas (IPA) and Areas of Zero Extinction (AZE)
Global Forest Watch and World Intact Forests	Indicator for the location of primary forests
Global Distribution of Mangroves	Location of mangroves by UNEP-WCMC
Global Forest Resources Assessment	Location of primary forests (available in Fall 2012)
Regional and national grassland datasets	Location of high-biodiverse grasslands (see Appendix G)

Source: compilation of Oeko-Institut

In addition to this data, national authorities responsible for nature protection should be consulted to request further datasets indicating areas of significant biodiversity value.

If no adequate mapping data is available, an on-site assessment is needed to verify that the cultivation area has no significant biodiversity value. For the assessment, well established methods may be applied or reference must be given to a mapping comparable activity considering the cultivation area.

Table 5-13 Screening tool for biodiversity: conventional biofuels feedstock cultivation

Environmental Component	Applicable to	GO	CHECK	STOP
Conservation of areas of significant biodiversity value	All setting except those using wastes	Proven that cultivation land is **not** located in area of significant biodiversity value (GIS data + on-site assessment)	If located in such an area: management plan to ensure cultivation and harvest do not interfere with nature protection purposes.	If located in such an area and management plan is missing or not detailed enough to demonstrate non-interference
Promotion of agricultural practices with low negative impacts on biodiversity	**Not** applicable for **low-input** settings	Proven that cultivation practices with low negative impacts on biodiversity are applied (description of management practices)	Description of management practices not detailed enough	Description of management practices missing

Source: compilation by Oeko-Institut

The collection of organic wastes and secondary biomass residues bears very low risks to impact biodiversity, as this biomass is not related to a specific production area. Thus, these biomass sources can be used without further requirements ("**GO**").

Advanced biofuel settings use lignocellulose which can come from dedicated energy crops such as perennial grasses or short-rotation coppices or from either agricultural (straw) or forestry (wood chips) residues. For **all** these settings, the requirements of Table 5-16 apply.

The **conversion** of feedstocks, residues and wastes may impact areas of significant biodiversity value mainly due to liquid effluents from the conversion plants. To assess related risk, information on the location of the conversion plants in relation to valuable areas (e.g. downstream) is required. In case that the effluents of a conversion plant may impact such an area, the management plan muss show that the amount of biological oxygen demand (BOD) and other water pollutants is low enough to avoid negative impacts on these valuable areas.

Further sufficient mitigation measures for non-routine operation must be elaborated in the management plan (see 5.7).

Table 5-14 Screening tool for biodiversity: biofuels feedstock conversion

Environmental Component	**applicable to**	**GO**	**CHECK**	**STOP**
Conservation of areas of significant biodiversity value	All settings	Proven that it is not located in areas of significant biodiversity value **and** that the areas in vicinity will not be negatively affected by effluents of conversion plant	If located in such an area: sufficient mitigation measures for non-routine operation; downstream impacts of pollutants below thresholds; management plan to avoid interfere with nature protection purposes.	If located in such an area and inadequate mitigation measures and management plan missing or not detailed enough to demonstrate non-interference
Promotion of agricultural practices with low negative impacts on biodiversity	**Not** applicable for conversion			

Source: compilation by Oeko-Institut

5.6 Category: soil

Apart from providing the base for biomass cultivation, soils also perform numerous environmental functions such as the storing, filtering and transformation of substances (nutrients, contaminants and organic carbon) and serve as habitats for species. All these functions are essential and need protection.

Since soil formation and regeneration processes are extremely slow whereas degradation can be very rapid, soil must be considered a non-renewable resource in human time scales.

Soil degradation defined as the loss of the soil's ecosystem functions and services has a major impact on other sustainability aspects, e.g., surface and groundwater quality, climate impacts due to losses in soil carbon stocks and food insecurity as a result of a decline in soil fertility. Land conservation and rehabilitation are an essential part of sustainable agricultural development. To prevent soil degradation from agricultural changes, improved agronomic practices will play a key role.

Various types of human activities and natural causes may result in direct soil degradation impacts, which need to be evaluated in the light of biofuel feedstock production.

Direct impacts from biofuel feedstock production can occur from improper soil and crop management, as well as from deforestation, removal of natural vegetation and overexploitation of vegetation, including negative impacts from conversion and overuse of natural habitats on ecosystem functions. The protection of natural habitats is not covered here, but a focus is put on the mitigation of soil degradation that emerges from soil and crop management while cultivating biofuel feedstock. Key issues leading to soil degradation that may relate to bioenergy feedstock production include the following:

- erosion,
- decline of soil organic carbon (SOC),
- compaction, and
- salinization.

Soil erosion represents the most prominent degradation factor in agriculture that leads to loss of fertile top-soil within in periods of years, whereas soil formation by natural processes can take hundreds to thousands of years. Any biofuel feedstock cultivation practice should reduce soil erosion to a level near or below the natural erosion rate.

The decline of **soil organic carbon** due to improper soil and crop management impacts the fertility of soils, but also the environment (e.g. nutrient leakage into water bodies, GHG emissions from SOC loss). Factors leading to SOC decline are climate, soil characteristics, natural vegetation type, topography, and land management. Good agricultural practices for biofuel feedstock production systems need to guarantee balanced SOC processes and should aim to increase SOC to improve soil fertility.

Soil compaction is mainly caused by agricultural machinery. The degree of compaction depends on the type of machine, applied loads and frequency of use, which are related to the production system and the type of biofuel feedstock. The impact of machinery also depends on soil types and especially water content, i.e. the timing of machinery use is an important factor. Thus, soil compaction may especially be a risk for high yield biofuel feedstock harvested under wet soil conditions.

Salinization is the process that leads to an excessive increase of water-soluble salts in the soil. Primary salinization involves salt accumulation through natural processes due to a high salt content of the parent material or in groundwater. Secondary salinization is caused by human interventions such as inappropriate irrigation practices, e.g. with salt-rich irrigation water and/or insufficient drainage. Soil salinization, e.g. due to inefficient irrigation systems, poor on-farm management practices and inappropriate drainage management, also reduces crop yields.

These four key issues are strongly interlinked. For example, erosion leads mostly to a loss of the top soil where most soil carbon is found. Compaction can increase the run-off of water increasing erosion and a loss of SOC can increase the risk of salinization due to an increase in soil evaporation. Similarly, individual soil protection measures can have positive effects on all factors – e.g. mulching reduces the erosion rate and increases SOC which in turn can increase the stability of soil texture and may reduce the risk of salinization at sensible sites. As a consequence, these key issues are not evaluated as single parameters but more in the sense of soil conservation measures. However, depending on the biomass origin and production stage, single relevant key issues are highlighted. Details on data for soil are given in Appendix G.

Table 5-15 Screening tool for soil impacts

Environmental Component	**applicable to**	**GO**	**CHECK**	**STOP**
Productive Capacity of Soil	All settings except those using wastes; **not** applicable for conversion	Soil conservation measures are in place guaranteeing that SOC will not decline within the applied crop rotation scheme	No measurements for positive SOC balance. Proof needed that cultivation or residue extraction will not negatively affect SOC balance over crop-rotation period.	Cultivation area on land with low SOC (e.g., < 1%; threshold depending on soil conditions)
Soil Erosion		Area is located in region with low erosion risks (e.g., flat slope) and low risk of salinization (e.g., climate and salt content of ground water	Site has risks of erosion, proof needed on suitable soil protection measures adapted to the site conditions	No soil conservation measures planned

Source: compilation by Oeko-Institut

5.7 Category: water

The unsustainable management of water resources is a key global environmental challenge. Freshwater is already scarce in some regions of the world and existing freshwater resources are under heavy threat from overexploitation due to growing population and changing diets, pollution, and climate change.

Access to safe water resources is a limiting factor for sustainable development, and water resources have a key role in socio-economic development: Without better water management, the Millennium Development Goals for poverty, hunger and a sustainable environment cannot be met, since improvements in the water sector will directly improve access to safe drinking water, basic sanitation, food security and poverty reduction efforts.

Developments in the agricultural sector for food and non-food crops will have important implications for water usage and availability. In this context, water demand for bioenergy feedstock production could lead to increasing agricultural water use worldwide, since bioenergy crops optimised for rapid growth are likely to consume more water than natural flora and many food crops (see Appendix F). Agricultural products already take 70% of the freshwater withdrawals from rivers and groundwater. In some countries especially in the Mediterranean and Sub-Saharan Africa, this could lead to further water stress in regions where water is already scarce and rainfall is highly variable, which might induce increased competition over water resources.

The International Water Management Institute predicts that without further improvements in water productivity and efficiency in the agricultural sector or major shifts in production patterns, the amount of water consumed by evapotranspiration in agriculture will increase by 70%–90% (IWMI 2007). The amount of water needed to produce fiber and biomass for energy as well as conversion of biomass to biofuels would add to this, so that competition between agricultural, industrial, domestic and environmental water requirements as well as pollution risks for water bodies could be intensified by biofuel feedstock production and processing. In this context, the mitigation of water scarcity and the protection of water resources against contamination have been identified as key issues that should be addressed on a project scale:

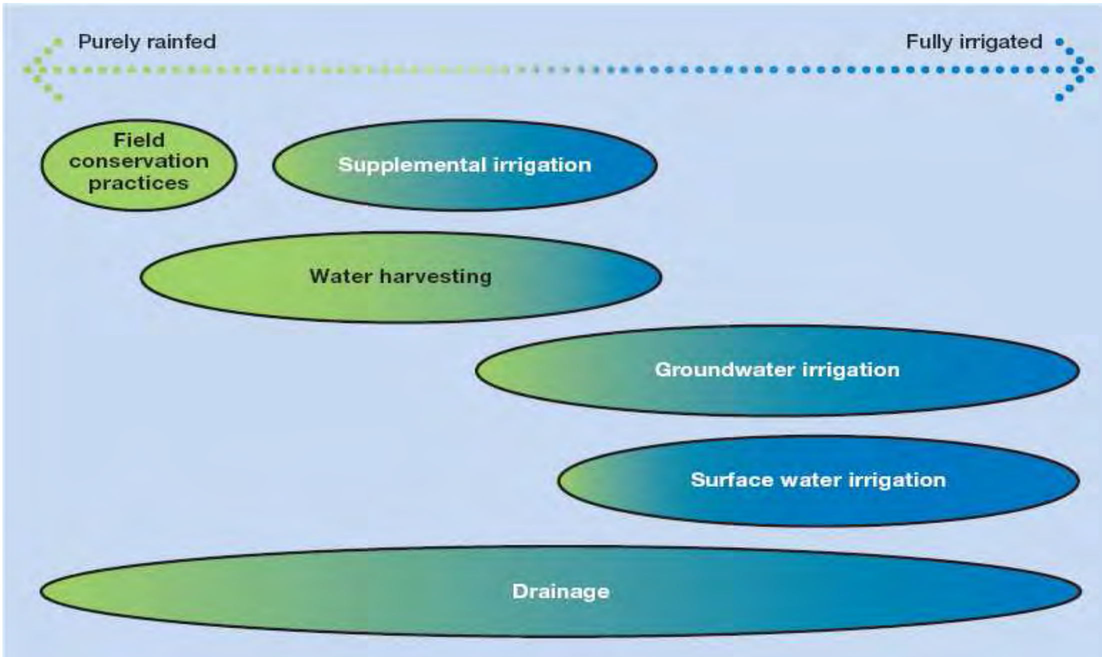
- Water scarcity risk at a catchment scale and downstream
- Water contamination risk from cultivation
- Water contamination risk from processing

Water scarcity at a catchment scale and downstream

Options for water use in agriculture stretch from rainfed agriculture with improved storage of water in the soil to supplemental irrigation from water storages and full irrigated cultivation (Figure 5-2). Today 55% of the gross value of our food is produced under rainfed conditions on nearly 72% of the world's harvested cropland, while 28% use irrigation.

Water withdrawal leads to hydrological changes, i.e. reduction of runoff in rivers and lowering lakes and groundwater level, and, in extreme situations, rivers temporarily do not reach the sea (e.g. Colorado River, USA) or lakes dry up and get salty (e.g., Aral Sea).

Figure 5-2 Options for agricultural management with regard to water



Source: IWMI (2007)

Problems caused by irrigation are most often associated with physical water stress or scarcity in arid regions. Sufficient water supply for high-productive bioenergy crops in such regions is very likely to increase existing problems. In consequence, any additional irrigation needs to be embedded in sound water management plans and policies to optimise water use by all relevant sectors – from agriculture to industry and municipals. Furthermore, future demands, environmental constraints, feasibility of water storage as well as water needs in downstream neighbouring countries require consideration. This is also needed for regions with abundant water resources to avoid a development towards water stress or water scarcity.

In some cases it might be more beneficial for local people or agriculture industries to shift water use from existing cultivation systems or from industries – especially when producing commodities for international markets – to bioenergy cropping systems. However, as irrigation represents a high risk for negative impacts on water resources, it should not be the standard practice for cultivating biofuel feedstocks.

Instead, **rain-fed cultivation should be preferred**, as under most circumstances, these cropping systems rely on water from precipitation, and competition with other water demands is limited. The greatest potential for increases in yields is in rain-fed areas, especially through enhanced management of soil moisture and improving soil fertility management.

Thus, decision makers should give strong priority to rain-fed bioenergy cropping systems during the planning processes and to cultivation practices that improve drought resistance, especially in regions where water is already scarce.

Still the displacement of former natural vegetation (e.g., forests or woodlands) may have decreased evapotranspiration and soil absorption capacities and levels of groundwater table and water run-offs may have increased. In case that these additional water recourses are used today for purposes such as irrigation or industry, rain-fed bioenergy feedstock cultivation with high water use rates similar to former natural vegetation may result in water competition.

The mitigation of water scarcity should mainly be addressed at two levels, the catchment scale and downstream needs. The catchment scale (up to some square kilometers) is chosen because most water withdrawals and related negative effects occur at this scale. Furthermore, when water scarcity is avoided at catchment scale, risk of water scarcity at basin scale is relatively low. Larger downstream water demands from municipals and industries and from environmental flow (e.g., peat lands, river flood plains) needs are also considered and may require water-use restrictions upstream. Details on available databases for regional water scarcity are given in Appendix G.

The contamination from agricultural, and bioenergy feedstock, production is a major threat to water bodies, especially leakage of nitrogen from fertilisers (organic or inorganic) and pesticides to groundwater and surface waters.

The challenge is to reduce such leakage of nutrients and pesticides to a minimum without implying significant losses in yields. For this, existing Good Agricultural Practices (GAP) gives useful guidance to producers and decision makers. On a global level, FAO provides an internet portal on GAP including a database covering studies, reports and information materials on various agricultural systems from different regions of the world.

Low-input cultivation systems can reduce contamination risks of water bodies. For example, organic farming practices generally avoid the application of pesticides and chemical fertiliser, leading to significantly lower contamination risks.

A further significant source for contamination of water bodies could come from inadequate irrigation with waste water. Besides contamination of soils with e.g., heavy metals, waste water pollutants can be transported to water bodies by direct run-off from irrigation or by washing-out during heavy rain events. Therefore, the use of waste-water irrigation systems should comply with, e.g., WHO guidelines on the safe use of waste water, excreta and grey water to reduce risks for human health and for the environment.

The plants for **processing** biomass to liquid biofuels, especially ethanol plants and oil mills, imply risks of significant organic discharges due to high on-site stocks of process water. Respective nutrient inputs from non-routine operation (leakage, accidental spills, tank rupture etc.) could contaminate adjacent water bodies. In case that biomass wastes are processed, additional contamination risk might occur due to other pollutants (e.g. heavy metals). To reduce those risks, the sitting of conversion plants should consider adequate distances from sensible wetlands and water protection areas, and licensing procedures should ensure necessary (technical and managerial) safeguards against non-routine discharges. During typical operation, waste water pollution can be reduced through:

- recirculation systems
- waste-water treatment (including potential biogas use from anaerobic treatment) to reduce routine organic loads below critical threshold of local water bodies
- re-use of certain waste-water treatment sludges as fertilizers

Table 5-16 summarises the environmental sustainability requirements for the water category.

Table 5-16 Screening tool for water impacts

Environmental Component	Applicable to	GO	CHECK	STOP
Water scarcity risk, catchment and downstream	All settings except those using wastes	**No** irrigation, **or** irrigated cultivated land not in risk area **and** water management plan exists	**No** irrigation, **no** data on risk area; water management plan exists	Irrigation, **no** data on risk areas
Water contamination		Local/regional legal requirement met	Local/regional legal requirement unclear	**No** local/regional legal requirement

Source: compilation by Oeko-Institut

5.8 Summary: global environmental impacts -other than GHG emissions

The "traffic light" thresholds suggested in this study were derived from life-cycle and material flow analyses for the settings selected, and are subject to significant uncertainty and variation, especially for the feedstock cultivation. There is a lack of empirical evidence and representative data for some of the life-cycles and settings, so that future GEF activities should concern compiling more comprehensive data on non-GHG emissions, and especially address regionalized water use.

A key requirement to successfully meet the environmental challenges on the project level is the availability of adequate **spatially explicit** data on land use and biodiversity, especially high resolution maps. In that regard, enabling activities are crucial to consider for future GEF funding.

Priority for GEF project portfolios should further acknowledge that in the coming decades, conventional agricultural practices are not adequate to meet climate change challenges, and food security needs especially in rural areas. Thus, GHG mitigation measures and adequate biodiversity safeguards should be considered as "standard" requirements for GEF-finances projects, and **best practices** for biofuel projects should be demonstrated by project developers

6 Social impacts of liquid biofuel production

6.1 Social standards, criteria and indicators for biofuels

As mentioned already in section 5, sustainability aspects of biofuels were mainly discussed in the context of **voluntary** standards for biomass until the early 2000’s. After that, the development of **mandatory** criteria for sustainable liquid biofuels mainly in the EU changed the focus. Besides GHG emissions and other environmental effects, the social impacts of biofuels were also addressed.

Outside of the EU, countries such as Argentina, Brazil and Mozambique as well as Thailand, among others, have or are in the process of establishing and implementing national legislation and subsequent or alternative voluntary schemes with criteria and standards for bioenergy development, especially regarding biofuels for transportation.

Internationally, the GBEP Sustainability Task Force recently agreed list of sustainability indicators for the national level also includes, after extensive debate, social impacts (GBEP 2011).

In parallel, the International Standardization Organization (ISO) is aiming to develop voluntary criteria for sustainable bioenergy, but results of this process cannot be expected before late 2012 or early 2013. However, among these standards there are **no binding rules** for biofuels concerning social impacts, only reporting obligations and the RED scheme in the EU.

The already mentioned FAO BEFSCI overview of regulatory and voluntary schemes for biofuels also addresses social issues (see next tables).

Figure 6-1 Social sustainability aspects/issues addressed under the initiatives reviewed by BEFSCI – Regulatory Framework

	Biofuels Life Cycle Assessment Ordinance (BLCAO) - Swiss	Biomass Sustainability Order (BioNachV)	RED	Low Carbon Fuel Standard LCFS (USA)	Renewable Fuel Standard - USA	Renewable Transport Fuel Obligation - UK	Social Fuel Seal (Brazil)	Testing Framework for Sustainable Biomass (NL)
Land tenure/access and displacement			x			x		x
Rural and social development						x	x	x
Employment, wages and labor conditions			x			x		x
Health/Safety				x		x		x
Energy security/access								x
Food availability				x				x
Food access				x				x
Food utilisation						x		x
Food stability							x	

Source: FAO (2011a), edited by Oeko-Institut

Figure 6-2 Social sustainability aspects/issues addressed under the initiatives reviewed by BEFSCI – Voluntary Standards/Certification Schemes

	Basel Criteria for Responsible Soy Production	**GBEP**	**International Sustainability and Carbon Certification**	**Nordic Ecolabelling of Fuels**	**RTS**	**RSB**	**RSPO**	**SEKAB**	**SBA**
Land tenure/access and displacement	x	x	x		x	x	x		
Rural and social development	x	x	x	x	x	x	x	x	x
Employment, wages and labour conditions	x	x	x	x	x	x	x	x	x
Health/Safety	x	x	x	x	x	x	x		x
Energy security/access	x	x	x		x	x	x		x
Food availability			x	x					x
Food access			x		x				
Food utilisation	x		x		x		x		
Food stability									

Source: FAO (2011a), edited by Oeko-Institut

Figure 6-3 Social sustainability aspects/issues addressed under the initiatives reviewed by BEFSCI – Scorecards

	IDB	**WB/WWF**
Land tenure/access and displacement	x	x
Rural and social development	x	
Employment, wages and labour conditions	x	x
Health/Safety	x	x
Energy security/access	x	
Food availability		x
Food access		x
Food utilisation	x	
Food stability		

Source: FAO (2011a), edited by Oeko-Institut

The BEFSCI screening is in accordance with key findings from other studies (see CIFOR (2010, 2011), IFEU (2008), SLU (2010a), UNEP (2009), Winrock (2010)): The most relevant social impacts of biofuel projects are:

- food security (section 6.2),
- land access and tenure (section 6.3),
- workforce issues, health and safety (section 6.4), and

- employment effects (section 6.5).

Additionally, gender issues must be considered.

6.2 Category: food security impacts of biofuels

Food security as a key element of social sustainability is defined by FAO as follows (World Food Summit, Rome 1996):
"*Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life*".

Still, the reality for more than one billion people is food insecurity (FAO 2010k), and hunger is the unfortunate reality for several hundred million people, especially in Africa. In that context, potential food security impacts of biofuel development are not only important, but concern a basic human right (UNGA 2010).

The intense discussions on biofuel policy impacts of food prices and respective food security impacts of the last years[30] cannot be adequately presented here, but the recent literature agrees that such impacts are relevant, and need consideration[31].

Before presenting project-based requirements for GEF it should be noted, though, that adequate food supply to meet growing global demand faces severe challenges in the next decades[32].

However, global sustainable biomass potentials could still be significant enough without compromising the global food base[33]. Biofuel investments in developing countries, if managed adequately, could contribute to secure future food supply, and access[34]. The impact of biofuels on food security is not only a function of the crop grown, the land used, conversion technologies used, and how the bioenergy supply chain is integrated into agricultural, social and economic systems. It depends on the level of poverty, the potential positive effects on rural development and household income (FAO 2008).

Furthermore, food security impacts of biofuel development are different for net agro-commodity exporting or net food importing countries, and differ within countries between rural and urban populations, i.e. the vulnerability towards negative food security effects varies (FAO 2010e-j).

Thus, for the analysis of food security impacts of **biofuel** development, three principal effect levels need to be considered:

a) Direct effects on land competition and food production

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30 See e.g. see e.g., Chakravorty (2011), FAO (2011b), IEED (2010a), IFPRI (2010), IIASA (2009), HLPE (2011), Kaye-Blake (2010), Mueller/Anderson/Wallington (2011), NBER (2011), Ratmann/Szklo/Schaeffer (2010), SLU (2010b), Tyner (2010), UNGA (2010)

31 see FAO/OECD (2011), UNCTAD (2011); WB (2010a+b, 2011)

32 see e.g. FAO (2009, 2010b+c), Grethe/Dembélé/Duman (2011), Nature (2010).

33 see e.g. Beringer/Lucht/Schaphoff (2011), Cai/Zhang/Wang (2011), CE/OEKO (2010, IEA (2009), IFF (2009), IPCC (2011)

34 see Best (2008), Faaij (2008, 2010), FAO (2008, 2011c); FAO/IFAD (2010), Fritsche (2011), MNP (2008), Raswant (2011)

b) indirect effects on food prices, including yield increases, oil price changes, and dietary changes

c) net direct and indirect effects on income from biofuel development, including oil price changes

In this study, the discussion of food security impacts addresses only the potential impacts from biofuel developments. It should be noted, though, that, given the comparatively small share of current global land use dedicated to biofuel feedstock production (Faaij 2010, IEA 2009, IPCC 2011), the majority of food security impacts for the majority of people depend on other "drivers" such as weather, dietary changes, oil price development, and food stock market dynamics, among others (Schneider 2011).

The suggested approach for food security impacts of biofuel projects under evaluation is, therefore, structured into three levels (tiers).

6.2.1 Simplified screening (feedstock level – tier 1)

The most simple – and, given the complexity, potentially misleading – level is to consider which feedstock a biofuel project will use, and on which land the cultivation will occur.

Land to cultivate biomass feedstocks for biofuels is a limited resource that may already be in use, so that increased competition for this land from biofuel feedstock production might affect food security both directly in crowding out food and/or feed production (impact on food availability and access to food), and indirectly through food and feed price feedbacks which might negatively impact affordability of food.

To avoid such effects and to ensure that bioenergy feedstock production does not directly worsen food security in the country or region where bioenergy feedstock cultivation will occur, edible (staple) feedstocks should be considered as a **STOP** indicator. Another STOP-indicator would be if non-edible crops are cultivated on land in direct competition with food production.

Table 6-1 Screening tool for food security – tier 1, feedstock level

Social Component	applicable to	GO	CHECK	STOP
Food security – tier 1 (feedstock level)	All settings	**Non-edible** feedstock grown on marginal land **not** in competition with food/feed, or intercropping or agroforestry or unused/underused marginal land	**Non-edible** feedstock grown on marginal land for which competition is unclear	**Edible** feedstock or **non-edible** feedstock grown on land **in competition** with food/feed

Source: compilation by Oeko-Institut

The most basic tier-1 test for land use competition is to check if land for cultivating biofuel feedstocks has been in use already for food/feed before the biofuel project was considered, or if there is land use planning or zoning qualifying such land for food/feed production.

Given the reality of developing countries where marginal people may use land for subsistence without official land entitlement or tenure allowance, and where grazing, herding and hinting rights are unsecure, this indicator should be seen in context with the land tenure indicator (Table 6-4).

6.2.2 Causal-descriptive analysis (project/country level – tier 2)

Clearly, the Tier 1 considerations give only a very rough first-order view on potential food security implications. The more elaborate analysis suggested for Tier 2 goes beyond the immediate project vicinity and considers the potential impact on the national "food basket".

This explores the impact of biofuel use and domestic feedstock production on the price and supply of a – country-specific - food basket which includes staple crops, i.e. the crops that constitute the dominant part of the diet in a country. The analysis should consider the methodologies suggested by GBEP (2011), and concerns

- the determination of the relevant food basket(s) and of its components;
- an initial indication of changes in the price and/or supply of the food basket(s) and/or of its components expected in the context of biofuel developments;
- a "causal descriptive assessment" of the role of biofuels in those expected changes, taking into account other factors such as oil price and trade developments

The causal descriptive assessment aims to provide an indication of the probability that a biofuel project in a country led to reduced supply and increased prices - of the relevant food basket(s), i.e. it represents a **risk**. This analysis could also lead to considering possible corrective actions/measures to be taken in order to mitigate the identified risks.

Table 6-2 Screening tool for food security – tier 2, project/national level

Social Component	applicable to	GO	CHECK	STOP
food security – tier 2 (project/ country level)	all settings	as Tier 1, but **no** restriction to non-edible feedstocks if analysis indicates low price risk, **and** project improves agricultural infrastructure	as Tier 1, but analysis indicates some price risk, and unknown effect on agricultural infrastructure	as Tier 1, but analysis indicates significant price risk; **or** large project using existing infrastructure, risk of smallholder exclusion or restricted access

Source: compilation by Oeko-Institut

6.2.3 Detailed analysis (country/international level – tier 3)

The scope of the Tier 2 analysis is restricted to national effects, but food security impacts could also occur outside due to international trade. Furthermore, income effects need to be considered which might compensate (some of) the price effects.

Thus, the Tier 3 analysis will apply computable general equilibrium (CGE) or partial equilibrium (PE) modelling of the impacts of the biofuel production on the price and supply of the national food basket, and could also identify possible effects outside of the country ("leakage").

It should be noted that the data needs, analytical skills and access to modelling required for Tier 3 are significant and usually go well beyond capacities and resources available to project developers and the GEF staff reviewing projects.

In that regard, Tier 3 analyses should be seen in the context of country studies considering sustainable biofuel (and bioenergy) development options.

For the further development of the methodology, it is recommended to follow closely the GBEP indicator work on food security.

The GBEP proposes a four-step approach to measure food security in combination with welfare impacts of households. The approach is described in the following (GBEP 2011):

Table 6-3 Screening tool for food security – tier 3 (country/international level)

Social Component	applicable to	GO	CHECK	STOP
food security – tier 3 (country/ international level)	all settings	as Tier 2, but analysis demonstrates positive income effects which offset low price risk, and that agricultural infrastructure improvements increase food availability and access; no "leakage" of food security risks to other countries	as Tier 2, but analysis indicates unclear income effects and some leakage risks	as Tier 2, but analysis indicates insufficient income effects and significant leakage risk

Source: compilation by Oeko-Institut

Step 1: Determination of relevant food basket and of its components

The first step should be the identification of the "representative" food basket. This basket, which reflects current food consumption patterns, may be determined, for instance, by ranking crops based on their contribution to the average per capita calorie in-take (either through direct consumption or via the foods that these crops are processed into), with the 'main staple crops' providing the highest share. Therefore, the most significant food items in people's diets will be included in the food basket. Large countries with significant differences in diets across regions and/or segments of the population should identify regional food baskets.

Generally, food consumption patterns are not subject to rapid variations, especially in developing countries, due to a number of factors (both economic and non-economic). If these changes occur, the composition of the food basket should be adjusted accordingly. In this case, it would be important to identify and analyse the main drivers of these changes, in order to assess the role (if any) played by biofuels.

In particular, one would need to monitor the effects of biofuel use and domestic production on the nutritional quality of the food basket over time. In order to do this, the "representative" food basket would need to be compared with a "nutritious" food basket, which fulfils basic nutritional guidelines while reflecting the range of foods typically eaten in a country. This "nutritious" food basket should contain a sufficient amount of food per day and contain specific food and nutrient groups that are typical of a country's food consumption patterns.

Step 2: Indication of changes in prices and/or supply of the food basket in the context of biofuels

It is necessary to get an initial indication of whether biofuel production and/or use have increased significantly in the country of its value added chain components. In particular, if levels of biofuel production and/or use have increased significantly, the following variables should be tracked:

- Supply of the food basket(s) and its components disaggregated by end-use
- "Real" (i.e. inflation adjusted) prices of the food basket(s) and its components.

Domestic supply of a given crop is the sum of domestic production and imports minus exports. If a crop is stockpiled, then domestic stocks should be considered and analysed. Once the domestic supply of a given crop has been determined, it should be possible, through market surveys and based on expert judgment, to estimate the share of this supply that is used for feed and fibre and the share that is available for food. This would provide a preliminary indication of the role (if any) played by biofuel production and use, should a decrease in the supply of food basket components for food be observed.

If biofuel production is distributed across the country in proportion to the production patterns of main staple crops, then a national focus should suffice. However, if biofuel is produced in regions close to urban centres or major transport hubs (as it is likely to be), then local price levels, and variations, should be considered as well. For instance, prices of the food basket(s) and its components might be distinguished between rural and urban areas. This split would implicitly capture: differences in the import-content of urban households' food baskets, and transaction costs associated with moving foods from rural to urban areas. With regard to rural areas, it would be especially important to focus on those where food production is displaced. Particular attention should be given to local price variations in food insecure and vulnerable areas. Mapping these areas and identifying the most vulnerable groups would be quite useful in this context, as it would help countries target the analysis of the domestic impacts of bioenergy.

If there is a significant increase in the price of the identified food basket(s) and/or of its components, it is important to also get an initial indication of the resulting welfare implications at both national and household levels. In order to do so and identify countries and population groups that are likely to benefit and those that are likely to be worse off, the net trading position of both the country as a whole and of poor households should be determined with respect to the food basket components that experienced a price increase. An increase in the price of a certain commodity will have positive welfare effects on countries that are net exporters and households that are net producers of that commodity. On the other hand, net importing countries and net consuming households will be negatively affected by this price increase. The estimate of household and national welfare impacts should be based on experts' opinion.

If in the context of increasing levels of biofuel production and/or use, the "initial indication" detects a decrease in the supply of the food basket(s) and/or of its components for food and/or an increase in the "real" prices of such basket(s) and/or components, a Causal descriptive assessment of the role of bioenergy (in the context of other relevant factors) in the observed supply decreases and/or price increases should be conducted. This assessment would also be useful in case of significant variations in the composition of the food basket(s), especially when the diversity of the latter is reduced.

CGE Modelling of the impacts of biofuel production

Food price is an intrinsically multivariate indicator that captures many of the factors that can determine whether a biofuel project is socially and economically sustainable. The variables to be considered will vary country-by-country. Using the data collected on the factors affecting the price of national food basket countries can perform straightforward economic analyses to estimate the relative effects of these many factors (including bioenergy production) on the price of a national food basket. The multivariate nature of the problem invites a computational approach.

CGE models are a standard tool widely used to analyse the impacts of economic changes and are suitable to study the impacts of a nascent biofuel sector. Advanced partial equilibrium forward-looking models can be employed to more thoroughly explore the impact of biofuels on the price of a national food basket. These models highlight challenges and opportunities that might materialise in some countries/commodity markets as they analyse key relationships and trends that could develop in agricultural markets.

Forward-looking models are based on historical inputs, but require sets of assumptions and parameter estimation. As such, it is essential that they be utilised with appropriate caveats and clear expression of the underlying assumptions. Forward-looking projections are an established component of modern agricultural economics. They are resource intensive and require considerable support.

Partial equilibrium models facilitate policy and market analysis of agricultural markets by allowing the modeller to observe the impact of various changes in policies and/or market conditions, such as the development of a bioenergy sector. The described approach is not immediately applicable for a potential GEF Tier 3 work. Published country analyses are available for Cambodia, Peru, Tanzania and Thailand. FAO is currently working to expand these country studies.

Furthermore, FAO recommend that policy makers have to identify the risks of price changes for food staples within a country. One method is the measurement of the household welfare impact. The household welfare impact based on the fact that price changes can have positive or negative impacts on a country. Due to the influence on the household level the net household position (net consumer or net producer) has to be analysed. In a net consumer household the income from crops is less than total purchases. In a net producer household the income from the crop exceeds total purchases. The overall household impact is measured by the effect of the price change on a household's net welfare. The analysis it based on household income data and expenditure surveys and requires expertise in household data handling, household data analyses, market knowledge and price movements. Therefore, it can be expected that for GEF Tier 3 work, such data will become available. It is the responsibility of countries/governments to analyse the characteristics of their own country and then data can possibly be divided into regional differences.

Example Cambodia (FAO 2010e): The household level analysis for Cambodia showed that from a food security perspective, the price of rice should be monitored closely for particular segments of the population. Rice is the most important food crop in Cambodia and Cambodia is a net rice exporter. Especially lower rural income households benefit from price increases, while urban households do not profit. Furthermore households without landownership and woman households are vulnerable due to price increases. Therefore land tenure and gender issues influence the results.

Example Tanzania (FAO 2010g): Maize and cassava are the most important staple foods in Tanzania. Dependent on the income level other staple foods play a role, e.g. rice and wheat are more important for high-income consumers in urban areas. Cassava and sorghum are more important in low-income households in rural areas. Maize is an intermediate position and is a staple food in both urban and rural areas. Over the last few years there does not appear to be a close connection between world prices and domestic markets.

Example Thailand (FAO 2010h): It can be ascertained that factors like household sizes, rural or urban location, small or high income and landownership are very closely connected to the question of food security.

Further methodological issues are given for Thailand in Appendix H.

6.3 Category: social use of land

Land use is not only a key issue for biodiversity and climate protection, but also has direct implications in the social realm. As biofuel development could be socially beneficial from a development point of view, possible negative impacts associated with land use should be minimised in the near-term and avoided in the longer-term.

The social use of land is primarily related to the theme of access to land, water and other natural resources. Land access is a consequence of land tenure. From a social sustainability perspective, this might be one of the major concerns associated with bioenergy development in some areas.

The social sustainability of bioenergy development is directly related to changes in land tenure and access. In many developing countries no land market has been established. The local poor population grow agro-products (food and feed mainly) even without having any kind of legal title or security of the land used. Similarly common permanent meadows and pasture lands are essential to communities' livelihoods that depend on breeding livestock and consuming livestock sub-products. When arable lands and lands under permanent crop, permanent meadows and pastures and forest areas are given in concession or leased to private bioenergy investors, the local poor population might lose their capabilities to ensure their life subsistence.

Land to be leased by the state or a domestic authority and/or sold through one-to-one negotiations to individual or corporate investors for biofuel development will require some kind of formal contract or titles from the government. As land tenure as well as local communities' livelihood conditions are influenced by land customary rights, land acquisition for biofuel development must acknowledge these conditions.

Foreign land acquisition is on the rise. The High Level Panel of Experts on Food Security and Nutrition (HLPE) formulated policy recommendations according to land tenure in the following three areas (HLPE 2011):

1. the respective roles of large-scale plantations and of small scale farming, including economic, social, gender and environmental impacts
2. reviewing the existing tools allowing the mapping of available land
3. comparative analysis of tools to align large scale investments with country food security strategies

The report reflects that many problems due to land investment could be dealt with through more effective enforcement of existing policy and legislation on national and local levels. Governments and investors get a better balance by differentiation in terms of sector, level and actors involved (HLPE 2011).

All measures, instruments or standards include that food security is paramount. For biofuel projects, two aspects are key:

- Degree of legitimacy of the process related to the transfer (i.e. change in use or property rights) of land for new bioenergy production. This legitimacy can stem from either a legal process or a socially recognised domestic authority, including customary ones.
- Extent to which due process is followed in the determination of the new title. Following due process with regard to land transfers means that all procedural requirements are followed, including the assessment and recognition of the rights of current owners and users under the national legal framework and customary practices; and compensation measures according to the assessment results.

If the land used by investors is recognised as community/common land it is important to require adequate mechanisms of participation or consultation carried to be out by the investors with the local community (FAO 2011d).

If the land is recognised as land with secure rights by national legislation, it is important to provide evidence of the negotiation agreement for any contingent compensation between the investor and the land owner. Table 6-4 summarises the suggested requirements for biofuel projects.

Table 6-4 Screening tool for biofuel cultivation regarding land tenure

Social Component	Applicable to	GO	CHECK	STOP
Land rights	All settings except those using wastes	Titles, contracts or other formal registration of land tenure held by actors in a national or local registry, traditional land rights are recognized and upheld/defended by formal legal system	Titles, contracts or other formal registration of land tenure subject to negotiations	No titles, contracts or other formal registration of land tenure available, no or unclear recognition of traditional land rights
Public land allocation		Procedure follows due process	Procedure unclear	No procedure if dispute between public and traditional land access/ownership/rights
Dispute settlement		Effective access to fair adjudication, including court system or other dispute resolution processes	Access to settlement unclear; adjudication system possibly unfair, any open disputes are unresolved	No access, no evidence of effective and fair judicial processes can be demonstrated
Inclusion of landless people		No restriction on access	Access unclear	No access, uncompensated displacement risk

Source: compilation by Oeko-Institut

6.4 Category: labor conditions and healthy livelihoods

Labour conditions and human health are closely related, as workers occupied in crop cultivation and harvesting procedures can be exposed to human health risks from pesticides, emissions from burning fields, and occupational accidents.

Therefore, the key labour standards and principles of the ILO Declaration on Fundamental Principles and Rights of Work must be met which will massively reduce possible negative impacts on the overall livelihoods of people living in bioenergy feedstock cultivation areas.

While biofuel production includes employment opportunities, labour conditions are key, especially with regard to wages, child labour, and safety. Jobs in the bioenergy sector should adhere to nationally recognised labour standards consistent with the ILO Declaration on Fundamental Principles and Rights at Work. This includes the following ILO standards:

- freedom of association and collective bargaining
- elimination of forced and compulsory labour and abolition of child labour
- elimination of discrimination in respect of employment and occupation
- health and safety

- working conditions and wages.

In Table 6-7 the suggested requirements for biofuel projects are summarised.

Table 6-5 Screening tool for biofuel projects regarding workforce

<table>
<tr><th>Social component</th><th>Applicable to</th><th>GO</th><th>CHECK</th><th>STOP</th></tr>
<tr><td>ILO standard on wages</td><td rowspan="5">All settings</td><td rowspan="4">Fully implemented in country, enforced & monitored on project level</td><td rowspan="4">Implemented in country, enforcement & monitoring on project level unclear</td><td rowspan="4">Not implemented in country or no enforcement & monitoring on project level</td></tr>
<tr><td>ILO standards on labour</td></tr>
<tr><td>ILO standards on discrimination</td></tr>
<tr><td>ILO standards on health & safety</td></tr>
<tr><td>Scheme of small-scale farmers</td><td>Smallholder or outgrower schemes</td><td>Centralised outgrower scheme, use of non-local workforce</td><td></td></tr>
</table>

Source: compilation by Oeko-Institut

6.5 Category: gender

Gender discrimination has to be paid attention due to the importance of biofuel production for poverty reduction. Resilience to shocks, vulnerability and stress factors is a gender specific challenge, where especially women have to be involved. Gender inequality is a social risk, which is as important as economic risks. Both economic and social risks are influenced by gender dynamics and have important impacts on men and women (FAO 2011e).

On the political level exists a lack of understanding and consideration of differentiated socio-economic impacts on male and female households. Due to biofuel production men and women face different risks according to access to land, employment, employment conditions and food security.

Example: In several Sub-Saharan African countries women are often allocated low quality lands by their husbands. Traditionally women cultivate crops for household consumption on marginal lands. In the case of energy crop cultivation could cause a partial or total displacement of women towards marginal lands, with negative impacts on women's ability to meet household obligations like food security. Unequal rights to land create unequal opportunities to profit from biofuel production (FAO 2010l).

Despite the fact that gender induced risks influence the sustainability of biofuel production, all biofuel strategies have to be gender sensitive. GEF should be ensure that women and female headed households have the same opportunity as men and men headed households to engage in and benefit from the sustainable production of biofuels. Especially for the growing number of households headed by women (42% in Africa), particularly in food insecure countries, the access of women to land must be ensured. This would improve the welfare of families and increase the agricultural productivity (FAO 2011l).

Table 6-6 Screening tool for biofuel projects regarding gender equity

Social Component	Applicable to	GO	CHECK	STOP
Land rights	All settings	Men and women have the same opportunities and benefits	Women have higher risks and are vulnerable due to socio-economic shocks	Project **threatened** food security of households due to unequal land rights, employment conditions etc.
Employment				
Employment conditions				
Food security				

Source: compilation by Oeko-Institut

6.6 Category: employment effects of biofuels

ILO refers to the "employed" as comprising all persons above a specified age who during a specified brief period, either one week or one day, were in "paid employment" (at work or with a job but not at work), and/or "self-employment" (FAO 2008).

Employment within biomass fuel cycles consists of direct and indirect jobs:

- Direct employment results from the construction and operation of plants and fuel production. This refers to the total labour necessary for crop production, for the construction, operation and maintenance of the conversion plant and for transporting feedstocks and the respective products.
- Indirect employment means jobs generated within the economy as a result of expenditure related to said fuel cycles. Input-output analysis is used to derive indirect employment estimates from multiplier impacts.

In addition, induced employment, which stems from spending additional wages and profits from both biomass production and conversion activities, should be recognised. Furthermore employment creation is distinct and different for traditional and modern bioenergy systems. It differs in such areas as skilled and unskilled labour, direct and indirect labour, formal and informal sectors and direct and indirect impacts (FAO 2003). Nevertheless bioenergy can contribute to employment on local, regional and national levels. Numbers vary depending on the methodology.

Due to data limitations, input-output analyses can be a methodology but is difficult for developing countries. The quantity and quality of employment depends on the stage of the bioenergy system, the conversion process, the specific country setting and whether it's labour intensive or mechanised. There is a large difference between developing and developed countries. Several studies have been carried out that focus on employment effects of bioenergy production on specific regional areas. They use different calculation methods or focus not only on bioenergy but also on renewable energies themselves.

The question of jobs created has been a key part of the debate over the economic and environmental merits of biofuels. Job effects vary according to the feedstocks that are produced. Biofuels require about 5 times more (such as Jatropha and oil palm) workers per joule of energy content produced than fossil fuels. Oilseed crops in developing countries hold the most promise for job creation because of manual harvesting.

Job potentials of advanced biofuels are estimated e.g. for the US with 123,000 jobs by 2010 and up to 20,000 new jobs for every billion gallons of cellulosic fuels. This roughly translates into 0.25 jobs/$TJ_{biofuel}$. Job potentials in the bioethanol and sugarcane industry in Brazil say that 36,000 people are employed permanently and 326,000 people will be employed permanently (FAO 2003).

An FAO (2003) study estimated employment within the bioenergy sector for several countries: such as Brazil, India, Ivory Coast, Kenya and Cameroon, Pakistan, and the Philippines. The study concluded that

- employment required for the production of bioenergy is about 5 times higher than that of fossil fuels
- the level of direct jobs needed for the operation of bioelectricity systems is about four times higher than that required for the operation of fossil fuel power plants
- bioelectricity production requires far more direct jobs (15 times) than the production of nuclear electricity

The ratio between direct and indirect employment generated by a general biofuel system is 79 persons (direct) to 34 persons (indirect). The direct employment resulting from the biofuel system is as follows (30 MWel): 14 persons (construction), 42 persons (fuel production), 4 (logistics), 19 (conversion). This is equivalent to 0.37 man-years per GWh, or 0.29 jobs/TJ_{input} (FAO 2003).

Some general comparisons and conclusions from employment in the bioenergy sector are:

- larger projects tended to have less specific impacts on employment and income as opposed to small projects, mostly due to economies of scale
- multiplier effects appear to be slightly lower than what is found in the general literature and may be caused by the methodology used
- detailed calculations were extremely difficult to perform due to the variable quality of data and the complexities of the variables to be considered (FAO 2003).

Further methodological issues are given for Thailand in Appendix H.

6.6.1 Indicator: direct employment effects

The determination of direct employment along the value chain can be derived from industrial surveys. Direct employment is generated in cultivation, harvesting and processing. A detailed analysis and description of the employment situation in Thailand can be seen in Appendix I. Table 6-7 shows direct employment effects for the settings.

Table 6-7 Direct employment effects of biofuel production

			Direct employment	
Feedstock	**Country**	**Setting/year**	**jobs/ha/yr**	**jobs/TJ**
Palm	ID	> 1 year/2010	0.38	3.4
Palm	MY	> 1 year/2010	0.30	2.4
Sugarcane	BR	2010	0.27	1.6
Sugarcane	MZ	11/2010	0.14	0.9
Sugarcane	MZ	12/ 2010	0.23	1.2
Sugarcane	MZ	16/2020	0.23	1.5
Sugarcane	MZ	17/2020	0.23	1.1
Jatropha	IN, low input	average of 0 and 23 plantation years/2010	0.11	9.7
Jatropha	IN, intermed.	average of 0 and 23 plantation years/2010	0.28	16.5
Cassava	MZ, low input	42/2010	0.32	24.9
Cassava	MZ, intermed.	43/2010	0.37	19.3
Cassava	TZ	44/2010	0.24	9.3
Cassava	TZ	45/2010	0.28	7.2
Cassava	TH	46/2010	0.11	1.8
Cassava	TH	47/2010	0.11	1.6

Source: Oeko-Institut calculations based on setting results

The results for palm and sugarcane compare well with other studies, while for Jatropha in India and cassava in Mozambique and Tanzania; the figures indicate quite immature situations. The cassava data for Thailand compare well with sugarcane data.

6.6.2 Indicator: indirect employment effects

The calculation of indirect employment effects is based on input-output analysis. In the case of Thailand, a hybrid approach was tested (see Appendix I). Based on this approach it is possible to calculate indirect employment effects for each country. The OECD statistics provide, for some countries, input-output tables for further calculations (e.g. Argentina, Brazil, China, India, Indonesia, South Africa, Thailand, Vietnam).

Country-specific databases have to be checked when using the hybrid approach. Especially within developing countries an analysis is restricted due to lack of data. By using a combination of an analytical approach for the micro level and the input output model for the macro level, the investigation of employment effects could be assessed. The analytical approach uses the production process analysis. A detailed analysis description in the case of Thailand can be seen in Appendix I.

6.7 Summary: social standards, criteria and indicators

The "traffic light" approach developed in this study to address social issues of biofuel developments should be tested (and possibly refined). Both for food security and employment effects, key requirements on the project level are the availability of adequate data, and analytical skills and access to modelling. Usually, this goes beyond capacities and resources available to project developers or the GEF staff reviewing projects. Therefore, GEF is dependent on the responsibility of countries and governments to analyse the characteristic of their own country and provide the necessary data sets. Here, **collaboration should be sought with the GBEP activities** on implementing sustainability indicators for bioenergy on the national level for which a new Working Group on Capacity Building for Sustainable Bioenergy (WGCB) was created in the GBEP. A key focus for this should be on the food security indicators, and employment effects.

With regard to strategic issues, priority for GEF project portfolios should consider countries which already analysed biofuel production impacts on prices and food security. Potential GEF projects must further pay attention to land tenure, labour conditions and gender issues. These impact categories influence human welfare and can avoid poverty and hunger. Due to increasing population, increasing demand for food, and the growing needs for modern energy services, biofuel production and use – also for stationary applications – should focus on projects which deliver on all those issues without major negative tradeoffs. Here, the sustainable use of biogenic residues and wastes and of sustainably using marginal and degraded land for biofuel feedstock cultivation should receive priority in project funding strategies.

7 Next generation of liquid biofuel production

More than 99% of all currently produced biofuels are classified as "first generation" (i.e. fuels produced primarily from cereals, grains, sugar crops and oil seeds) (IEA, 2008b). "Second generation" or "next generation" biofuels, on the other hand, are produced from lignocellulosic feedstocks such as agricultural and forest residues, as well as purpose-grown energy crops such as vegetative grasses and short rotation forests (SRF). These feedstocks largely consist of cellulose, hemicellulose and lignin. Conversion to bioethanol fuel is via hydrolysis of the cellulose and hemicellulose to sugar, after which fermentation of sugar is performed. These feedstocks can also be converted to fuel via gasification or pyrolysis to produce synthetic diesel, bio-oil and other fuels. To be competitive with fossil fuels, there is a need to overcome several technical challenges – which is the focus of current R&D.

Generally, the advantage of next generation biofuels (over 1st generation biofuels) is their ability to utilise many different types of lignocellulosic materials as feedstock and lower land use impacts. However, the environmental impact of lignocellulosic biofuels depends on the conversion route, the feedstock and site-specific conditions. Moreover, unlike the mature 1st generation biofuels, next generation biofuel technologies are still under development (pilot and demonstration stages), and commercialisation is anticipated in the next decade.

This section analyses the short term and long term technical and economic performance as well as the potential development of next generation biofuel industries in five developing countries under some defined settings as shown in Table 7-1.

Table 7-1 Settings for "Component 6" next generation biofuels

Setting No.	Country	Feedstocks	Time-frame	Land quality[35]	Biofuel technology
67/68 69/70	Argentina	Switchgrass	2020 2030	Less suitable	BtL/ Next EtOH
58/59 61/62	Brazil	Eucalyptus	2020 2030	Less suitable/ Suitable	Next EtOH
10		Sugarcane bagasse	2020 2030	-	Next EtOH
71 73	China	Rice straw	2020 2030	-	Next EtOH
57 60	Mozambique	Eucalyptus	2020 2030	Less suitable	Next EtOH
63/64 65/66	Ukraine	Poplar	2020 2030	Less suitable/ Suitable	BtL
72 74		Wheat straw	2020 2030	-	Next EtOH

Lignocellulosic feedstocks selected for this analysis include: perennial crops, such as eucalyptus species in Brazil and Mozambique; poplar in Ukraine; switchgrass in Argentina and agricultural residues, such as rice and wheat straw in China and Ukraine.

[35] Suitable land is equivalent to good agricultural land while less suitable land refers to marginal or degraded land

7.1 Feedstock production and supply

The performance of the selected cropping and residue systems for each country is provided in this section. Development of energy crop plantations involves four major phases: site preparation, planting, maintenance and harvesting. Specific activities at each stage depend on the site quality which influences the degree of site preparation that is necessary; choice of species, planting density, and rotations; required cultural management and soil amendments (fertilisation, weed control, animal control, and pest management); as well as transport and logistics.

At each stage in the production of biomass, cost factors such as labour, machinery investment, fuel costs as well as chemical and energy inputs have to be accounted for. The technical specification of equipment such as tractors is also incorporated into the calculations. An important aspect in energy plantations, especially short rotation woody crops such as eucalyptus, is the ability to coppice over successive rotations periods until it is finally stumped out and replanted.

It is assumed that all feedstock production systems are carried out under well managed agricultural systems – meaning the proper application of appropriate amounts of fertiliser (to replenish plant nutrient extraction and support high biomass growth), pesticide and herbicides (to ensure protection of energy crops against diseases, pests and weeds). It also assumes adequate silvicultural management, but does not take into account irrigation. Planting is assumed to be done during the rainy season to take advantage of rain-fed growth. However, some water may be applied to young seedlings, during the first three weeks of growth, should they encounter moisture stress.

Appendix E provides details of the general approach used to estimate production costs of energy crops – from land preparation until biomass is harvested and forwarded to the roadside ready for transportation to the processing plant. Key assumptions for each crop relate to:

- Plant spacing and yields
- Fertiliser, herbicide, pesticide application
- Mechanised/manual operations
- Planted seedlings/cuttings
- Plantation lifetime and coppice cycle
- Harvesting and forwarding technology

7.1.1 Eucalyptus production costs in Brazil and Mozambique

Eucalyptus is considered as the energy crop for Mozambique and Brazil. In Mozambique, it is assumed that seedlings are planted manually at a spacing of 3x3-m in a semi-arid region. Extensive manual weeding and chemical pesticide application are required during the first 3 years, before the eucalyptus trees reach full canopy cover. Harvesting is carried out every 8 years over 24 years before the stand is re-established. It is assumed that in Mozambique, harvesting is done using chainsaws. Forwarding to the roadside is done using a skidder.

Table 7-2 Cost elements for eucalyptus production in Mozambique

Cost Item	Description
Land	Costs of land vary between 20 $/ha/yr (2009) for agricultural land uses depending on locations (CPI, 2009).
Labour	Minimum wage is 0.3 $/hr in the agricultural sector
Diesel	36 litres per ha at cost of 1.02 $/litre
Seeds	1,333 plants per ha at cost of 0.20 $/plant
Herbicides	3 litres/ha at costs of 2.23 $/litre
Pesticide	0,1 kg/ha of fungicides and 0.6 litres/ha of pesticides at average cost of 9.55 $/litre
NPK	60 kg/ha of N fertiliser, 23 kg/ha of P fertiliser and 48 kg/ha of K fertiliser at average cost of 0.77 $/kg

Chemonics and IFCD (2007); Laclau et al (2003); van der Hilst et al. (2011)

Eucalyptus productivity in Mozambique is estimated to vary from 4.5 to 35 tdm/ha (Batidzirai et al. 2006; van Eijck et al. (2012); Laclau et al. 2003; Ugalde et al. 2001; Savcor, 2006). For a given species, the biomass yield is a function of the management applied as well as climate and soil conditions. According to van der Hilst & Faaij 2012, the mean annual increase (MAI) is estimated to be 1.5% per annum. The projected maximum attainable yield in 2030 is still well below the estimated maximum attainable yield for Mozambique.

Table 7-3 Eucalyptus production performance in Mozambique on marginal land

	2020	2030
Yield (tdm ha^{-1} yr^{-1})	7	10
Production costs (USD/tdm)	75	62

Source: Van der Hilst & Faaij (2012)

The estimated biomass feedstock production from eucalyptus in Mozambique is 3.96$/GJ in 2020 and 3.27$/GJ in 2030 at the farm gate. This is equivalent to a production cost of 37.6 $/ton,wet (2020) and 31.1$/ton,wet (2030) assuming a moisture content of eucalyptus at harvest of 50%. Fertilisation contributes the most to the total production costs at 30%, while land clearing (18%) and stand establishment (17%) are also significant. Harvesting and extraction contributes only 13% to the total costs, because in this case manual harvesting is assumed.

Future changes in feedstock production cost -- Long term pressure on land is expected under a business as usual scenario and thus the cost for land is likely to increase, pushing up biomass production costs. Similarly, as Mozambique's economy grows, it is expected that labour wages will increase. When labour costs increase, efficient machinery will become more attractive. Energy input costs are also expected to grow, but with improving infrastructure, diesel distribution costs could go down. When diesel prices go up, full mechanisation will be less attractive. In the future, improved seeds and breeding as well as technological learning about seed technology are expected to result in higher biomass yields which will result in decreasing production costs. Globally, fertiliser prices will increase due to higher fossil fuel prices and to P fertiliser scarcity. Locally, prices could go down when there is critical mass for the establishment of domestic production. All these factors are expected to have varied impacts on the biomass production costs, but increase in yields is likely to have a much bigger impact on overall costs – and thus future costs are expected to decrease.

Eucalyptus production costs in Brazil -- For Brazil, eucalyptus production costs are estimated using a set of assumptions shown in Appendix E. For the different soil qualities, the required amount of fertiliser and corresponding biomass yields are shown in Table 7-4 and Table 7-5 respectively.

Table 7-4 Fertiliser requirements for eucalyptus production in Brazil by land suitability

Required fertiliser amounts (kg/ha)	**Suitable**	**Less suitable**
NH_4	83	60
P_2O_5	32	23
K_2O	67	48
CaO	97	70
Total	279	201

The highest reported yield level was 85 m^3 ha^{-1} yr^{-1} with harvesting at the age of 6 years (van de Bost, 2010). In this most optimistic case (using current technology), the cost of the feedstock at the plant gate would be reduced to 1.95 $/GJ, or represent 5 $/GJ of ethanol at an energy efficiency of 39%. Current Brazilian average yields of eucalyptus are around 42 m^3 ha^{-1} yr^{-1}, from very marginal soils to the very suitable soils. Projections for the Brazilian potential average vary, but are generally estimated to be around 50 m^3 ha^{-1} yr^{-1} (ABRAF, 2009; SBS, 2009; IPEF, 2008).

Table 7-5 Eucalyptus production performance in Brazil on different suitable land quality

	2020		**2030**	
Land quality →	Suitable	Less suitable	Suitable	Less suitable
Yield (tdm ha^{-1} yr^{-1})	22	10	24	12
Production costs (USD/tdm)	40	56	35	47

Source: Smeets et al 2009

The various cost items for eucalyptus production in Brazil are listed in Table 7-6 below and further details are given in Appendix E. Land rent differ depending on soil quality and range from 49-146 $/ha. Harvesting is assumed to be mechanised using Claas harvesters which cost about 322,000$.

In Brazil, the estimated biomass feedstock production from eucalyptus is given in Table 7-6 and the cost by component is shown in Figure 7-2. For marginal soils, the cost of biomass production is estimated to be 3.3$/GJ in 2020 and 2.9$/GJ in 2030 at the farm gate. This is equivalent to per hectare production costs of 4,684 $ in 2020 and 3,887 $ in 2030. Similarly, for the more suitable land quality, eucalyptus production is estimated to be about 2.44$/GJ in 2020, while decreasing to 2.22$/GJ in 2030. In per hectare terms, production costs are 7,834 $ in 2020 and 6,500 $ in 2030. Due to the use of mechanised harvesting, the contribution of harvesting to overall costs is very high in Brazil (at 27% for marginal soils and 29% for good quality land). Fertilisation also contributes significantly at 21% (for marginal land) and 24% (for good quality soils). Land costs are also high contributing between 10-14% depending on land quality. As shown in Figure 7-2, other important eucalyptus production cost elements include stand establishment (9-15%), extraction (10-13%) and weeding (5-8%).

Table 7-6 Value of cost items for eucalyptus production in Brazil

Cost Item	Value	Unit	Source
Wages-Field workers	2.87-7.74	$/h	calculated
Tractor	13.13	$/h	WSRG, 2004
Fencing -material and machinery	439.17	$/ha	Faundez, 2003
Plant costs	0.07	$/plant	various, own calculations
Herbicides	126	$/ha	Faundez, 2003
Fertilisers	68.6-207.2	$/ha	various, own calculations
Pesticides Chemicals	8.4	$/ha	Faundez, 2003
Fungicides Chemicals	4.2	$/ha	Faundez, 2003
Land rent	49-145.6	$/ha	World Bank
Harvesters - Claas harvester	322	k$/machine	Gillard
Harvesters - tractor & trailer	135.8	k$/machine	Gillard

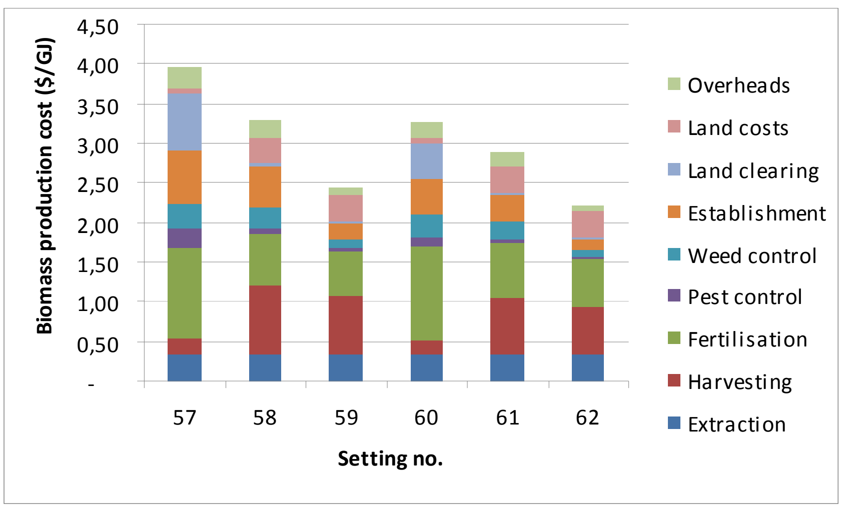

Figure 7-1 Eucalyptus production costs in Mozambique and Brazil by component

In the long term (2030), the contribution of the various cost elements to the production costs vary slightly compared to the short term (2020). As expected, land costs increased marginally from 10% to 11% for marginal land, and from 14 to 15% for the suitable areas. Fertilisation costs increase and their contribution correspondingly increase from 21 to 24% for marginal areas, while for good quality land they increase from 24 to 27% of overall costs.

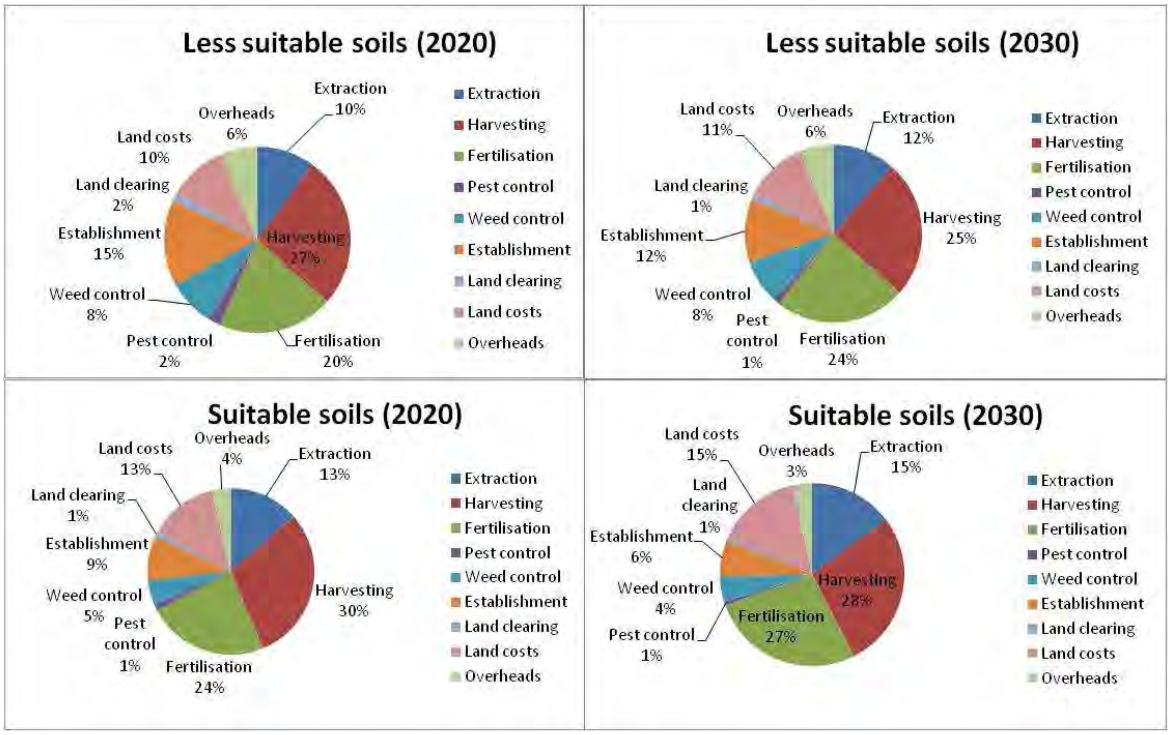

Figure 7-2 Breakdown of eucalyptus production costs in Brazil (2020 – 2030)

7.1.2 Poplar production costs in Ukraine

Currently there is no poplar production in Ukraine except for a few test plantations. Studies indicate that the optimal planting density of seedlings in Ukraine would be 4,000-6,000 plants/ha (Fuchylo et al 2009). In this case, a planting density of 5,300 is assumed with 2 year rotation over 10 years. Poplar productivity is estimated to vary from 6 to 14 tdm $ha^{-1}yr^{-1}$ in marginal areas and suitable soils respectively. Table 7-7 shows the corresponding amounts of fertiliser input requirements by land suitability. Wages vary from 0.63-2.1 $/hr, while land rent is about 38 $/ha. Fuel costs range from 960 $/ton for diesel to 1080 $/ton for petrol. Current inflation and discount rates are 10.7% and 17% respectively.

Table 7-7 Poplar SRC yields and fertiliser inputs in Ukraine by land suitability classes

	Suitable	**Marginally suitable**
Yield (tdm $ha^{-1}yr^{-1}$)	14	6
NH4 input (kg/ha)	71	34
P2O5 input (kg/ha)	20	10
K2O input (kg/ha)	52	24
Manure (organic fertiliser equivalent*) (tons/ha)	20	11

** According to SEC Biomass (2011) manure is used instead of chemical fertilisers and estimates are based on a range of 11-40 tons per hectare. Equivalent chemical fertilisers are estimated by Smeets and Faaij (2009).*

Poplar production costs are estimated to be 3.5$/GJ on marginal soils in the short term, decreasing to about 3$/GJ in 2030. Similarly, on good quality land, poplar can be produced at a cost of 2.26$/GJ in 2020 and at 2.02$/GJ in 2030. Production costs per hectare (without considering the productivity are higher for suitable soils (4,670 $/ha in 2020 and 3,875 $/ha in 2030) compared to 3,528 $/ha in 2020 and 2,927 $/ha in 2030 (for less suitable soils). As shown in Figure 7-3, harvesting represents the largest cost component for both marginal (35-38%) and good soils (29-31%), with the latter representing the long term. Fertilisation is also an important cost component contributing up to 29% of poplar production cost. Another important cost element is stand establishment, ranging from 11-19%.

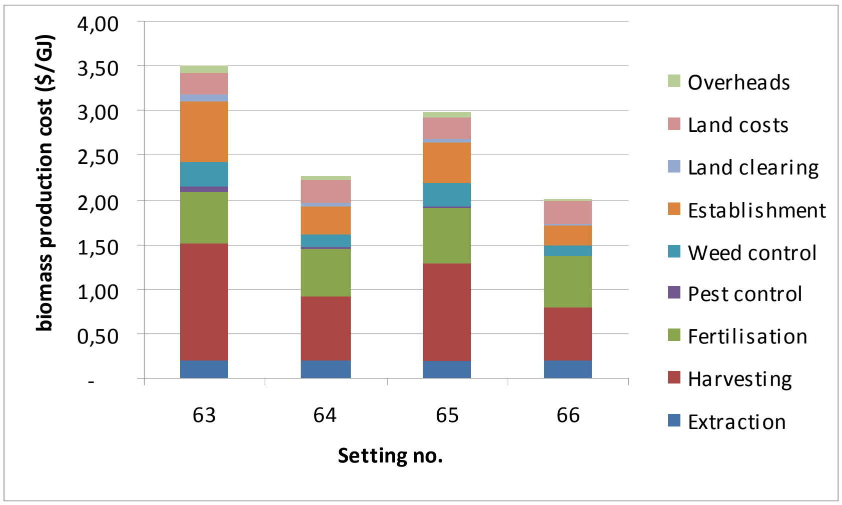

Figure 7-3 Poplar production costs in Ukraine by component

7.1.3 Switchgrass production costs in Argentina

Switchgrass is already being produced in Argentina and is mainly used for forage production for livestock (INDEC, 2006). It is assumed that the switchgrass plantation is established solely on marginal soils using imported seeds and the plantation is expected to last a lifetime of 15 yrs before it is re-established. The productivity for switchgrass on marginal land is assumed to be 5 tdm/ha/year. Future yield increases are estimated to be between 32–67% in 2030 compared to the current situation (van Dam, et al 2009).

Land rent in Argentina ranges from 100 to 300 US$/ha/year depending on land suitability type and location. In 2030, land prices for marginal land remain constant; however for good quality land prices go up from 300 to 450$/ha. Labour wages range from 2.18-3.18 $/hr and in 2030; labour rates are expected to go up to between 3.98-8.29$/hr. Switchgrass seeds are imported from Texas at 20 US$/kg compared to a possible local production cost of only 10 US$/kg. Fertiliser costs in Argentina vary from 0.315 US$/kg (P) to 0.48 US$/kg (N) (Margenes 2007). Aggregate switchgrass input production costs per hectare are shown in Table 7-8.

Switchgrass production costs are estimated to be 3.22$/GJ (306 $/ha) in 2020 and 2.97$/GJ (373 $/ha) by 2030. See Figure 7-4 and Table 7-8. The major cost elements in switchgrass production are machinery costs (37% short term and 44% for long term). Land costs are also quite significant (at 29% in 2020 and 36% in 2030). Fertiliser costs increase significantly from 3% in the short term to 12% in the long term.

Table 7-8 Cost assumptions of key switchgrass production inputs in Argentina

Item	2020	2030	Units
Land rent	110	110	$/ha/yr
Seeding input	22.5	22.5	$/ha
Fertiliser input	12.0	49.5	$/ha
Herbicides input	2.85	6.41	$/ha
Labour costs	295.87	552.04	$/ha
Fixed costs machinery	1,964	2,015	$/ha
Fuel costs	493.11	688.30	$/ha
Aggregate costs	306	373	$/ha

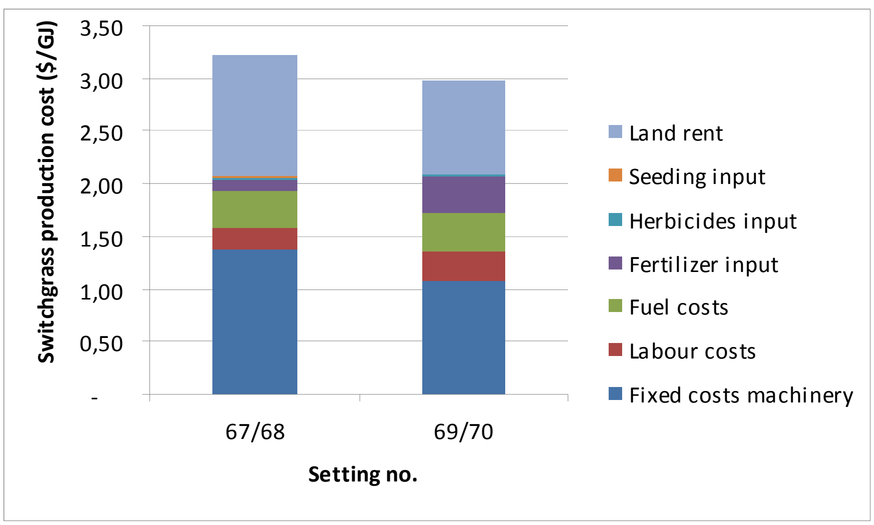

Figure 7-4 Switchgrass production costs in Argentina by component

7.1.4 Rice and wheat straw production

Rice and wheat straw have advantages as biomass feedstock because utilising them does not require recovering land costs, which are already covered in the grain enterprise. The cost of the straw supply is taken as the opportunity cost of the agricultural residue at a grain plantation (usually taken as its fertiliser value or alternatively compared to the next application such as fodder). Cost elements include chopping/cutting/swathing, raking, baling and on-farm hauling of crop residues. Because unused residues may have value (in that they reduce fertiliser needs or soil erosion), appropriate adjustments must be included in cost estimates. However, estimating nutrient requirements is very site specific and needs detailed soil analysis to evaluate sustainable residue removal rates.

Wheat straw production in Ukraine -- Table 7-9 shows the cost estimates for wheat straw collection and packaging in a typical Ukrainian facility. Sustainable wheat straw yields are estimated to be about 1 tons per ha at 15% moisture content.

Table 7-9 Cost estimates of wheat straw collecting and packaging in Ukraine

Straw harvesting activity	**Tractor**		**Fuel**		**Labour**	
	$/ha	$/hr	$/ha	$/hr	$/ha	$/hr
Cutting and raking	35	97	35	100	0.4	1
Baling (square baler + tractor) Bales 30kg	20	33	14.5	25.2	0.58	1
Forwarding to roadside (500m)/baler pick up (tractor front end loaders)	20	40	10	22	0.48	1

The production cost of wheat straw is estimated to be 2.88 $/GJ in 2020 and 1.89 $/GJ in 2030. As shown in Figure 7-5, cutting and raking wheat straw is the most costly item in straw production, contributing nearly 50% of the total costs. Baling is also a significant cost adding another 25% to the overall costs while bale collection and forwarding also contributes about 21%. Roadsiding and storage adds another 5% to the costs.

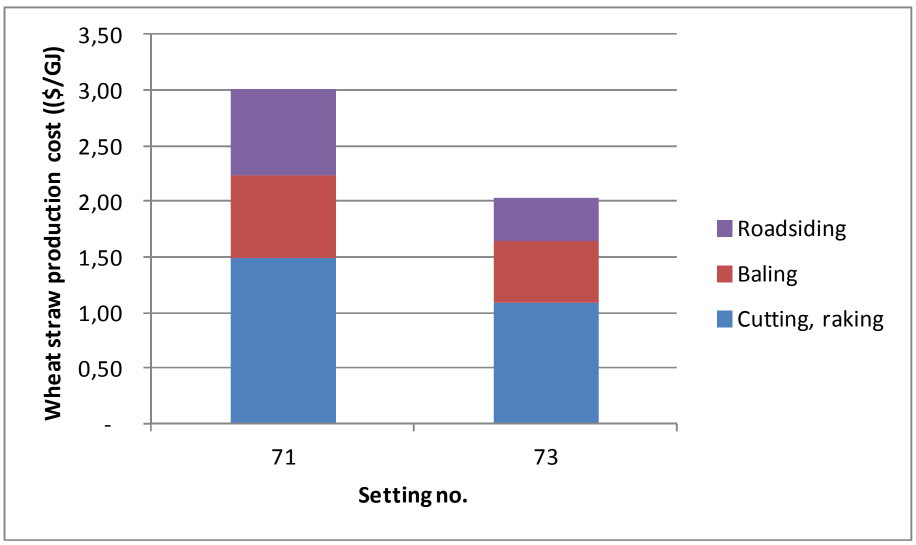

Figure 7-5 Wheat straw production costs in Ukraine by component

Rice straw in China -- Production of rice straw also involves swathing, raking, baling and roadsiding as shown in Figure 7-6. Sustainable rice straw yield is estimated to be about 1 ton/ha. Rice straw is estimated to cost 2.24 $/GJ in 2020 and 1.47 $/GJ in 2030 at the farm gate in China. Swathing and baling dominate the overall costs at 43% and 38% respectively, both in the short term and long term. Raking and roadsiding contribute about 10% each.

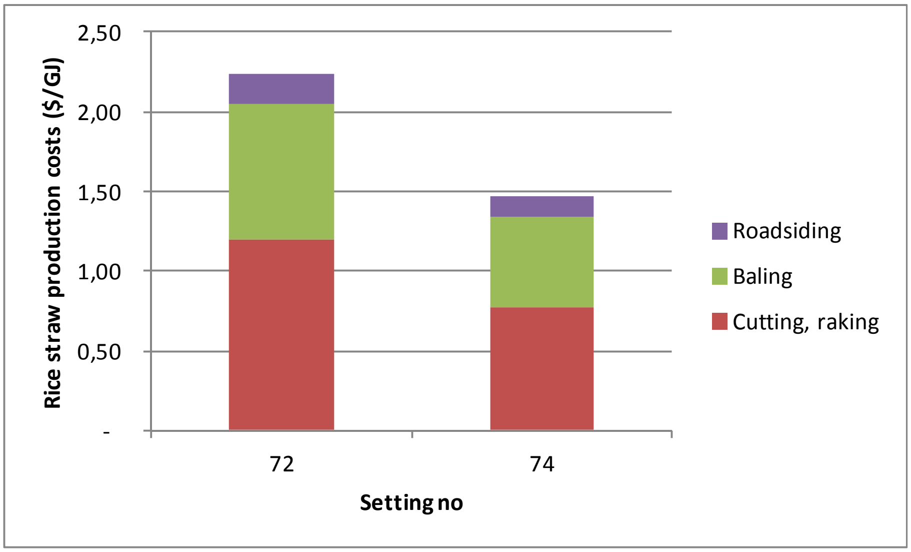

Figure 7-6 Rice straw production costs in China by component

7.2 Supply chain analysis

Biomass energy supply chains start with the feedstock production until final biomass fuel is delivered in the market as shown in Figure 7-7. The number of intermediate stages in a chain varies depending on the feedstock characteristics, pre-treatment requirements and infrastructure. Generally harvested biomass is collected at production sites and transported to a gathering point (GP) at a road or railway siding. Trucks provide first transport to the GP while second transport to a central gathering point (CGP) is by truck or train. At the CGP, biomass undergoes pre-treatment, e.g., sizing, drying, densification but also conversion to liquid fuels like bioethanol and synthetic fuels. The purpose of pre-treatment is to increase energy density, improve fuel homogeneity and reduce handling costs.

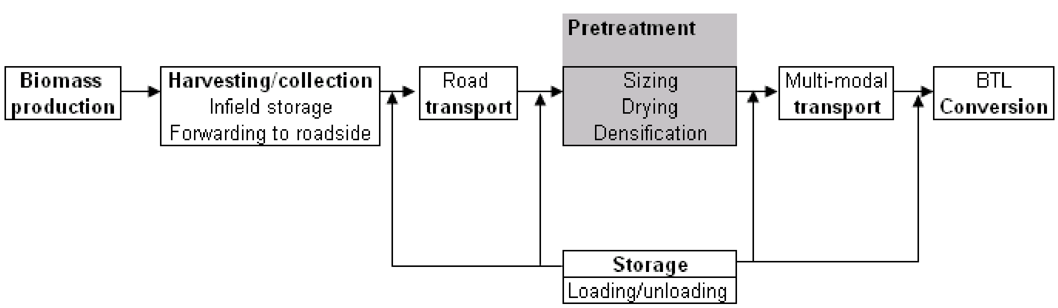

Figure 7-7 Outline of typical biomass energy supply chain logistic elements

7.2.1 Biomass pre-treatment options

Pretreatment of biomass is necessary to improve logistic efficiency. It includes sizing, drying and densification. The purpose of sizing is to meet subsequent step feedstock specifications and to improve handling. It has been noted that the moisture content of fresh biomass is about 50% and that drying is necessary to meet feedstock criteria at conversion plants: the gasification process, for instance requires feedstock with a moisture content of less than 8%. Biomass also needs to be densified to increase its energy density and to reduce logistical costs. Key technologies used for densification include baling, pelletising and torrefaction. Drying and sizing steps always precede densification, because of strict feedstock specifications.

7.2.2 Conversion

There are two main promising routes used to process biofuels from lignocellulosic feedstock: bio-chemical and thermo-chemical. In the bio-chemical route, enzymes and other micro-organisms are used to convert cellulose and hemicellulose components of the feedstocks to sugars prior to their fermentation to produce ethanol. The thermo-chemical pathway (so-called Biomass-to-Liquids (BtL) technology) employs gasification to produce a synthesis gas from which a wide range of long carbon chain biofuels, such as synthetic diesel or aviation fuel, can be derived.

7.2.3 Ethanol production from lignocellulosic biomass (next EtOH)

The production process of lignocellulosic biomass to ethanol consists of three stages, namely biomass pre-treatment, hydrolysis and fermentation. Chemical and physical pre-treatment breaks down cell structures and separates the lignin from cellulose and hemicellulose and thereby facilitates the hydrolysis (saccharification). Acid or enzymatic hydrolysis converts the cellulose and hemicellulose into fermentable monomeric and oligomeric sugars, with enzymatic hydrolysis using cellulases and hemicellulases being the preferred route. The lignin residue can be used for electricity generation. The sugars are fermented to ethanol, which is then purified and dehydrated.

7.2.4 Syngas based biofuels (BtL)

Synthetically derived liquid transport fuels are able to use almost any type of biomass, with little pre-treatment other than moisture control. Thermo-chemical conversion of biomass to biofuels generally involves higher temperatures and pressure than those needed for the biochemical route. It is based on either gasification or pyrolysis. Biomass feedstock is pre-treated to required specifications before being fed into a gasifier. The syngas produced is further cleaned by removing tars, particulates and gaseous contaminants before being fed to a Fischer Tropsch (FT) reactor where syngas interaction with catalysts results in the production of different types of fuels. The FT process is an established technology and is already applied on a large scale in order to produce liquid fuels from coal or natural gas.

7.2.5 Technology status

Next generation biofuels are not yet produced commercially, although a number of pilot and demonstration plants are underway mainly in North America, Europe and a few emerging countries. IEA Bioenergy Task 39 estimates that there are 66 pilot- and demonstration-sized projects being undertaken worldwide. About 50% of the facilities are operational, 25% is under construction or under commissioning, and the remaining 25% are planned projects. At the end of 2009, total annual production capacity in demonstration facilities (both routes) was around 60,000 tonnes of fuel, and if all planned projects are completed, the annual production capacity is estimated to be about 680,000 tonnes by 2012. Significant progress is being made in R&D and demonstration, and it is likely that commercial scale plants will be deployed over the next decade. However, a number of technological and cost barriers need to be overcome for the successful commercial deployment of next generation biofuel technologies.

7.2.6 Lignocellulosic biofuel production costs

Biofuel production costs include feedstock production costs (see section 7.1), pretreatment costs, transport costs, storage costs and conversion costs. The costs that are analysed here are very generic, in the sense that it is important to include spatial detail and biomass distribution detail to come up with more representative estimates. However, country specific information is also included, such as expected transport distances and truck transport limitations as well feedstock production costs. See Table 7-10. Technology cost estimates are also generic and represent state of the art knowledge in biomass pretreatment and conversion, which is expected to be applied in the respective countries in 2020 and 2030.

Table 7-10 Key assumptions for biomass transportation in selected countries

	Mozambique	**Brazil**	**Ukraine**	**Argentina/China**
Distance from farm to conversion plant (km)	100	200	50	120
Truck capacities (tons)	20	40	40	40

The next EtOH conversion technology route considered here involves use of physical and acid pretreatment followed by enzymatic saccharification of the remaining cellulose after which the resulting sugars undergo enzymatic fermentation to produce ethanol. A base capacity of 400 MWth input capacity is assumed at a load factor of 90% (see Table 7-11). Investment costs are expected to decline from 374 M$ in 2020 to 290 M$ in 2030 due to learning effects in conversion technology.

For BtL conversion, the technology route considered is a combination of circulating fluidised bed gasification and tubular fixed bed FT reactor. A base scale of 400 MWth is also assumed at a 90% load factor. Investment costs are expected to decline from 422 M$ in 2020 to 327 M$ in 2030 due to learning effects in conversion technology.

Table 7-11 Summary of biofuel conversion technology costs

Conversion factor	Next EtOH		Fischer Tropsch CFB	
	2020	2030	2020	2030
Base Scale (MWth LHV input)	400	400	400	400
Base Investment (M$)	374	290	327	327
Scale factor	0.7	0.7	0.78	0.78
Lifetime	25	25	25	25
Load factor	90%	90%	90%	90%
O&M (% of investment)	4%	4%	4%	4%
Efficiency fuel only (LHVwet)	40%	40%	45%	45%

7.2.7 Next generation ethanol production costs from eucalyptus

Figure 7-8 provides a comparison of next EtOH production costs from eucalyptus in Brazil and Mozambique. Conversion costs dominate overall costs, accounting for 48 to 53% of the production costs. The higher biomass feedstock production costs on marginal land are a major driver of costs in setting 57 (about 20% of overall costs in Mozambique less suitable land – 19.8 $/GJ) and setting 58 (Brazil less suitable land-19.4 $/GJ). EtOH is produced at marginally higher costs in Mozambique due to higher feedstock production costs and higher electricity charges. Future ethanol production costs are expected to fall in line with falling feedstock production costs and lower conversion costs (16.8 $/GJ in Mozambique and 16.2 $/GJ in Brazil). Truck transportation is also a significant factor in overall costs contributing up to 27%.

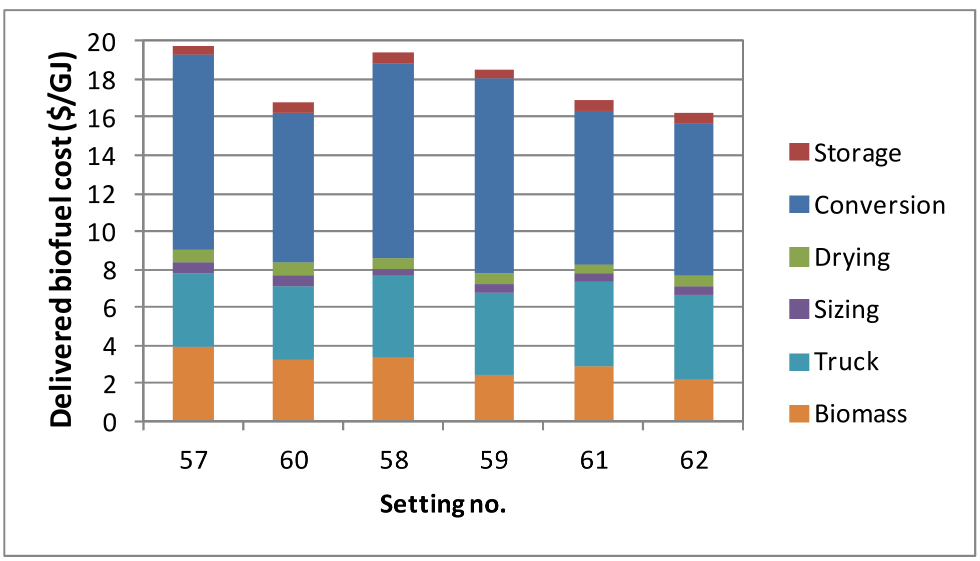

Figure 7-8 Eucalyptus to next EtOH production costs (Mozambique and Brazil)

7.2.8 BtL fuel production costs from poplar in Ukraine

BtL production in Ukraine is estimated to range from 13.9 to 17.8 $/GJ for the selected settings, with the latter representing production on more marginal land in the short term. There is a 16% difference in costs between the short term and long term, mainly attributed to learning effects in agricultural production and conversion technology. See Figure 7-9. Truck transport has a lower impact on overall costs (12-16%) due to the shorter distances assumed for Ukraine compared to other countries. Feedstock production costs and conversion costs are the main contributors to total costs, at 14-20% and 57-65% respectively.

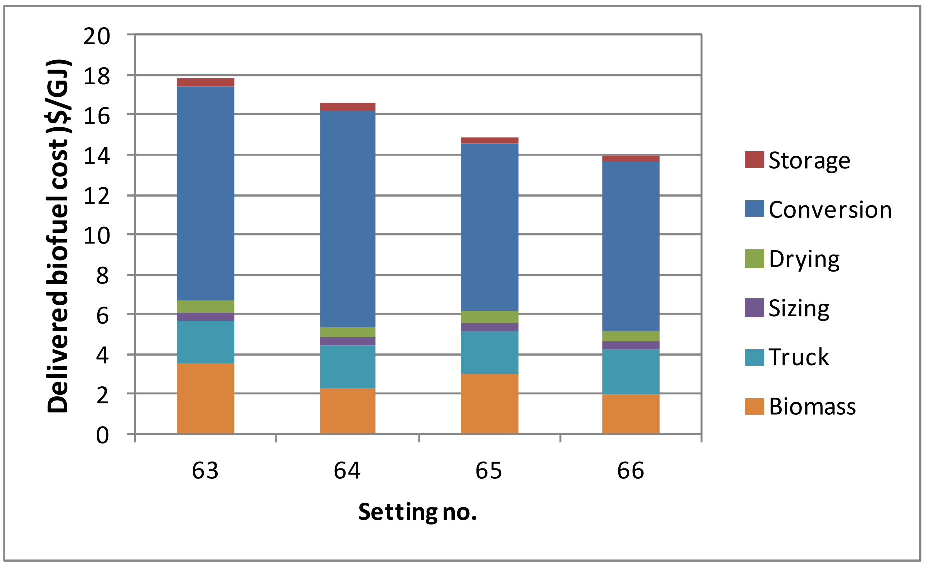

Figure 7-9 Poplar to synfuel production costs (Ukraine)

7.2.9 BtL and next ethanol fuel production costs from switchgrass in Argentina

A comparison of BtL and next ethanol production from switchgrass in Argentina shows that next ethanol production costs are marginally higher (18.5 – 21.0 $/GJ) compared to (18.3 – 20.8 $/GJ) for BtL. This is mainly attributed to the higher conversion efficiency for BtL, which offset the higher BtL investment costs. As shown in Figure 7-10, conversion costs are dominant in the overall costs (43-52%) while truck transport costs are also quite high at 23-29%. Storage of switchgrass bales and produced ethanol also contributes up to 10% of overall costs. Similarly, biomass production costs are also significant at 16%.

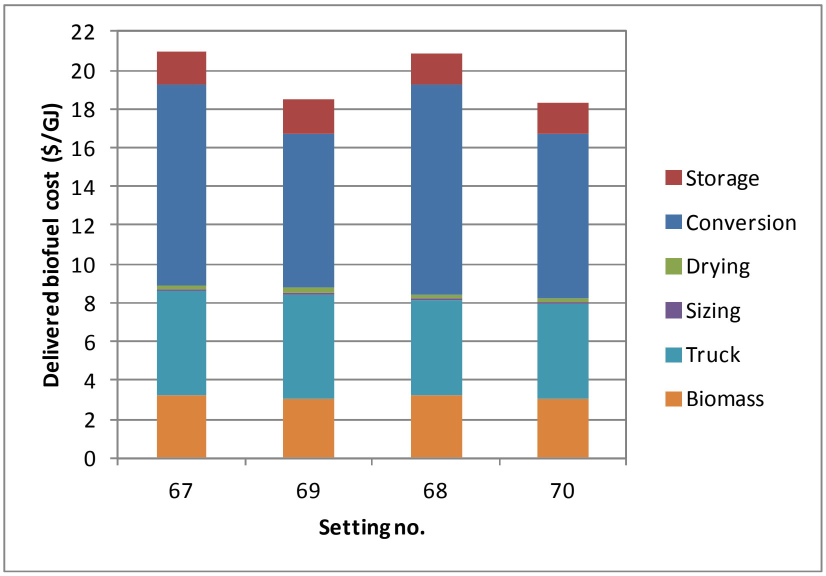

Figure 7-10 Switchgrass to next ethanol and synfuel production costs (Argentina)

7.2.10 Next generation ethanol fuel production costs from rice straw in China and wheat straw in Ukraine

Next generation bioethanol production from straw is estimated to cost between 20.1 and 26.1 $/GJ in China and Ukraine. Bioethanol production from wheat straw in Ukraine is cheaper at 20.1-23.4 $/GJ compared to that from rice straw in China (23.0 – 26.1 $/GJ). The differences between the two countries can be attributed to the large truck transport distances considered for China, which contribute 31-35% of the total costs compare to 20-23% for Ukraine. Contribution of conversion costs is comparable for the two countries at about 35-44%.

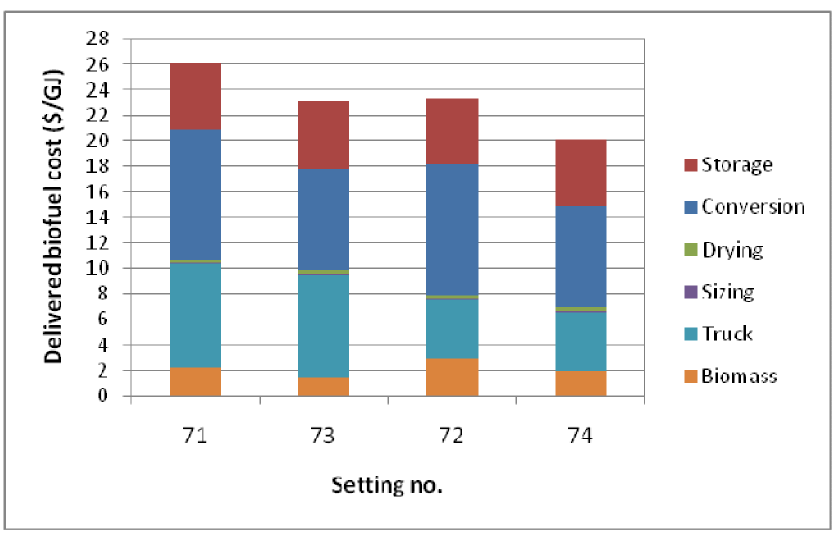

Figure 7-11 Straw to next ethanol production costs (China and Ukraine)

As shown in Figure 7-11, storage costs for straw bales and produced ethanol are also high, contributing between 20 to 26% of overall costs. Storage costs for other supply chains are very low, at about 2% of total costs. Feedstock (straw) costs are relatively low compared to other cost elements (and other supply chains) at about 6-26%.

Figure 7-12 summarises the biofuel production cost by country for both next ethanol and BtL pathways. The BtL route results in biofuel production costs of between 13.9 -20.8 $/GJ. Bioethanol production costs range between 16.2-26.1$/GJ.

Production costs are much lower in Ukraine, due to the lower input costs reflected especially through the use of cheaper organic manure instead of chemical fertilisers in the production of poplar. However, the cost of fuel produced from wheat straw is high due to the higher logistical costs such as storage and truck transportation. As shown in Figure 7-12 and Figure 7-13, biofuel production costs in China are relatively higher than other countries due to the long transportation distances of low energy density rice straw. Truck transportation contributes about 8 $/GJ to the overall fuel production costs in China. This demonstrates the need for reducing the energy density of agricultural residues by densification of straw early in the chain to reduce the logistical costs.

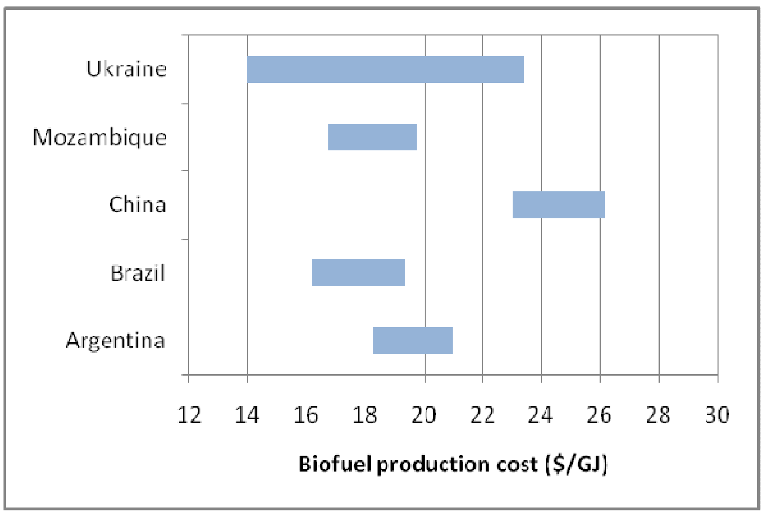

Figure 7-12 Biofuel production costs by country

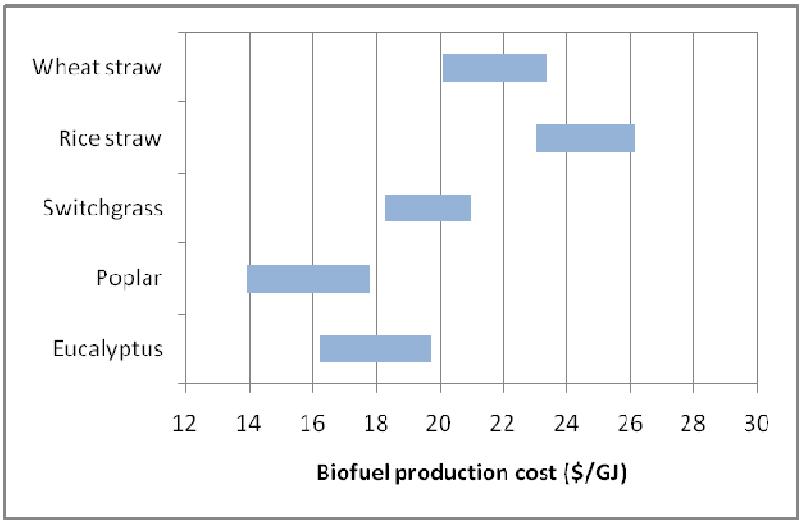

Figure 7-13 Biofuel production costs by feedstock type

Sensitivity analysis

Biofuel production costs depend on a number of factors as already shown by the differences among countries and feedstocks. For feedstock production, the feedstock productivity is important and developments in plant selection and breeding leading to experience/technological learning has a significant impact on future feedstock production costs. At the conversion stage, the capital investment cost and associated cost of capital are the key determinants of the biofuel production cost levels. It is expected that future capital investment costs will decrease with technological learning and scaling up of production facilities. A sensitivity analysis shown in Figure 7-14 was performed to assess the impact of technological learning, interest rates, conversion efficiency and feedstock production inputs.

Table 7-12 Selected variation in parameter used in sensitivity analysis

Parameter	Variation
Technological learning in conversion facilities (progress ratio)	0.88 - 0.98
Interest rate	4%-12%
Conversion efficiency improvements	- EtOH from 39% to 47% - BtL from 45% to 53%
Variation in feedstock production costs	Labour increase to 319% in 2030; land rent by 50%; fertiliser by 300%; agrochemicals by 121%

The sensitivity analysis shows large variations in fuel production from wheat straw (14.0-17.6 $/GJ) and rice straw (16.6-30.3 $/GJ). These supply chains are influenced by the future conversion efficiency improvements, which result in lower feedstock requirements and lead to corresponding decrease in logistical costs, especially long distance transport and long term storage of feedstock. All the supply chains are heavily influenced by conversion costs and the lower cost range reflects cheap cost of capital (i.e. 4%) and faster technological learning (progress ration of 0.88). Overall, biofuel production costs vary by 67% from 10.0 to 30.3 $/GJ. The production costs of next ethanol varies over a much wider range from 12.0-30.3 $/GJ, while BtL production costs range are marginally lower at 10.0-24.0 $/GJ.

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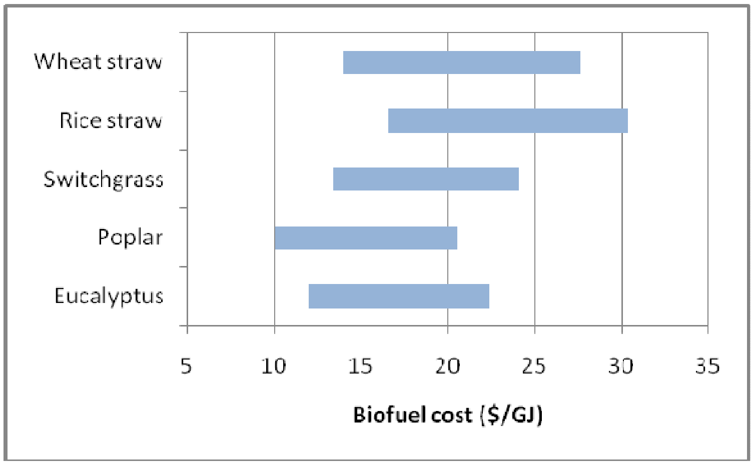

Figure 7-14 Range in biofuel costs by feedstock type

For comparison, recent state of the art analysis estimate that second generation production costs for bioethanol range from 13-30 US$/GJ, while BtL derived fuels are estimated to cost 16-30 US$/GJ. See Appendix E.

7.3 Potential development of second generation biofuels in developing countries

It is clear from recent investigations and this analysis that significant volumes of next generation biofuels can be produced at competitive costs in various developing countries. A key pre-requisite is that several technological hurdles be overcome and that a large, stable supply of lignocellulosic biomass be guaranteed. Other important pre-conditions for ensuring competitive biofuel production and supply include rationalisation of agricultural production in developing countries (which will be essential for realising significant feedstock volumes), as well as the availability of efficient logistics (which are needed to ensure competitive biomass supply).

Initial focus on feedstock production

Given the status of the technology and investment requirements to establish processing plants, it is unlikely that second generation biofuels production can be achieved in developing countries in the coming decade. However, developing countries can already develop a biofuel feedstock production industry, which could be the basis for a strong biofuel industry when the technology matures. Investment in feedstock production could offer an option for developing countries to profit from the growing biomass market for second-generation biofuel production outside their borders, provided that transport infrastructure is suitably developed.

Need for developing capacity, improvement in infrastructure

Profits could be invested in the rural sector to improve infrastructure and the overall economic situation, and at the same time to develop skills for feedstock cultivation and handling. However, there are still risks that small landholders' interests are ignored when large investments are undertaken by foreign companies and this concern needs to be carefully addressed through sound policy regulations. Furthermore, only certain feedstocks with high energy density (e.g. woody biomass), are suited for long-distance transportation. Poor infrastructure in many developing countries and little experience with biomass production and supply form significant barriers for feedstock trade and can prevent international trade in many cases.

Need for cooperative RD&D and technology transfer

As a next step, cooperation on R&D at a scientific level would be needed in many emerging and developing countries to build capacity for second-generation biofuel production. Besides exchange of knowledge and capacity building, technology access is ensured through cooperation, an important factor to implement a sound second-generation biofuel industry in the future. During the transition to second generation biofuel commercialisation in developing countries, cooperative RD& D could stimulate technology transfer and generate important experience. Skills development and adaptation of technology – especially the local fabrication of part of the facilities, training of personnel on requisite techniques for equipment operation and maintenance and the emergence of private sector participation are important prerequisites for commercialisation of second generation biofuel technologies.

Investment strategies

For developing economies, where project finance for the capital intensive industries is a major barrier to investment, it makes practical sense to develop the biofuels sector using the backbone of already existing industries. This goes a long way on reducing the overall investment costs of project. A typical example is found in first generation biofuels - the establishment of annexed ethanol distilleries on existing sugar mills. An autonomous distillery would costs significantly more as there is still need to invest in sugar processing plant. Similar piggybacking relationship with for example the coal or oil sector could result in valuable synergies that can bring costs to competitive levels in the medium term.

7.4 Summary: Evaluation of potential future (next generation) types of biofuels

Next generation biofuels can be produced in developing countries at costs that range from 10 to 30 $/GJ for next ethanol and synfuel derived fuels. Feedstocks considered in this study include eucalyptus, poplar, switchgrass wheat straw and rice straw. Key to the competitive production of next generation fuels is the optimisation of the conversion process, which dominates overall production costs (conversion costs range from 35-65% of total supply chain costs). Also important is the efficient organisation of supply chain logistics, especially for the low energy density feedstocks such as wheat straw – the handling, storage and transportation of bulky agricultural residues requires densification of the feedstock early in the chain to reduce subsequent step costs. For wheat and rice straw, storage costs account for up to 20% while their truck transportation accounts for up to 35% of the total supply chain costs. Feedstock production costs are also important – for the selected energy crops, feedstock costs account for 20% of total costs for eucalyptus and poplar, and 16% for switchgrass.

The estimated biomass feedstock production from eucalyptus in Mozambique is 3.96 $/GJ in 2020 and 3.27 $/GJ in 2030 at the farm gate. For eucalyptus in Brazil, the estimated biomass feedstock production on marginal soils is 3.3 $/GJ in 2020 and 2.9 $/GJ in 2030 at the farm gate. For the more suitable land quality, eucalyptus production is estimated to be about 2.44 $/GJ in 2020, decreasing to 2.22 $/GJ in 2030. In Ukraine, poplar production costs are estimated to be 3.5 $/GJ on marginal soils in 2020, decreasing to about 3 $/GJ in 2030. On good quality land, poplar can be produced at a cost of 2.26 $/GJ in 2020 and at 2.02 $/GJ in 2030. Switchgrass production costs in Argentina are estimated to be 3.22 $/GJ in 2020 and 2.97 $/GJ by 2030, in all cases on marginal land. The production cost of wheat straw in Ukraine is estimated to be 2.88 $/GJ in 2020 and 1.89 $/GJ in 2030. In China rice straw is estimated to cost 2.24 $/GJ in 2020 and 1.47 $/GJ in 2030 at the farm gate. It is important to note that these costs are estimated based on current market prices and the projected technological and socio-economic dynamics in the respective countries.

Given the status of the technology and investment requirements to establish processing plants, it is unlikely that second generation biofuels production can be achieved in developing countries in the coming decade. However, developing countries can already develop a biofuel feedstock production industry, which could be the basis for a strong biofuel industry when the technology matures. Investment in feedstock production could offer an option for developing countries to profit from the growing biomass market for second-generation biofuel production outside their borders, provided that transport infrastructure is suitably developed and key socio-economic and environmental sustainability frameworks are institutionalised. As a next step, cooperation on R&D at a scientific level, skills development and adaptation of technology would be needed in developing countries to build capacity for second-generation biofuel production. Similarly, investment strategies need to be developed and piggybacking on existing industries could be one route to overcoming the project finance barriers.

8 Fuel and vehicle compatibility

8.1 Introduction

Many countries have created or are in the process of creating national biofuel targets or blending mandates as part of their strategy to de-carbonize the transport sector and decrease oil dependency. Identifying the 'right' biofuel blending mandate or target in a given country context depends on a range of factors including: sustainability concerns (such as biodiversity loss, water competition, food security and GHG balances) biofuel feedstock availability, cost competitiveness, and infrastructure and vehicle fleet composition. Although finding clarity within sustainability concerns is one of the most critical steps in the national planning process, there is also a great importance when it comes to how to implement a blending policy with regard to compatibility with fuel infrastructure and vehicles. If these compatibility implementation challenges are not analysed during the national planning process, the potential impacts of these mandates can be detrimental and lead to unnecessary spending from the consumer, private sector and government. Recognising this importance, this report will address key compatibility barriers for developing countries that are hoping to achieve blending mandates or targets in the present or in the medium-term. The key issues identified will be then used to formulate recommendations for decision-makers in regards to the sustainable development of biofuel mandates and blending targets.

The purpose of this section is to highlight the challenges related to fuel/vehicle compatibility in an effort to provide recommendations for decision-makers in regards to the sustainable development of biofuel mandates and blending targets. This chapter contains not only a look at compatibility issues related to fleets, but also at external constraints and "bottlenecks" that should be taken into consideration in a national planning process to define targets such as: infrastructure requirements of different blends, supply demands, and effective policy measures. Through defining these barriers, developing country governments can better understand how to effectively resolve certain challenges and how to identify what an appropriate blend level is for their current light-duty passenger vehicle fleet.[36]

For policy purposes, the definitions are as follows:

Biofuels: fuel produced directly or indirectly from biomass such as fuel wood; plants; grains; charcoal; bioethanol; biodiesel; biogas (methane); or biohydrogen (UN-Energy, 2010).

Biofuel blend mandate: a regulation that defines the proportion of biofuel that must be used in (road-) transport fuel (at the point of distribution) (IEA, 2011).

Biofuel blend target: a graduated future target for the level of biofuel that is blended at the point of distribution or the total volume of biofuels produced.

Blend wall: a term to define the point where there is a limitation on increasing a biofuel blend to a higher blend level. This term can be used to explain compatibility limitations due to both physical compatibility and supply constraints.

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36 Although it is important to analyze the total fleet compatibility, including heavy-duty vehicles, light-duty vehicle, light-duty truck, etc. this paper will concentrate solely on light-duty passenger vehicles.

8.2 Key questions and concerns for decision makers

For developing countries that are considering putting in place national blending mandates for biofuels, a critical look at the capability of the current and future fleet to utilise certain fuel blends is important to the sustainability of the sector. For countries that have already instituted a blending mandate, increasing further the biofuel ratio in the fuel blends and/or target to utilise a higher volume of biofuels in the transport sector might be a policy consideration. In these cases, the issues related to compatibility are still important to analyse. A list of questions decision-makers should address before considering the establishment of a blending mandate and/or altering an existing one can be found in Table 8-1.

Table 8-1 Key questions and concerns for decision makers

Fuel/ Vehicle Compatibility Questions for Developing Countries	
No existing blending mandate	**Existing blending mandate**
Specific compatibility related questions: • What is the make-up of the current vehicle fleet? • What are the compatibility concerns for the existing fleet? What blend levels in mass market fuels (both for bioethanol and biodiesel) can the current fleet utilise? • What refining, blending, storage and distribution infrastructures are necessary for different blends and fuels? What infrastructure already exists? • Does the biofuel introduction require a mass market fuel or a dedicated fleet? Beyond compatibility: • What are the supply constraints of the market regarding both domestic production and imports of biofuels? • What is the cumulative economic cost of introducing the blending mandate? • What policies can support the blending mandate? What vehicle emission regulations/current standards are currently in place? • What is the current consumer confidence in biofuels?	Specific compatibility related questions: • What is the future fleet projection (passenger cars/ heavy duty)? Will the future fleet be compatible with a higher blend? What will be the future of vehicle emission regulations/ other policies? • Is the existing infrastructure compatible with a higher biofuels blend? If not, what physical changes need to be made? Beyond compatibility: • What is the current sustainable supply of biofuels that is consumed? What is the additional volume that can be produced and utilised by the transport sector? • What are the economic costs of increasing a blending mandate? • What policies can support this transition? • What is the current consumer awareness about compatibility with their own vehicles?

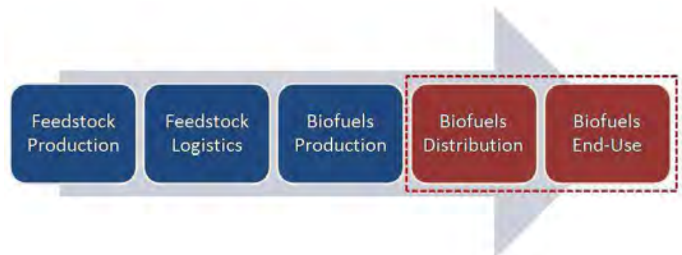
The key questions show that in order to find a suitable biofuel blending mandate/target that can be implemented successfully certain considerations need to be made. At the outset, there should be an inventory conducted of the current fleet make-up to help inform decision making. This is because certain vehicles may be able to adopt higher blends more than others. For example, if a country's current fleet is comprised of older vehicles (sometimes referred to as "legacy vehicles") that may present a bottleneck as those vehicles are not adapted to higher blends. A key question is: Will the existing fleet be able to utilise the blend of biofuel without affecting the durability and performance of the fleet? Questions related to the capacity and compatibility of existing infrastructure are also key.

For instance, decision makers must ask: is the current infrastructure compatible with the mandate or target?

Even though compatibility considerations might be a narrow issue, there are still questions to consider in the planning process beyond just physical compatibility itself. Some issues that might affect the successful implementation of a blending mandate might be for example: having supply constraints, having the mandate as an economic burden for the consumer or retailer, or introducing supporting policies that are ineffectual.

8.3 Supply chain compatibility

As evident from the key questions, decision makers should assess compatibility not only in the vehicles/ fleets themselves (end-use), but also along the supply chain, beginning at the point of distribution (see Figure 8-1).



Source: Adapted from U.S. Department of Energy, Energy Efficiency and Renewable Energy Program 2011.

Figure 8-1 Biofuel compatibility along the supply chain

At the *biofuels distribution point*, physical compatibility with distribution materials might begin to become a problem. Materials used in equipment such as storage tanks, piping, trucks and distribution/dispensing materials might be affected or damaged if they are in contact with blend levels that are too high. These materials should all be equipped and warranted by manufacturers for those blend levels.

At the *end-use* the compatibility concerns are heightened as there are many challenges that might emerge from utilising biofuel blends in vehicles/fleets that are not compatible. Problems can occur that affect vehicle durability and operability if proper fuel blends are not used. *Vehicle compatibility*, in the context of this report, refers to the adaptability of a vehicle to utilise and combust biofuel blends while maintaining long-term durability and operability as warranted by the vehicle manufacturer. The factors in vehicle compatibility are depicted in Figure 8-2. (Department of Sustainability, Environment, Water, Population and Communities, Government of Australia, 2011).

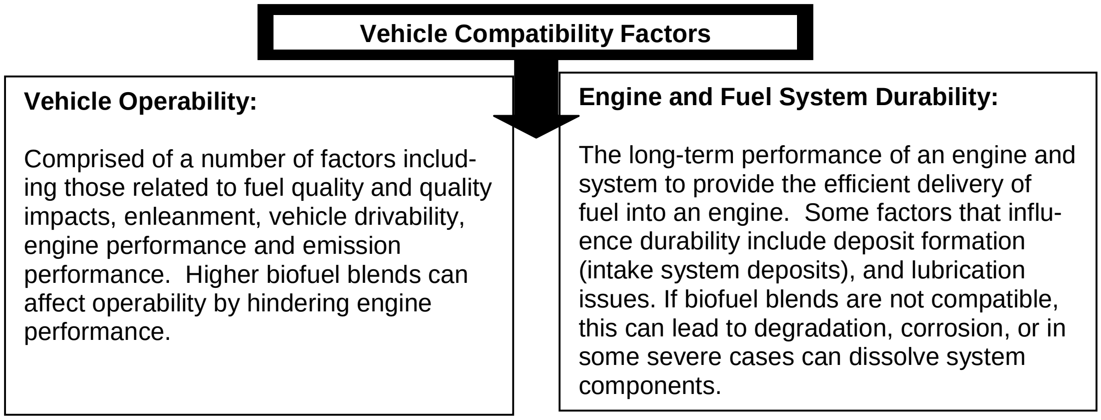
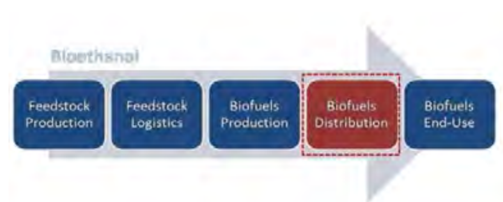


Figure 8-2 Vehicle compatibility factors

8.4 Compatibility challenges with bioethanol

In considering the appropriate blend level of bioethanol for a particular fleet, certain compatibility barriers have to be taken into consideration. If a country is developing a biofuel mandate for the first time, there must be an assessment of the current fleet and infrastructure before a mandate and/or target is set. Additionally, current infrastructure compatibility needs to be considered if a country is increasing a bioethanol blend level. The following will be a discussion of the main compatibility concerns associated with bioethanol blends at various levels.

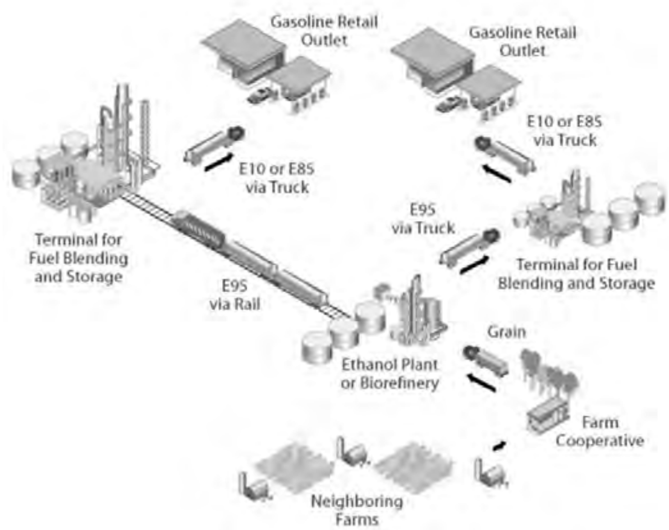
8.4.1 Bioethanol – compatibility challenges in distribution



There are unique challenges that are specific to developing efficient infrastructure and distribution systems for bioethanol, whether bioethanol blends are low level blends (E5-10), intermediate/medium (E15-E20), or higher blends (E20 – E100) (US Department of Energy, 2011). Infrastructure needs for various bioethanol blend levels will vary according to the blend level. A schematic graphic of two types of bioethanol distribution system can be found in Figure 8-3.

Both distribution systems of bioethanol, (1) through dedicated pipelines and (2) through the use of trucks and road, have their own challenges with regard to compatibility. Because bioethanol has solvent and corrosive properties, dedicated pipelines and equipment in trucks have to be properly equipped with materials that are warranted to withstand certain percentages of bioethanol. In developed biofuel markets, lower blends, such as E5-10, pose little compatibility challenges in distribution. However, for blends higher than E10, issues related to corrosion and wear start to become a problem. In developing countries, or countries without a current biofuel industry, E5 is assumed to be the blend wall (Rimmer, 2011).

As bioethanol blends increase, there have been concerns regarding the compatibility of older storage tanks (that were originally made to support lower blends such as E5-10) to support higher blends of bioethanol. Although there is not a lot of substantial research in this area, there is evidence to assume that higher blends of bioethanol will damage incompatible tank systems. More corrosive than lower blends, these higher blends can not only damage tank systems, but can cause bioethanol to leak into the groundwater. This can pose numerous health and environmental risks. In the case of the United States, storage systems for bioethanol are able to store an E10 mixture, and government authorities now warn that this might not be compatible with E15 or higher; thus, distributors would have to retrofit existing systems to ensure public health and the environment are not harmed (Government Accountability Office, 2009).



Source: US Department of Agriculture, 2007

Figure 8-3 Schematic distribution of bioethanol

One response to these challenges is retrofitting existing distribution systems to be compatible with the level of bioethanol used. This could be an option if a country decides to increase its bioethanol target or mandate. However, in some cases, the economic burden on retailers may be significant. For instance, retrofitting retail stations to distribute higher blends (E10 +) costs somewhere between 100,000 to 200,000 USD per station (Rimmer, 2011). In addition when moving to higher bioethanol blending, fuel infrastructures must sell in parallel two petrol grades: a protection grade for non-compatible fleet and the new grade (Lahaussois, 2011).

Policy Options for Compatible Bioethanol Distribution Systems

Some countries have demonstrated that there can be a policy response if retrofitting distribution systems is necessary. Policies can enable the conditions for higher bioethanol blends to be distributed and lower the costs on retailers (see box below). However, some of these policies then come at a financial cost to the government, or relayed back to the consumer (Hart Energy, 2012). A full assessment should be done to find the most appropriate solution.

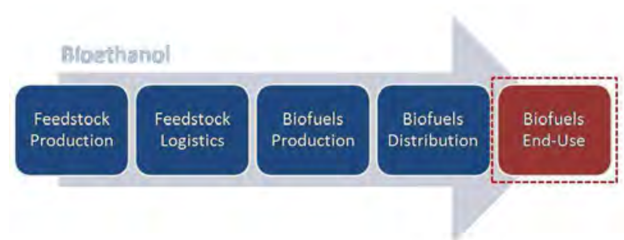
Policies needed to facilitate the necessary transformation of fuel infrastructure changes: State centered policy incentives for upgrading to E85 – Illinois, USA

Enacted in 2005, the 'Governor's Opportunity Returns' is a fund that was set up to help stations cover the costs of installing E85 pumps. The fund operates by setting aside $500,000 in matching grants to help gas stations buy the equipment they need to sell E85. The effort provides an incentive to create new E85 fueling sites throughout the state. As part of this initiative, the Illinois Department of Commerce and Economic Opportunity (DCEO) E85 program provides up to 50% of the total cost of converting an existing facility to E85 operation or constructing a new fueling facility. Grants are available to qualifying individuals or companies operating retail gasoline stations, with grants up to $2,000 for converting a site and up to $40,000 for building a new facility.

Source: National Renewable Energy Laboratory, 2007.

For developing countries that are initiating a bioethanol mandate, there are still peripheral concerns to consider with regard to compatibility of distribution systems. The availability and reliability of basic infrastructure such as roads and rail systems is one of these considerations. Without this basic infrastructure biofuel markets will not be sustainable or be able to reach end-users.

8.4.2 Bioethanol – compatibility challenges in vehicles



An extensive literature review suggests that low levels of bioethanol blends (i.e. under E10), have little impact on vehicle compatibility in most light-duty passenger vehicles as levels of ethanol are too low to cause significant impacts (Ministry of Transport NZ, 2006). However, when introducing mid-level blends (i.e. E15-E20), compatibility issues have been documented with problems occurring particularly in older vehicles (and legacy vehicles). Often these vehicles have no manufacturer's warranty to assure compatibility and long-term performance with higher biofuel blending. Higher blends (E20-E100) require dedicated vehicle technology and can only be used in certified flex-fuel-vehicles (FFV).

Compatibility Challenges with Mid-level to High-level Bioethanol Blends

For currently available bioethanol blends that range from E15- E100, the compatibility issues that need to be addressed to ensure that vehicles maintain their full performance are variable. It is worth noting that these compatibility challenges are most often related to anhydrous bioethanol, which is the most common mixture of bioethanol found in the market. Anhydrous bioethanol (ethanol) has a concentration of between 93-96% ethanol to water and is distilled through a dehydration step. In contrast hydrous ethanol has a purity of at least 99% and can be produced through simple distillation processes. At the time of writing there are few available studies that test the performance of hydrous ethanol and compare it to anhydrous (Brewster et al., 2007).

There is evidence that suggests that mid-level blending levels can affect fuel system durability if not warranted by the vehicle manufacturer. Some of these impacts include the increased presence of fuel system deposits in non-compatible engines, which can ultimately cause fuel blockages in the system. For engines that were equipped with carburettor engines and steel fuel tanks, using mid to high level bioethanol blends might impact the fuel system by disrupting the air/fuel ratio; this can be the case for most vehicle engines that are made before 1986, which can represent a substantial share of the existing fleet in many developing countries. Seals may also be affected. Corrosion of both fuel tanks and fuel lines from bioethanol can be seen, and this system disruption can ultimately block the delivery of efficient fuel supply. The presence of water that is found in bioethanol can also make an engine run ineffectively (Consumer News, 2010).

Mid to high-level bioethanol blending levels have been shown to also affect the vapour pressure (V/L) in automobile engines. As a result incompatible vehicles might run the risk of forming a vapour lock, causing engines to stall and preventing the fuel from moving efficiently to the engine (Grabner Instruments, 2010). Studies have shown that as the ethanol content in bioethanol increases to 7%, vapour pressure increases. This is a critical point, as most developing countries begin their bioethanol programs with lower ethanol blends, and then progressively move to higher blends. Upwards of 7%, the vapour pressure decreases, with the most dramatic decrease occurring in mid-level bioethanol blends from around E70-E100 (see Figure 8-4).

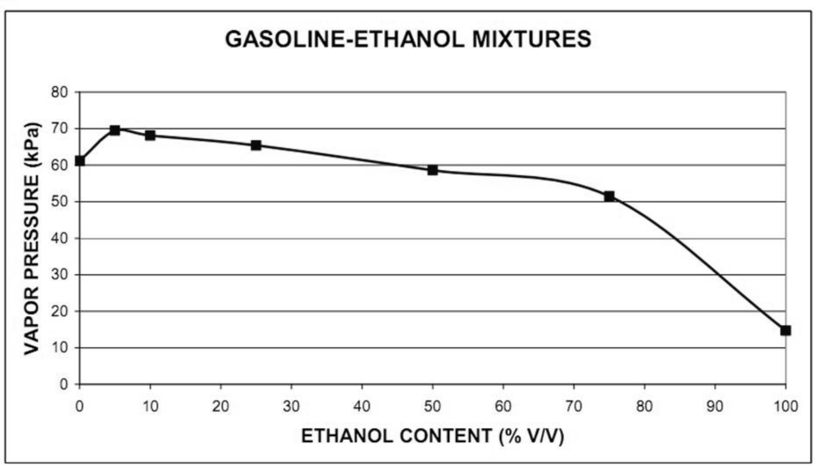


Figure 8-4 Vapour pressure in various levels of bioethanol (source: Ford Motor Company, 2007)

Another impact of mid to high-level bioethanol blends is the susceptibility for phase separation or partial phase separation. Phase separation occurs when water molecules separate from hydrocarbons in gasoline, and most likely it is a result of lower temperatures or quality standards. This can cause the bioethanol/water mixture to reside below the gasoline at the bottom of the vehicle fuel tank, causing a vehicle to potentially break down. A summary of the risks and issues that are related to compatibility of engines and mid to high blend bioethanol can be found in Table 8-2 (Sah, 2007).

Table 8-2 Properties of bioethanol and associated implications

	Properties of Bioethanol and Associated Implications
Hydrogen Bonding/Vapour Pressure	This property means that pure ethanol has a very low vapour pressure compared to gasoline. But it also means the vapour pressure of a mixture can be higher than the gasoline alone. Where the peak vapour pressure occurs depends on the base gasoline vapour pressure and ethanol concentration. Vapour pressure directly affects the evaporation rate and potential hydrocarbon emissions.
Hydrogen Bonding/Water Attraction	Easy hydrogen bonding makes ethanol attract water. The presence of water, in turn, increases the risk that certain metals will corrode. This becomes a problem when fuel remains in storage (including vehicle fuel tanks) and handling systems for a long time.
Oxygen Atom	Ethanol mixed with gasoline makes the air-to-fuel ratio leaner than with gasoline alone. Controlling the air-to-fuel ratio is critical to the combustion process and engine performance. Performance problems include hesitation, stumbling, vapour lock, and other impacts on driveability. Pre-ignition also can occur, causing engine knock and potential damage.
Oxygen Atom	Manufacturers calibrate the oxygen sensors (generally used in modern vehicle technologies but not in off-road equipment) to recognise specific levels of oxygen in the exhaust stream. If a mixture is outside the calibration range, the sensor will send inaccurate signals to the air-to-fuel feedback and on-board diagnostic systems. This could cause improper air-to-fuel ratios as well as an increased risk of causing one of the dashboard's warning lights (MIL) to illuminate.
Higher Combustion Temperature	Excessive combustion temperatures can cause engine damage.
Higher Latent Heat of Vaporization	This can delay catalyst "light-off," which is period of time before the catalyst warms up and can increase exhaust emissions of HC, CO, and NOx.
Higher Electrical Conductivity	This property increases galvanic corrosion of metals.
Permeability	Ethanol readily permeates at significant rates through elastomers, plastics, and other materials used widely for hoses, o-rings, and other fuel system parts.
Solvency	Under certain conditions, the presence of ethanol can cause certain additives to precipitate out of solution, leaving the engine unprotected from gummy deposits. Deposits can increase emissions, lower fuel economy and increase driveability problems.

Blends E20 and higher do not comprise much of the global bioethanol market. These fuels though, can be safely combusted in dedicated fleets called Flex-Fuel Vehicles (FFVs). Any conventional vehicle will be unable to run on these fuels. FFVs vehicles are equipped to utilise bioethanol blends that range from E0-E100 as they contain specific engine control modules that identify what percent blend is being utilised, and adjust the vehicle system automatically to that blend (US Environmental Protection Agency, 2011). It should be noted that FFVs vary from country to country in terms of their compatibility. In the United States, for example, FFVs are compatible with E0-E85. In Brazil, however, the case is different as dedicated FFVs are able to run on 100% hydrous ethanol as well (i.e. FFVs are compatible with E0-E100) (Hart Energy, 2012).

Policy Options for Bioethanol Compatible Vehicles

As discussed, not all light-duty passenger vehicles are compatible with medium or high level bioethanol blends. Often times, older vehicles and/or legacy vehicles will experience long term durability and operability impacts and must also continue to have access to a protection grade. This protection grade is a fuel that must be on the market (at fuelling stations) in parallel to new blending levels to allow non-compatible fleets access to the old fuel (Lahaussois, 2012). If these older vehicles constitute a majority of a country's fleet this can pose a problem in the sustainability of a bioethanol mandate. This is often the case in developing countries (with the exception of Brazil) where a large percent of the vehicle fleet is comprised of older vehicles.

There are policy options, however, that can influence the renewal of the national fleet so that more vehicles on the road are newer, and might be more compatible with the blend level that is chosen. On the supply side, import regulations should be made consistent and harmonise with the blend mandate. For example, Algeria has an import regulation on vehicles that states that second-hand vehicles must be less than three years old. This is the case for Tunisia as well (UNEP, 2009).

Harmonising policies is an important part of ensuring that a mandate will be successful and sustainable. Apart from the import regulation example given, some economies such as Brazil have illustrated that coordinated policies can also introduce compatible FFV vehicles onto the market through tax incentives (see box below).

Market Support to Encourage Uptake of FFV, an Example from Brazil:

Brazil has a progressive biofuels for transport policy and is the second largest producer of bioethanol in the world. In 2001, after seeing the opportunity to further bolster the bioethanol market, make future fleet compatible with higher blends and respond to shifting ethanol supply, Brazil introduced a preferential tax treatment for the sales of flex-fuel vehicles. Each flex-fuel vehicle would be sold with a 14% sales tax, as compared to a 16% sales tax on non-bioethanol vehicles. This and decisive support from the OEMs has led to a substantial growth of FFVs in the country. In terms of passenger vehicles, fleet estimate models predict that in Brazil the proportion of gasoline (only) vehicles and bioethanol (only) vehicles will decrease in the medium-term. The fleet changes will really occur in a significant increase in flex-fuel vehicles which will represent 78.2% of the total feet by 2020 (table below).

Fleet by Fuel (% Total Fleet) in 2009 and 2020

	Gasoline	Flex-Fuel	Diesel	Bioethanol	Automotive Natural Gas (NGV)
2009	49.8	35.1	4.5	5.3	5.3
2020	14.6	78.2	4.5	0.4	2.4

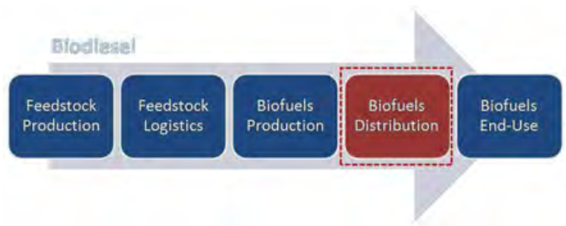
This growth of these vehicles provides some lessons on the ability of the auto industry to adapt and scale-up production on FFVs and the consumer willingness to accept a somewhat "new" technology.

Source: Losekann, 2010.

8.5 Compatibility challenges with biodiesel

Although globally biodiesel production is small relative to bioethanol feedstock production, biodiesel production (Fatty-Acid Methyl Ester (FAME)) is still expected to be an important energy crop in developing countries. For countries that are creating mandates for biodiesel, similar compatibility challenges found in bioethanol exist. These are both related to distribution compatibility and vehicle compatibility.

8.5.1 Biodiesel – compatibility challenges in distribution

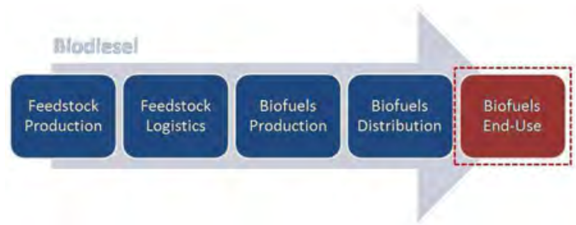


Biodiesel blending (FAME) can be done in one of three ways, depending on the type of feedstock and location of physical infrastructure: (1) splash blended at the end use stage in a storage tank (2) blended by a distribution company and sold as a final blend product, or (3) blended at the petroleum terminal. (The last method is the recommended one as it presents the most assurance to customers that the blending is complete.) Depending on the method of blending and different infrastructure needs, infrastructure adjustments will need to be made to make systems compatible (National Renewable Energy Laboratory, 2009).

A literature review suggests that there is a need for additional research concerning the long term storage compatibility of different biodiesel blend levels in storage systems. Unlike bioethanol, research on the compatibility of distribution systems for biodiesel blends is nominal. At all levels however, there is some evidence that precautions need to be taken to ensure that storage materials during the distribution phase are compatible. For example, a mitigation step that has been illustrated is that at all blend levels, the addition of a synthetic oxidant, along with consistent monitoring of biodiesel in storage and tanks should occur to ensure that oxidation stability levels are kept at optimal levels. This is an issue related to fuel quality. If not it could have corrosive effects and also create conditions for microorganisms, which might end up affecting fuel quality and eventually fuel system durability (National Renewable Energy Laboratory, 2009).

Compatibility at petroleum terminals and facilities will be a big challenge for the long term sustainability of biodiesel. Evaluations of the terminals are important for independent retailers to conduct, and regulations and certain certification might have to be approved to maintain quality standards. Some equipment might have to go through retrofitting, depending on the level of biodiesel that is being distributed at the pump (the higher the blend level, the greater compatibility issues will be present at the terminal). Some equipment use components include seals, hoses, tanks and piping that are in terminal facilities. In order to retrofit these materials they might have to be made from compatible materials such as: stainless steel, aluminium, fluorinated polyethylene, fluorinated polypropylene, teflon, and fibreglass (Bulktransporter Magazine, 2007).

8.5.2 Biodiesel – compatibility challenges in vehicles



Low Level Biodiesel Blends and Compatibility in Vehicles

Biodiesel blends, most commonly blended with petroleum diesel, pose less material compatibility issues than bioethanol blends. However, this is very contingent to the quality of FAME used. For instance, heavily oxidized FAME can have very detrimental impacts on diesel engines. Biodiesel blends should meet prescribed quality standards, set by national regulation, before going to the end-user (Lahaussois, 2012).

For light-duty passenger vehicles, low level blend levels are considered to fall within the range of B5-B7. Fuel and injection system manufacturers have previously made statements that in the United States, B5 is recognized as being the maximum blend level; in the European Union (EU) it is B7. Both of these levels are compliant with an ASTM and EN 590 standard for the US and EU respectively. In this case, B5 could be considered a safe blend level for a low FAME blend in a mass market fuel. If the blend level is higher (greater than B5) there might be a need for a protection grade at the pump for non-compatible vehicles (Lahaussois, 2012).

Mid-High Level Biodiesel Blends and Vehicle Compatibility

Passenger vehicles that utilise blends of B7 and higher have been shown to experience technical compatibility problems in durability tests performed by private auto manufacturers. These field tests reveal the possible dangers higher blends have on unmodified engines. For FAME blends that are used in captive fleets with dedicated engines (e.g. B30), there are specific maintenance and operational instructions to ensure performance. A list of common operational risks from the utilisation of high blend biodiesel in non-modified vehicles is summarised in Table 8-3.

Table 8-3 Vehicle compatibility risks with high level biodiesel blends

Operational Equipment	Risk
Fuel filters	Clogging caused by contaminants, sterile glycosides, microbes or under cold climate conditions (*not only restricted to high blends)
Fuel system parts – high pressure pump, injector	Sticking and corrosion after certain standstill periods
Injector	Nozzle coking and deposits of fuel that is accelerated through by-products of biodiesel
Piston rings and exhaust gas recirculation systems	Deposit formation
Engine (general)	Increase of engine oil dilution under low load operation, sludge formulation of engine oil

Source: Diesel Technology Forum, 2011

The most common problem seen in engines is that biodiesel blends might “clean out” vehicle fuel tanks and fuel systems. As diesel sometimes forms sediments that accumulate in engine storage systems, biodiesel blends have been shown to have properties that dissolve these sediments. Components such as seals, gaskets, adhesives, and parts made from natural or nitrile rubber can be affected. In that case, these engines would have to go through modification/retrofitting in order to sustainably utilise higher levels of biodiesel without causing engine problems (Schmidt, 2004). Degradation of FAME could also impact the operability or driveability of diesel vehicles.

Cold flow properties in biodiesel blends are one of the concerns that are commonly raised in the context of biodiesel /vehicle compatibility. In colder climates, there is a risk that biodiesel can freeze or gel in engines. As well fuel filter plugging could occur in low temperatures due to the specific cold flow properties of the FAME used that is typically related to feedstock used. For higher blends and climates that are above the freeze point, biodiesel can still be utilised, although additional blending infrastructure might be necessary, such as adding low-temperature flow additives (NREL, 2009).

Retrofitting for Biodiesel Blend Compatibility

For many developing countries, compatibility issues will become a considerable economic challenge if proper strategy is not put in place. Biodiesel vehicles that are not compatible with the mandated blend level might experience shorter operability lifetimes and pose an economic burden on households that operate an older vehicle. Retrofitting may be an option to maintain the performance of the vehicle. However, the costs of the retrofit might be substantial relative to household income or the cost of the vehicle itself. Additionally, retrofitting vehicles to be compatible with higher blends might not be possible in developing countries where some parts are unavailable. Thus, the option of retrofitting vehicles is not considered feasible in developing countries. Other policies that continually push the fleet make up to be more compatible, such as scrappage programs, where a car owner would receive a monetary incentive to turn in his/her old vehicle is one way of approaching the problem apart from retrofitting. Another can be to offer a protection grade for non-compatible vehicles until fleet renewal is compatible with the new FAME blending.

8.6 Beyond vehicle/fuel compatibility: other challenges that affect the implementation of mandates

Other issues besides vehicle/fuel compatibility influence the successful implementation of a national biofuel blending mandate. Many of these issues can be seen as external constraints and if considered before the development of mandates and targets, might prevent future economic losses. As previously discussed in the introduction, decision makers should consider these questions alongside compatibility questions. These considerations should aid in the development of appropriate mandates. These peripheral issues include (but are not limited to): the availability of sustainably sourced and produced biofuels, fuel quality, consumer awareness and use and industry engagement.

Availability of sustainably produced biofuel

The available supply of biofuels for transport should be determined from first conducting an assessment of domestic energy needs in the sector and available sustainable resources. These potentials, as well as the economic costs of importing biofuels, should be considered when determining the appropriate volume of biofuels that are feasible to enter the market and should guide the formulation of biofuel blending mandates. All of the assessments of potentials should take into account sustainable principles and criteria. A systematic process for conducting these assessments is advised using national planning tools such as the UN-Energy Bioenergy Decision Support Tool.

Biofuel quality

For countries that adopt blending targets and mandates there is a need to ensure that the quality of the biofuels and final fuels are meeting certain set standards. For mass market fuels, the use of internationally recognised standard such as CEN or ASTM is recommended to ensure vehicle manufacturers warranty. For end-users, these quality standards are an assurance that the biofuel that they are purchasing at the pump meets a certain quality standard and specifications that will not have negative effects on their engines (APEC, 2007).

Biodiesel fuel quality challenges are related to both fuel properties and biodiesel production processes and feedstock. These effects need to be monitored to ensure that quality standards are met. For example feedstock parameter properties, such as free fatty acid, insolubles, iodine value, phosphorus, stability and deposits, sulphur, and water are all necessary to monitor and specify in a standard. A study completed from Hart Energy Consulting reports that “biodiesel market problems often have less to do with the standards, and more with poor manufacturing practices and quality control resulting in biodiesel not complying to standards in place” (APEC, 2007). Therefore, for developing countries that are looking ahead to create national markets, monitoring approaches and systems for fuel quality standards need to be created and followed.

For bioethanol as well new guidelines and specifications could be aligned with other market standards. The Worldwide Fuel Charter Committee, for example, has released collective guidelines concerning the quality issues that are present in all bioethanol blends. The guideline document, representing the views of the automotive industry, outlines performance and measurement methods for various levels of bioethanol and is focused on the compliance of blenders and the quality of the blend (Auto Alliance, 2011).

Consumer awareness

Consumer awareness of new biofuel mandates should be undertaken by the government. Evidence has shown that often times, when a new blend level is introduced at the pump, consumers are unaware of which blend is compatible with their vehicle. If consumers are not aware of compatibility issues, this may lead to misfueling at the pump, or sometimes strong reactions against higher blends as consumers believe that it will affect their vehicles in the long term (without necessarily having sufficient information). This happened in Germany in early 2011 where consumers refused to buy the new petrol grade E10 despite having compatible vehicles. A combination of factors could explain the customers’ reticence such as lack of communication about vehicles’ compatibility or impact of the new fuel on the vehicles (Lahaussois, 2011).

Industry engagement

It is apparent that engaging and communicating with industry is critical when developing a biofuel mandate. Retailers, blenders, distributors and car manufacturers (OEMs) need to be not only made aware of new regulations, but invited and involved in the development process. As well, biofuel producers should also be involved in the dialogue as processes in their production could have an impact on the quality of FAME (and ultimately end use fuel) produced. Below is an outline of some challenges that industry faces when biofuel blending mandates are developed. It is important for decision makers to be aware of these challenges and find solutions to resolve them together. Table 8-4 shows an outline of challenges to industry when biofuel blending mandates are developed.

Table 8-4 Outline of challenges to industry when biofuel blending mandates are developed

Industry Party	Compatibility Challenge	Potential Policy Solution
OEMs	• New vehicles have to be warranted for new biofuel blend levels	• Provide longer lead times for regulation to be implemented in order for OEMs to have time to research and develop compatible vehicles (i.e. more than five years) • Provide incentives for OEMs to provide FFVs or those vehicles with higher biofuel blending compatibility
Retailers/ Distributors	• Higher blend levels have to be included at the pump, even though the demand for higher blends is low • Protection grade pumps need to be included at the retail station • Sometimes stations need to be retrofitted for higher blends	• Offer more lower fuel blends across a wide region, than concentrating higher blends in a few remote stations • Provide tax incentives/ cuts for retrofitting retailing stations

The following is an example of how a lack of industry dialogue affected the outcome of a blending mandate in Thailand.

Industry Engagement, Thailand

Thailand has instituted a mandatory blend of biofuels to be used in its national market. In 2007, the government made a concerted effort to push towards the uptake of E10, however, the effort failed because of the lack of the automotive industry to provide appropriate warranties on new vehicles. After this lesson, policy makers worked with major automobile dealers to agree to provide warranties to consumers for vehicles that would be compatible with the new *biodiesel* blending mandates. Through industry engagement both parties agreed on the warranties that would be developed for the future market.

Source: Biofuels Digest, 2010.

8.7 Conclusion: Informed, integrated policies are needed for biofuel mandates and targets

In the medium-term mandates are expected to increase as more countries become equipped to source and supply their own markets, or in some cases export to markets with biofuels. However, as this research has illustrated proposals to create or increase blending levels are constrained by the current fleet's ability to utilise the blend mandated or constrained by the current infrastructure. If a country is not equipped with either (1) a compatible fleet, or (2) compatible infrastructure for distribution/ storage, then compatibility issues might impact the successful implementation of a mandate. Therefore, it is imperative to develop mandates that allow biofuel blends that are compatible with a majority of the fleet, or create innovative policies that structure appropriate conditions to turn over old fleets in order to make new generations of fleets more compatible whilst ensuring in the meantime that non-compatible fleet have access to a protection grade. This encompasses both demand side policies (such as consumer incentives) and supply side strategies such as import regulations on non-compatible vehicles.

The research suggests that for developing countries that are interested in developing a bioethanol blending mandate, ***a safe level of blending is below E10*** (assuming there is not a high prevalence of FFVs) (Mass, 2011). This would assume that a blend level of E5 is suitable as an "entry" blend level, as bioethanol blends move incrementally from E5 to E10 to E15, etc. For developing countries that are considering an increase in bioethanol blend levels, it is imperative that a thorough assessment of the current fleet and infrastructure is done. From an economic and compatibility standpoint, diversifying the availability of lower blends might be more constructive than increasing the total national blend level (see Figure 8-5). With a mandate of E15, for example, only a few retail stations would supply it as only newer vehicles would be compatible. Thus, the demand is too low for it to be economical. Instead, it might make more sense to introduce lower blend levels and increase the availability of the supply throughout the country. This also implies that there are protection grades at the fuelling stations.

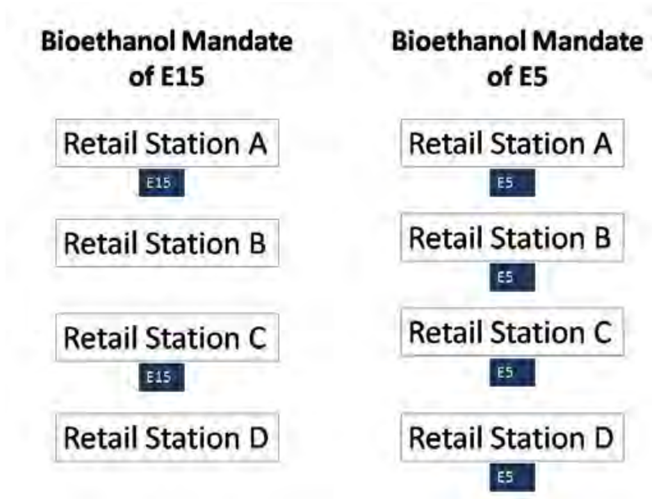


Figure 8-5 Blending concept

For countries that are considering the introduction of biodiesel mandates, research has shown that the ***blend wall for developing countries is B5 to B7*** (Rimmer, 2011). B7 can be seen as the maximum blending level if high quality standards are used (Lahaussois, 2011).

Without comprehensive and integrated planning, many compatibility challenges might emerge with current vehicle fleets and infrastructure. It is important that future policies, mandates, targets, etc. are harmonised with other cross-cutting policies for transport. For example, in some cases, emission standards between OEMs and retailers/ biofuel companies are different. The same can be said for fuel efficiency and quality standards. Fuel quality and vehicle emissions standards should always progress together as specific vehicle emission regulation will dictate specific after treatment systems that will require a specific fuel quality standard to ensure the correct performance of the vehicle technology to meet the emission regulations (Lahussois, 2011). This often times will set the maximum biofuels content that is allowed in mass market fuel to be used by a certain segment of the vehicle fleet. Therefore, the national planning process should create blending policies that are consistent with other policies that affect similar stakeholders and industry.

On a national planning level, compatibility is just one of many factors decision makers must consider when developing appropriate biofuel blending mandates and targets. The compatibility of a specific decision framework is presented below and the following steps are recommended for developing countries that are interested in creating mandates for biofuels or who are looking to alter/increase their existing blend level. Each of the steps requires reliable data and research, and input from various stakeholders in order to develop a comprehensive assessment (Figure 8-6).

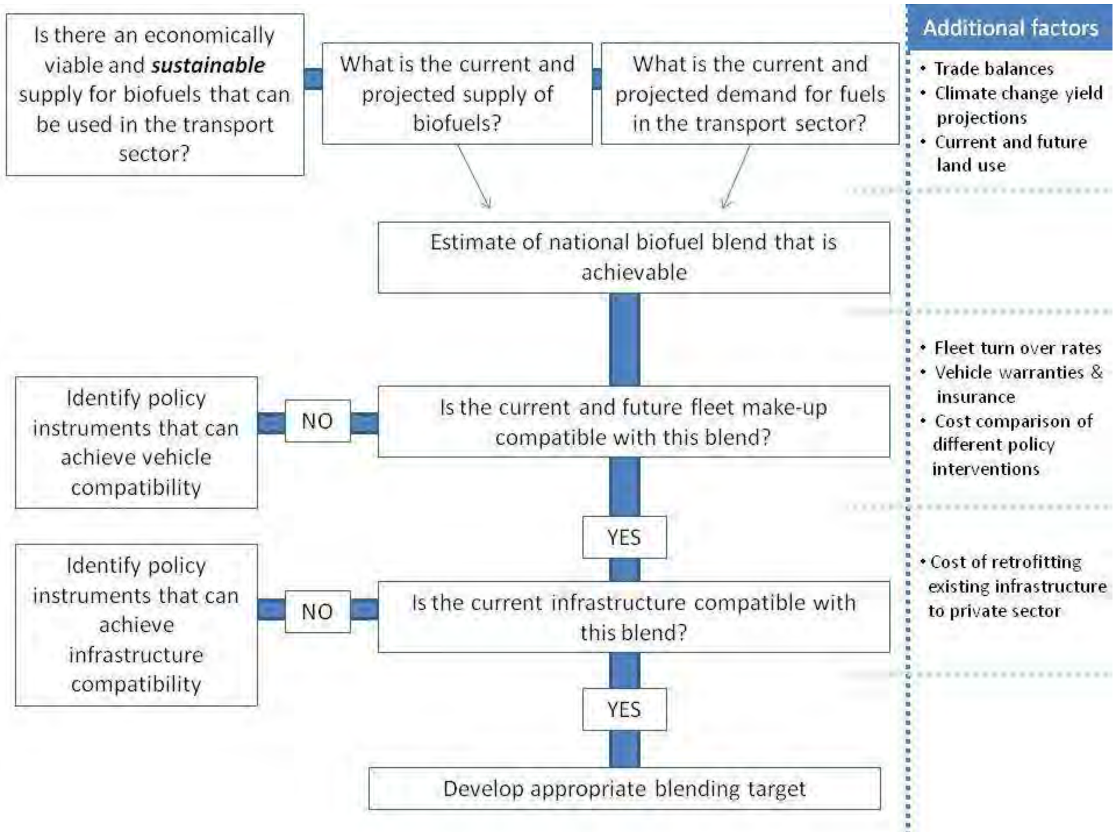


Figure 8-6 Decision tree for biofuel blending

8.8 Summary: Fostering fuel and vehicle compatibility

For countries creating biofuel mandates and/or targets, analysing whether or not certain biofuel blends will be compatible in vehicle fleets is a critical part of a national planning process. However, identifying the appropriate biofuel blend level (i.e. one that will not affect the durability and operability of a fleet) will depend on a range of different factors. If a country is not equipped with either (1) a compatible fleet, or (2) compatible infrastructure for distribution/storage, then compatibility issues might impact the implementation of a mandate. Therefore, it is imperative to develop mandates that are compatible with a majority of the fleet or create innovative policies that structure appropriate conditions to turn over old fleets in order to make new generations of fleets more compatible.

For developing countries that are interested in developing a bioethanol blending mandate, a safe level of blending is below E10 (assuming there is not a high prevalence of FFVs pre-existing). This would assume that a blend level of E5 is suitable as an "entry" blend level, as bioethanol blends move incrementally from E5 to E10 to E15, etc. For countries without prior blending mandate for bioethanol, the recommendation is to directly implement an E5 blending level.

Biodiesel mandates also have blend walls and constraints in terms of fleet compatibility. For countries that are considering the introduction of biodiesel, research has shown that lower blends from B5 to B7 would be suitable even in older vehicles. There is even some evidence that shows that in developed markets, all levels under B20 would be suitable. For countries without prior blending mandates for biodiesel, the recommendation is to gradually implement B3 and then increase to B5 blending levels.

Other issues besides vehicle/fuel compatibility influence the successful implementation of a national biofuel blending mandate. Many of these issues can be seen as external constraints and, if considered before the development of mandates and targets, might prevent future economic losses. Decision makers should consider alongside physical compatibility: the availability of sustainably sourced and produced biofuels, fuel quality concerns, consumer awareness and use of biofuels, and industry engagement to name a few.

Innovative policies and strategies can be undertaken to move a country towards compatibility. Some of these policies include: tax incentives to retrofit existing distribution infrastructure and vehicle fleets to become compatible to a higher blend; policies that help a country turn over their legacy fleet faster; and even policies that help maintain a protection grade (regular gasoline for older cars) while introducing new biofuel blends. To help guide decision making, a fuel/compatibility decision framework should be followed that outlines critical questions. Through addressing these questions and defining key barriers, developing country governments can better understand how to effectively resolve certain challenges and how to identify what an appropriate blend level is for their current light-duty passenger vehicle fleet.

9 Stationary applications

9.1 Introduction

Biofuels as energy carriers for transport are of interest to many countries (IEA 2011), and global trade in liquid biofuel is increasing (IEA Bioenergy 2011). Still, in many developing countries, the majority of bioenergy is used for **non-transport** services, especially cooking, electricity generation and (process) heat. To allow for a comparison of stationary and transport application, this section evaluates the possibilities to use liquid biofuels for **stationary** use in selected rural settings in terms of costs and environmental impacts.

9.2 Settings for stationary biofuel applications

The two main stationary biofuel applications settings of interest are village-based electricity generation and small-scale cooking, both based on straight vegetable oil (SVO).

As this study analysed just one setting which produces SVO from Jatropha, and such settings are typical for rural electrification schemes[37], the biofuel provision from this setting is used, even if currently no real-world SVO project in Tanzania is in operation (GIZ 2011). The only change from the setting is that instead of using a transport distance of 450 km for the field to the mill and from the SVO mill to the consumer, a transport distance of **10 km** is assumed for both, reflecting the village-based production and use of SVO.

In the comparison, SVO is used either as a transport fuel for buses or truck, as a fuel for village-sized diesel generators, or as a cooking fuel for stoves. The respective reference systems are fossil-based diesel (for transport and electricity[38]), and LPG for cooking.

As Tanzania imports practically all fossil-based oil products, this setting also indicates the potential benefits of substituting domestic biofuels for imports. As a sensitivity case, electricity from the grid is assumed instead of diesel generation.

Data for the Tanzanian electricity and oil system are based on IEA statistics. The data for the local diesel generator were derived from ETA (2003), Gül (2004) and WB (2009), for the LPG stoves from Afrane/Ntiamoah (2011) and Gaul (2011).

Data for the SVO diesel-generator were based on Gmünder et al. (2010) and Gaul (2011), for SVO stoves the data came from Gaul (2011) and Wagutu (2010).

The scenarios for the comparison of stationary biofuel applications were defined so that they imply the **same SVO consumption,** but SVO delivers different energy services.

Table 9-1 shows the key scenarios assumptions.

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[37] see Achten (2010), Duarte, (2010), FAO/IFAD (2010), Gaul (2011), Gmünder (2010), GTZ (2010), Kerkhof (2008), Kimming (2011), Raswant (2011), Wagutu (2010), Wijgerse (2008), Wiskerke (2008).

[38] A discussion of rural electrification is beyond this study, but it is noteworthy that more and more emerging economies deploy renewable energy options to provide electricity in off-grid rural settings, see IEA (2010). Until now, those schemes have mostly relied on hydro and solar PV, so the role of bioenergy so far has been small.

Table 9-1 Scenario definitions for the stationary biofuel applications in Tanzania

Scenario	electricity	cooking	transport
REF local	1 kWh local diesel	2 kWh from LPG stove	12 km diesel bus
REF grid	1 kWh grid	2 kWh from LPG stove	12 km diesel bus
SVO-el	1 kWh local SVO	2 kWh from LPG stove	12 km diesel bus
SVO-cook	1 kWh local diesel	2 kWh from SVO stove	12 km bus diesel
SVO-bus	1 kWh local diesel	2 kWh from LPG stove	12 km bus SVO

Source: Oeko-Institut assumptions; local electricity distribution excluded

The **reference** scenario assumes that 1 kWh of electricity is produced locally from a small-scale diesel generator, but costs of the local distribution systems are excluded.[39] For cooking 2 kWh of process heat from LPG is assumed, reflecting that energy needs for cooking are typically higher in rural villages. For transport, a diesel-run minibus is assumed which can transport (on average) 5 people plus the driver[40]. The **sensitivity** case to the reference scenario assumes that electricity is coming from the Tanzanian grid, all other assumptions are equal to the reference.

The three **SVO scenarios** assume that the Jatropha-based SVO is used for different services:

- In **SVO-el**, the diesel generator is run on SVO, while cooking uses LPG, and the bus is run on diesel (as in the reference).
- In **SVO-cook**, SVO is used for cooking (instead of LPG), while the local generator and the bus run on diesel (as in the reference),
- In **SVO-bus**, the bus is run on SVO, while the local generator is run on diesel and cooking uses LPG (as in the reference).

The scenarios deliver the same energy services to the local village, and the SVO scenarios use the same amount of (locally produced) SVO.

[39] The configuration of local grids is not possible for generic settings. The scope of the analysis made here is on the effects of using SVO for different energy services. Thus, the exclusion of the local distribution grid does not affect the differences between scenario results (see Gmünder 2010).

[40] The transport distance is chosen so that the minibus running on SVO consumes the same amount of SVO as in the other SVO scenarios.

9.3 Costs and employment of stationary biofuel applications

The compilation of cost and efficiency data for the stationary biofuel applications in the village setting used the SVO fuel cost data calculated in this study (see section 4). For the reference systems, data from GIZ (2011) for the 2010 diesel prices in Tanzania were used and own estimates on LPG prices were used based on studies in West Africa.

The results of the cost and employment analysis are shown in Table 9-2. The results for the cost analysis are shown in Figure 9-1.

Table 9-2 Scenario results for Tanzania – costs and employment (year 2010)

	annual costs [$€_{2010}$]		employment effects [jobs x 10^{-6}]	
Scenario	**@ 8%**	**@ 12%**	**direct**	**Total**
reference	1.08	1.08	0	6
sensitivity	0.87	0.91	0	15
SVO-el	0.99	0.99	149	169
SVO-cook	0.86	0.87	149	169
SVO-trans	0.99	0.99	149	169

Source: Oeko-Institut calculation with GEMIS 4.7; el = electricity; SVO = straight vegetable oil from low-input Jatropha cultivation on marginal land

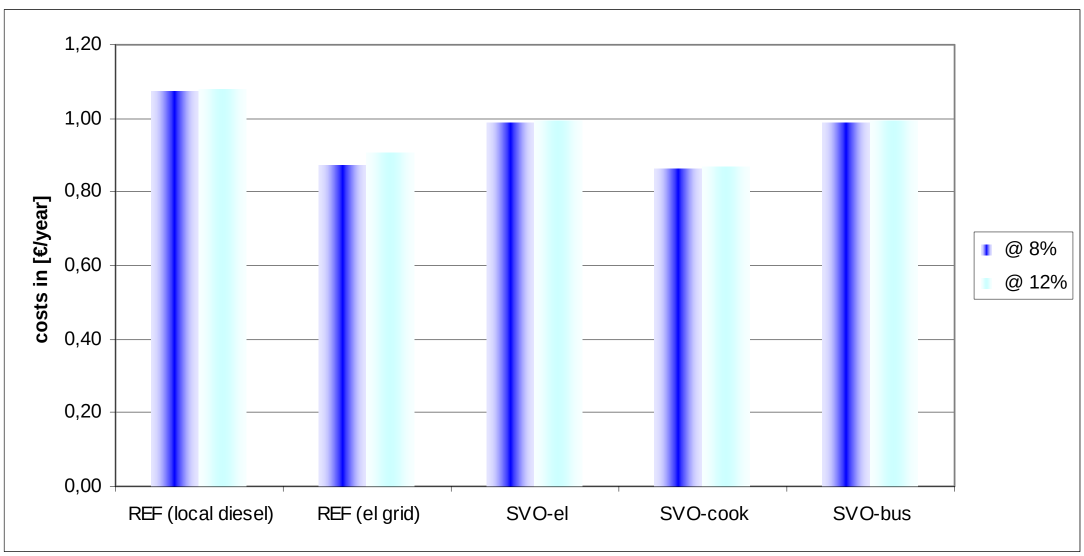

Figure 9-1 Scenario results for Tanzania – annual costs (year 2010)

The annual costs for delivering 1 kWh of electricity, 2 kWh of cooking heat and 12 km of bus service vary only slightly between the scenarios. The SVO cases would reduce the costs compared to the reference by 8% for electricity and bus, and by 20% for cooking, and these result are independent from the interest rate assumed for capital. Interestingly, the SVO cooking case would also be slightly less costly that the sensitivity case in which electricity would come from the Tanzanian grid (excluding local distribution).

With regard to employment, the SVO cases show a very significant increase over the reference and the sensitivity case, both for direct and for total jobs. The direct employment does not vary between the SVO scenarios as they consume the same amount of SVO.

9.4 Environmental effects of stationary biofuel applications

In addition to the cost and employment analysis, the comparison of key environmental effects of the scenarios is given in Table 9-3. The results for CO_2eq and CO_2 are shown in Figure 9-2.

Table 9-3 Scenario results for Tanzania – GHG emissions (year 2010)

Scenario	CO_2eq [g]	CO_2 [g]	CH_4 [g]	N_2O [g]
REF (local diesel)	3,285	3,180	3.0	0.10
REF (el grid)	2,522	2,410	3.4	0.09
SVO-el	2,170	2,088	2.1	0.10
SVO-cook	2,313	2,231	2.1	0.10
SVO-bus	2,157	2,076	2.1	0.10

Source: Oeko-Institut calculation with GEMIS 4.7; el = electricity; SVO = straight vegetable oil from low-input Jatropha cultivation on marginal land

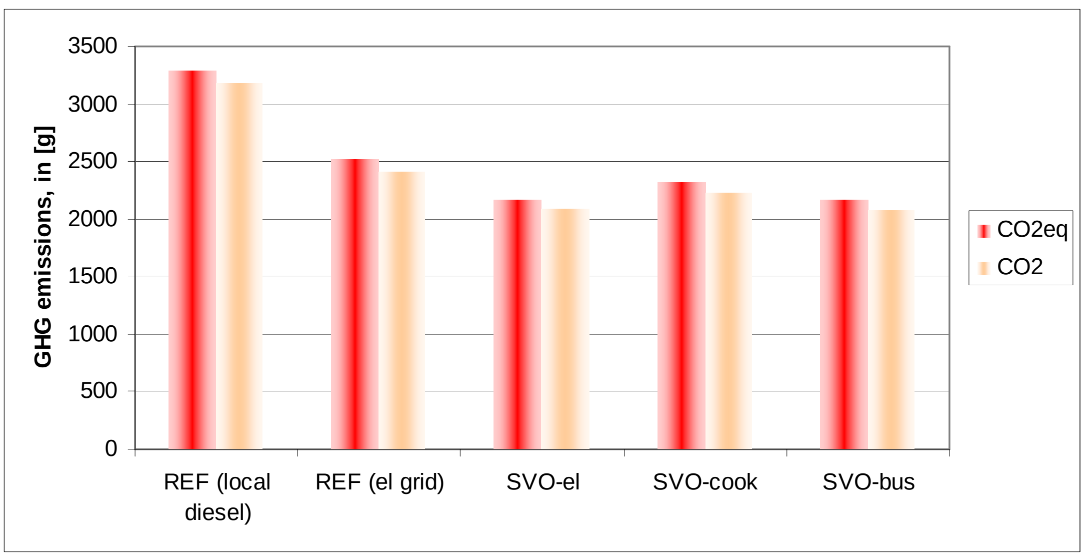

Figure 9-2 Scenario results for Tanzania – GHG emissions (year 2010)

All SVO cases reduce **all** GHG emissions compared to both the reference and the sensitivity scenario. The reductions in terms of CO_2eq against the reference scenario are 34% for the SVO-el and the SVO-bus cases, and 30% for the SVO-cook case. Interestingly, the SVO cases also reduce the CH_4 (by 30%) and N_2O (by 2%) emissions against the reference.

A similar analysis was carried out for the emissions of air pollutants from the scenarios, the results are given in Table 9-4. The results for the air emissions are shown in Figure 9-3.

Table 9-4 Scenario results for Tanzania – air emissions (year 2010)

Scenario [emissions in g]	SO_2eq	SO_2	NO_x	PM_{10}
REF (local diesel)	27.0	11.1	22.8	5.6
REF (el grid)	12.3	6.8	7.8	1.6
SVO-el	21.7	6.5	21.8	5.3
SVO-cook	24.8	9.4	22.1	5.5
SVO-bus	21.8	6.5	22.0	5.4

Source: Oeko-Institut calculation with GEMIS 4.7; el = electricity; SVO = straight vegetable oil from low-input Jatropha cultivation on marginal land

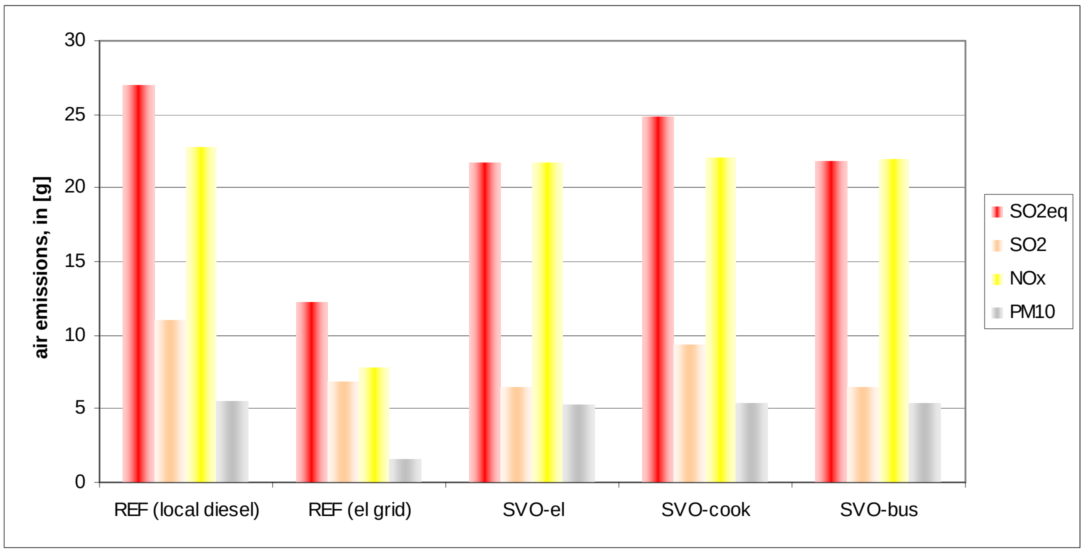

Figure 9-3 Scenario results for Tanzania – air emissions (year 2010)

Compared to the reference, **all** SVO scenarios reduce **all** air emissions though differently: The SVO-el and SVO-bus scenarios achieve a 20% reduction of SO_2eq, a 41% reduction of SO_2, a 5% reduction of NO_X and a 5% (SVO-el) and 3% (SVO-bus) reduction for PM_{10}.

The SVO-cook scenario shows a 8% reduction of SO_2eq, a 15% reduction of SO_2, a 3% reduction of NO_X and a 2% reduction for PM_{10}.

From the air emission point of view, the SVO-el and SVO-bus scenarios perform similar, with a slight benefit for the **SVO-el case**.

Box: Black carbon from biomass burning

Besides the GHG emissions usually considered (CO_2, CH_4, N_2O), there is a discussion on "black carbon" (BC) as another emission which changes the radiative balance of Earth's atmosphere[41]: BC consists of very fine particles which can both reflect and absorb light, change the albedo of surfaces, and cloud formation. With a comparatively short atmospheric residence time, the radiative balance of BC might increase warming in the time horizon of a few years up to a decade, which is not included in the 100-year time horizon of typical global warming potential scenarios. Still, as BC is mainly an issue of incomplete combustion of solid fuels, the role of emissions from forest fires, open burning of agricultural and forest residues, and from wood stoves can have a significant near-term climate implication. As BC is also considered a health threat, reducing BC has positive trade-offs beyond climate change.

Given the uncertainty and variation in data for both radiative impacts, and emission factors, this study does not analyse BC explicitly. The emissions of fine particulates (PM_{10}) are a proxy indicator for BC formation, though. Reducing PM_{10} will also reduce BC, and its respective impacts the radiative forcing balance.

9.5 Recommendations in the context of GEF activities

The findings of the exemplary analysis of stationary applications of liquid biofuels indicates that village-based, decentralized rural electrification might be more effective in reducing emissions that transport applications so that this option should be explored and possibly implemented where energy access is a key issue of sustainable development.
There are more options to use liquid biofuels in stationary applications (e.g., EtOH-based gelfuels for cooking), and also to convert both biogenic residues and bioenergy crops into biogas (and biomethane) which could be used for clean cooking, and electricity generation.

It is recommended to consider alternative uses of liquid biofuels during the evaluation of GEF project proposals, and to extend the available information on decentralized stationary uses of biofuels for more settings to substantiate the exemplary findings presented here.
Furthermore, there might be opportunities to "modernise" provision of biomass-based energy services – especially traditional use in stoves – using liquid biofuels to replace firewood and charcoal, which could reduce pressure of forests, and respective negative impacts. These options should be explored in more detail, taking into account the cost and investment implications, and potential benefits on health.

41 For a comprehensive summary of current knowledge on BC see: UNEP (United Nations Environment Programme)/WMO (World Meteorological Organization) 2011: Integrated Assessment of Black Carbon and Tropospheric Ozone: Summary for Decision Makers; Nairobi/Geneva http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_SDM.pdf

9.6 Summary: liquid biofuels in non-transport applications

The exemplary analysis of stationary applications of liquid biofuels indicates that village-based, decentralised rural electrification can be more effective than transport applications in reducing GHG and non-GHG emissions, without negative cost and employment impacts. Therefore, stationary biofuel options should be explored further and possibly implemented where energy access is a key issue of sustainable development. In this, applications such as EtOH-based gelfuels for cooking and conversion of biogenic residues and bioenergy crops into biogas could offer additional options for clean cooking, and electricity generation, and biogas production could be integrated in many biofuel production systems which would help reducing CH_4 leakage (e.g. in palmoil mills).

It is recommended to consider alternative uses of liquid biofuels during the evaluation of GEF project proposals, and to extend the available information on decentralised stationary uses of biofuels to more settings.

Furthermore, there might be opportunities to “modernise” provision of biomass-based energy services – especially traditional use in stoves – using liquid biofuels to replace firewood and charcoal, which could reduce pressure of forests, and respective negative impacts. These options should be explored in more detail, taking into account the cost and investment implications, and potential benefits on health, including effects on black carbon emissions.

10 Scale up and integration

This chapter focuses on the sustainability of scaling up the production of biofuels for transport in developing countries, looking at the case of three countries: Argentina, Mozambique and Ukraine. This chapter presents a summary of the Case Studies and the full assessment is available in the Report entitled: "Scale-up and Integration of Large-Scale Biofuels in Argentina, Mozambique and Ukraine" by (Van der Hilst et al. 2013).

The objective of the Case Studies is to make a first order and ex-ante analysis of the potential environmental and socio-economic impacts of large scale production of biofuels in the three countries, following two main methodological steps:

1. Assessment of the land availability for dedicated bioenergy crops spatially explicitly taking into account the development of other land functions on a national level.
2. Ex-ante assessment of the selected potential environmental and socio-economic impacts of large scale biofuel production on a regional level.

The methodological framework to assess the development of land availability for energy crops spatially explicitly over time is demonstrated for the three case study countries for the timeframe up to 2030. The methodological framework to assess the environmental and socio-economic impact of large scale bioenergy production ex-ante was demonstrated for the production of ethanol form Eucalyptus and Switchgrass in the Gaza-Inhambane and the Nampula region in Mozambique under the conditions of a Business as Usual and a progressive scenario in 2020 for a plant capacity of 1400 MW which equals an annual biomass feedstock input of 2.2 Mton. This is in line with the expected ethanol plant sizes in Brazil and the US in the near term future.

10.1 Methodology

Land availability

The key to this study is to assess how bioenergy potentials develop over time. Therefore a spatio-temporal land use change model was developed that enables spatially detailed assessment on when and where land is or could become available for bioenergy production while taking into account both the developments in other land use functions, such as land for food, livestock and material production, and the uncertainties in the key determinant factors of land use change. The developments in the main drivers for agricultural land use, demand for food, animal products and materials were assessed based on the projected developments in population size, Gross Domestic Product (GDP), food intake per capita and self-sufficiency ratio (SSR, i.e. the extent to which domestic supply meets domestic demand (FAO 2003).

The efficiency of the agricultural sector is a key factor for the land required to meet the total demand for food, animal products and materials. A scenario approach was used to explore potential long term developments in the productivity of the agricultural sector. The Business as Usual (BAU) scenario projects a future in which historical trends in yield levels and livestock productivity are continued, resulting in a low agricultural productivity. The progressive scenario assumes the implementation of improved agricultural management resulting in a high agricultural productivity. The land use changes in the timeframe towards 2030 were modelled for each year on a 1 km2 grid cell size level by allocating land to a land use class based on the suitability for the specific land use classes. The suitability of land was defined by a spatial weighted summation of a set of suitability factors specific for each country and specific for each of the land use classes (e.g. the vicinity of the same land use class; the productivity; the distance to road, water and main cities; population and cattle density; conversion elasticity; and the distance to forest edge). Areas that are not suitable (such as steep slopes) or not allowed (such as conservation areas) to be converted to agricultural land, were excluded. Based on the allocation of land use classes and the maps of excluded areas for bioenergy production (such as forest areas), the land availability for bioenergy crops is determined for each year.

The technical characteristics of the PC Raster Land Use Change model (PLUC) developed for the land use allocation are reported in Verstegen et al. (2012). The methods and the data inputs for the modelling and the resulting maps of the development in land availability for bioenergy crops in the business as usual and the progressive scenario for the timeframe 2005-2030 are available from the study of van der Hilst et al. (2012). The methodological adjustments of the model for Argentina are described in Diogo et al. 2013 (Forthcoming) The model specifications for land use change modelling in Ukraine are described in Van der Hilst et al. (Forthcoming).

Environmental and socio-economic impacts

The environmental and socio-economic impacts studied are based on the selections made in the previous chapters. The environmental impacts included are GHG emissions, impacts on water, soil and biodiversity. The socio-economic impacts addressed are legality, land rights, food security, economic viability, local prosperity, social well-being, labour conditions and gender. For all impacts it was aimed for finding an appropriate quantitative method to analyse the potential impacts taking into account the state of the art methods and the availability of data. Many of the socio-economic impact are directly related to the design, the implementation and the management of the project (social well being, labour conditions, and gender). Other impacts refer to compliance with (inter-) national law and regulations (land rights, labour conditions and legality). For those impacts, no ex-ante assessment of the impacts can be made but recommendations for best practice can be provided. The impacts that relate to economic markets such as food security, economic viability and contribution to local prosperity, would preferably be assessed by making use of economic equilibrium models. However, detailed data on regional level is often lacking, therefore other screening methods making use of background indicators were used.

10.2 Results

Land availability

The spatially explicit assessment of the development in land availability for bioenergy crops over time, shows how much land could become available, under which conditions and where. The case studies show that there is decreasing or no land availability for bioenergy crops in the business as usual scenario, i.e. when there is little improvement in agricultural productivity. However, in the progressive scenarios the case studies show that large amounts of land could become available for bioenergy crop production if the increase in productivity of the agricultural sector (crop + livestock production) exceeds the increase in food demand (see Table 10-1). This requires a discontinuation of current trends in productivity in agricultural sectors in all three countries.

Table 10-1 Development in land availabilility for bioenergy crops towards 2030 in the three case study countries for the BAU and the PROG scenario.

Case study country		**2010**	**2030**	
			BAU	**PROG**
Mozambique	Mha	8.7	7.7	16.4
Ukraine	Mha	0.01	0.3	32.1
Argentina*	Mha	0	0	32.0

*This is excluding the land that is already in use or expected to become in use for soy. As part of the soy complex is used for biodiesel, there is a biofuel production potential even in the BAU scenario in which no additional land becomes available.

The assessment is a first order sustainability assessment that enables to differentiate between the impacts of different energy crops in different regions under different scenario circumstances. There are however high uncertainties due to the low availability and reliability of data, which need to be significantly improved.

Environmental and socio-economic impacts

The environmental impact assessment is performed for two supply chains (eucalyptus and switchgrass ethanol), for two regions in Mozambique (Gaza-Inhambane and Nampula), for two scenarios (Business as Usual and Progressive). Table 10-2 shows an example of the results that can be obtained with the current methodological framework and data availability.

Table 10-2 Selected potential environmental and socio-economic impacts of the supply chains of torrefied pellets from Eucalyptus (EU) and switchgrass (SG) in the Gaza-Inhambane and Nampula region for the Business as usual (BAU) and progressive (PROG) scenario conditions.

			Gaza-Inhambane				Nampula			
			BAU		PROG		BAU		PROG	
	Impact	Unit	EU	SG	EU	SG	EU	SG	EU	SG
	Scale up potential [a]									
	Total land in selected region	Km^2	37324	37324	37324	37324	9974	9974	9974	9974
	Total land availability	Km^2	8323	8323	16129	16129	837	837	3146	3146
	Total land availability	% of region	22	22	43	43	8	8	32	32
	Potential suitability of available land	% of max yield	31	31	34	34	63	63	62	62
	Land requirements to meet input	Km^2	2039	2869	1567	2229	826	826	1313	1792
	Suitability of best available land	% of max yield	41	39	53	50	63	63	64	62
Impacts										
Environmental Impacts	**GHG Emission** [b]									
	Life cycle	Kg CO_{2-eq} /$GJ_{biomass}$	2.3	3.9	2.3	3.9	2.2	3.6	2.2	3.6
	LUC related emissions	Kg CO_{2-eq} /$GJ_{biomass}$	11.9	34.2	-20.4	-15.4	10.6	29.0	-27.3	-22.3
	Total emissions	Kg CO_{2-eq} /$GJ_{biomass}$	14.2	38.2	-18.2	-11.5	12.9	32.6	-25.1	-18.7
	Total avoided emissions	Kg CO_{2-eq} /GJ_{EtOH}	-36	24	-117	-100	-39	10	-134	-118
	Soil [c]									
	Soil Organic Carbon	Δ kg C /$GJ_{biomass}$	0.0	-2.1	-1.3	-3.3	0.0	-2.1	-1.5	-3.9
	Wind Erosion	Qualitative	-	0	+	++	-	0	+	++
	Water [d]									
	Water use efficiency	O dt $_{biomass}$/ l water	0.7	0.7	0.9	0.9	0.8	0.9	0.8	0.9
	Water depletion	mm/ season	426	-96	426	-96	523	-237	523	-237

	Biodiversity [e]									
	MSA	ΔMSA x100 /$GJ_{biomass}$	-0.4	-0.5	-0.1	-0.1	-0.3	-0.3	-0.1	-0.1
Socio-economic Impacts	**Legality** [f]		*No ex-ante analysis possible, recommendations to comply with national law are provided*							
	Land rights [g]									
	Land right risk	Qualitative	+	+	+	+	-	-	+	+
	Food security [i]									
	Food security	Qualitative	+/-	+/-	+	+	-	-	+	+
	Economic viability [j]									
	Feedstock	$/$GJ_{biomass}$	2.44	3.05	1.29	1.54	1.84	2.01	1.03	1.31
	End product	$/GJ EtOH	14.18	16.62	11.32	12.86	12.96	14.38	10.93	12.63
	Local Prosperity [k]									
	Total jobs	X 1000 jobs	9.7	6.9	8.0	5.9	4.8	2.3	7.1	4.7
	Local labour	%	100	100	100	100	100	100	100	100
	Total investment	M$	260	297	208	230	157	127	201	226
	Total wages	M$	10.1	7.1	8.3	5.8	4.9	2.4	7.4	4.9
	Social well-being [l]									
	Total no of people affected	X 1000 people	49	34	40	28	24	12	36	24
	Labour conditions [m]		*No ex-ante analysis possible, recommendations to comply with (inter-) national law and best practice are provided*							

The environmental impact assessment shows that the impacts are related to the biophysical and socio-economic conditions in the region, the characteristics of the supply chain (mainly crop selection) and are dependent on the scenario conditions. Most negative environmental impacts occur when native vegetation is converted to bioenergy plantations. Generally, positive environmental impacts occur when abandoned cropland or degraded land is used for bioenergy plantations. Negative impacts can partly be reduced or even be turned to positive impact by taking adequate management measures. Some of the socio-economic impacts are directly related to the design and the management of the project and can therefore not be assessed ex-ante. Other socio-economic impacts such as the impact on social well-being and local prosperity are directly linked to the amount of hectares and the total investment in the region. Consequently, the bigger the project the higher the positive impact on the local prosperity and local well-being. The ex-ante environmental and socio-economic impact assessment shows that there is no setting in which only positive impacts are achieved. It is not possible to provide one aggregated 'sustainability score' for the different settings as negative impacts on one sustainability component cannot be compensated by positive scores on others.

10.3 Conclusions

The land use model developed in this study is an advanced tool to assess future land use dynamics and land availability for bioenergy crops. Applying a scenario approach on the key drivers of land use change and using a food first paradigm, allows for an evaluation of the biomass potentials that can be achieved without competition with food and feed, and the required conditions to realize these potentials. As biomass yields, production costs, logistics, and environmental impacts are strongly related to location specific biophysical conditions, spatially explicit assessment of land availability for bioenergy crops is an important precondition to design bioenergy supply chains and logistics and assess bioenergy production potential and environmental and socio-economic impacts.

This first order assessment enables the selection of promising regions and supply chains and identifies the key concerns that need to be addressed when a project is implemented. However, it does not replace an environmental and socio-economic impact assessment of a specific project, which can address mitigating measures to address key concerns through appropriate land use planning, project design and management of the plantation.

10.4 Recommendations

1. Sound land use planning is key for the development of sustainable large scale biofuel production. The methodological framework to assess potential land use change and the potential land availability for energy crop production, and the framework to assess the environmental and socio-economic impacts show that these assessments require high amounts of accurate (spatial) data. For most countries, this data is not available on a national level or is outdated or unreliable. The global datasets should be improved in terms of accuracy, spatial resolution, consistency, classification, ground-truthing, updating and continuation. Therefore it is recommended that international bodies and governments contribute to improving data availability required to make land use planning and environmental and socio-economic impact analysis.
2. National governments should be encouraged to make long term land use planning for the entire country, indicate areas that are required or are likely to become required for several land use functions and designate areas for potential energy crop production, by mapping current land use and land cover, protected areas, vulnerable ecosystems, land use rights or land ownerships, community and customary land use rights. Government should also forecast population growth, dietary intake, urbanisation, import and export rates, agricultural productivity, livestock productivity, and developments in infrastructure, and in doing so, identify a strategy to achieve the scenario conditions.
3. Investors are advised to make a thorough ex-ante assessment on the biophysical properties of the land obtained for the biofuel project, the socio-economic conditions in the region, the biomass feedstock that will be produced, and the management that will be applied, keeping in mind compliance with national and international legislation and compliance with all sustainability issues. The investor should also take these issues into account as these may constitute a first step to being certified for sustainable production by international certification bodies, which could provide access to markets.

11 Recommendations for GEF policy

11.1 Summary

The *Global Environment facility (GEF)* needs to set clear policies and priorities for future work and investments in biofuel related projects while providing guidance to countries that are keen to engage themselves in this sector. UN agencies in collaboration with scientific institutions worldwide address issues such as life-cycle energy and greenhouse gas assessments, economics, social/food security and pricing as well as overall environmental impacts, fuel and vehicle compatibility plus stationary applications, scale-up impacts and next generation biofuels. The results of this *GEF Targeted Research Project* are summarised in this report and its associated databases. The overall goal was to identify and assess sustainable systems for the production of liquid biofuels both for transport and stationary applications worldwide.

11.2 Specific recommendations

Life cycle energy and greenhouse gas (GHG) assessment

Future activities related to biofuel projects

- The calculation of life cycle GHG emissions for 74 biofuel settings reveals that every pathway emits less GHGs than the replaced fossil fuel, provided that direct and indirect land use changes can be avoided. Given this, biofuel projects can contribute to climate change mitigation and thus should be part of the GEF-5 climate change strategy. The 74 settings cover a broad portfolio of biofuel pathways. As all show GHG reductions, GEF can tailor biofuel projects to the national circumstances and the specific needs of recipient countries.
- As has been shown in Chapter 3.1 and 3.2, biofuel GHG results strongly vary subject to yields, co-product use and production management. Therefore, GEF should strive for the best biofuel pathway design within the specific objectives and circumstances of a biofuel project. Furthermore, GEF should support capacity building with regard to these influences and raise awareness on the correlation between an improved GHG balance and a more efficient (and thus often cheaper) biofuel production.
- Among the different feedstocks, high yielding perennial crops have significant potential for GHG reduction. Also the use of agricultural residues such as straw is highly recommended as it is produced independently from agricultural land and therefore does not cause land use changes nor does it compete with food production. However, both types of feedstock are only accessible with second generation technologies that are often at an early stage of development. GEF should support awareness raising, capacity building and investment in pilot projects in order to enhance innovative technologies and make them available to developing countries.
- Projects involving biofuel production may be designed to have positive benefits in other focal areas (e.g. biodiversity, land management) in addition to GHG reductions (climate change mitigation) in a cost-effective, synergistic way.

Therefore, it is recommended to pursue a broader perspective in project design that takes into account other GEF focal areas, using their associated funding. The choice of a multi-focal project may improve productivity and reduce desertification (land degradation), which can also enhance the overall sustainability of biofuels, and may have further benefits with regard to GHG emission reductions.

Use of the GEF Biofuel Greenhouse Gas Calculator

- It is highly recommended that GEF projects use a science-based informational toolset, such as the GEF Biofuel GHG calculator, project preparation phases and project evaluations in order to generate scientifically sound, harmonised and transparent calculations of GHG reductions in biofuel projects. The biofuel greenhouse gas calculator gives an overview on GHG results for a broad portfolio of biofuel pathways in developing countries; and at the same time allows them to perform own calculations.
- For the successful implementation and dissemination of the tool and its further development it is recommended that GEF builds up competence and supports the implementation of the GHG calculator tool for project applicants during the PIF stage.

Establishment of certification systems (focusing on GHG balancing)

- It is highly recommended that GEF support countries in developing sustainability standards to provide a solid framework for the sustainability of biofuels, and continue to clarify sustainability standards for GEF projects. These standards should not only focus on greenhouse gas mitigation but take into account all relevant areas of sustainability.
- When it comes to GHG calculations within such standards and systems, the level of detail of the guidance should be adapted to the target groups (see Chapter 3.3). If concrete calculations have to be done by market actors, a clear and transparent calculation methodology should be provided together with the related capacity building. The schemes assessed in Chapter 3.3 can serve as appropriate examples. No matter how detailed guidance is, every method still gives ample room for interpretation and leads to differences in result.
- The GEF should carefully observe the developments at international level since more and more big economies (e.g. USA, Europe) ask for feedstock certification with GHG balancing being part of the process. Since calculation methodologies are far from being harmonised, GEF has to weigh between two aspects: implementing a methodology to check whether required thresholds would be met by a certain project or adapting the methodology to national or project specific needs.

Economic viability of the production of liquid biofuels

The differences in the biofuel production costs for the fuel production pathways indicate the importance of using specific settings that can take into account local circumstances.

- *Local data collection and specific case studies should be supported for decision-making.*
  These are keys to more accurate modelling of the biofuel production costs, the profitability for a farmer (by means of NPV calculations) and the identification of alternatives.

- *Various cost factors should be taken into consideration when analyzing the feasibility of biofuels. Costs are dynamic and long term costs should be considered indicative.*
  Generally production costs are expected to decrease over time following continuous process improvements, technological learning and increasing scale of production. Possibilities for cost reduction can also be linked to local technology adaptation and strategies need to be developed to identify technology components that can be locally fabricated. The cost of alternative energy source (for example fossil diesel fuel for usage in a diesel generator in a remote village) determines the competitiveness of the biofuel feedstock and should be considered.

- *Appropriate policies need to be devised to make biofuels production more competitive and reduce investment risks.*
  Key sustainability aspects are fully taken into account in these policies, when assessing biofuel supply. Studies have shown that inclusion of sustainability criteria has potential impacts on the amount of biofuels that can be produced as well as final delivered costs of the biofuels. A prerequisite is that sufficient data of high quality is available in the project proposals submitted to the GEF. Our report contains default values that facilitate an evaluation the compilation of results for other biofuels, if insufficient data is available; the data for the 74 biofuels pathways and settings can be used as a benchmark.

- *If the NPV < 0, the net cash inflows over the total project lifetime are lower than the cost of financing the project and it should not be undertaken.*
  When the NPV is close to zero, there is an expected no-profit no loss scenario, then the GEF could further research the financial viability by an extended Cost Benefit analysis, including other indicators such as, Internal Rate of Return (IRR), Benefit / Cost Ratio (BCR) and Pay Back Period (PBP), see Table ES-2 that includes all aspects of the economic analyses.

Global environmental impacts -other than GHG emissions

- *Future activities should compile more comprehensive data on non-GHG emissions, and especially address regionalized water use.*
  The “traffic light” thresholds suggested in this study were derived from life-cycle and material flow analyses for the settings selected, and are subject to significant uncertainty and variation, especially for the feedstock cultivation, and downstream conversion. There is a lack of empirical evidence and representative data for some of the life-cycles and settings, so it is recommended to use current and comprehensive data as much as possible.

- *Enabling activities on GIS-based spatially explicit data are crucial for future GEF funding in the biofuels realm.*
  A key requirement to successfully meet the environmental challenges on the project level is the availability of adequate spatially explicit data, especially high resolution maps. Supporting the extraction of GIS-based data will help provide further information on the sustainability of proposed projects.

- *Mitigation measures should be considered as “standard” requirements, and best practices for biofuel projects should be demonstrated by project developers.*

Social standards, criteria and indicators

- *Governments and ministries should be supported in collecting comprehensive and current data which can support decision making for biofuel projects*

  A key requirement to successfully meet the social challenges on the project level is the availability of adequate data. The evaluation and assessment of biofuel projects versus food security aspects requires data needs, analytical skills and access to modelling.

  Usually, this goes beyond capacities and resources available to project developers or the GEF staff reviewing projects. Therefore, GEF is dependent on the responsibility of countries and governments to analyse the characteristic of their own country and provide the necessary data sets.

- *Priority for GEF project portfolios should consider countries with analysed biofuel production impacts on prices and food security.*

  GEF activities have to pay attention due to land tenure, labour conditions and gender issues. These impact categories influence human welfare and can avoid poverty and hunger. Due to increasing population and increasing demand for food the subsequent decades will be very decisive and the social security of biofuel producers will play an increasingly important role.

Evaluation of potential future (next generation) types of biofuels

Similar to first generation biofuel projects, projects submitted to the GEF for next generation biofuels should be based on detailed and transparent life cycle cost calculations. This report provides a generic analytical framework and data and can be used as benchmark. But given the spatial heterogeneity of agro-ecological conditions and state of infrastructure in most developing countries, it is important that the local context of each project is taken into account. Table 4-9 shows a screening tool for GEF based on economic analyses.

- *For the production of energy crops or residues up to the farm gate, all the key activities in the development of energy crop plantations and procurement of residues must be itemised and taken into account.*

  Formula (II) in section 4.1 of the main report shows the equation that can be used for life cycle cost calculations. It is important to note that biomass costs are site specific and localised conditions (e.g. soil, water, climate, yields, terrain, accessibility, land and labour costs) need to be taken into account, as this can have a huge influence on the final biofuels costs. Specific crop production activities depend on the site quality and location which influences site preparation, choice of species, planting density, and rotations, required cultural management and soil amendments, degree of mechanisation, as well as transport and logistics and the market value of fossil alternatives.

- *For biomass energy supply chain calculations, it is important to have and use regional specific data*

This data includes information such as: distribution of biomass, percentage of land under energy crops, infrastructure by type and quality, transport distance by mode) and conversion plant specifications (including location, scale, efficiency, load factors).
The number of stages in a supply chain varies depending on the feedstock characteristics, pre-treatment requirements and infrastructure, but a clearly defined chain with detailed logistical capacity indications (e.g. truck capacities, speed, operational costs per tonne-km; specifications for sizing, drying, densifying, conversion, transfers, storage) as well as relevant mass balance is necessary.

- *It is important in a developing country context to determine what processes are cost effective at small scale and can be carried out locally, and to identify the more capital intensive conversion processes that benefit from scaling effects and centralised processing.*

  Biofuel conversion (especially for next generation biofuels) benefits from economies of scale and it is important to determine the optimal scale of production beyond which feedstock transportation costs become prohibitive. To ensure competitive delivery of biofuels, it is important to optimise the various chain elements against the required logistic capacity (i.e. volumes of biomass being handled), taking into account the supply operating windows and need for maintaining high equipment load factors. Examples of optimisation options include using large capacity trucks and ships, early densification of biomass, open air drying, improving effective use of equipment, maximizing the operating window and improving equipment load factors.

- *For next generation biofuels, the fuel conversion stages are especially capital intensive and thus it is critical that appropriate equipment is identified and costed (given the many potential conversion equipment combinations).*

  It is also important to take note of the relevant equipment specific cost factors (lifetime, interest rate, etc.) and different cost type information (capital-related and installation, consumption-related and operation related). As next generation technologies are not yet mature, it may be necessary to incorporate aspects of time dependent technological learning and scaling up effects in the economic analysis. The establishment of next generation biofuels will entail technology transfer in developing countries and thus involve import dependency risk. However, there are also opportunities for utilization of agricultural and forestry by-products, developing of new supporting industries and skills.

Fostering fuel and vehicle compatibility

Biofuel and vehicle compatibility needs to be fostered by developing countries before blending policies are instituted. Although the GEF, through this research, can assist in providing information on compatibility for developing countries, it is recognised that fuel/vehicle compatibility is beyond the scope of GEF activities concerning Global Environmental Benefits (GEB). Therefore, these recommendations are best directed towards developing country governments.

Without comprehensive and integrated planning, many compatibility challenges might emerge with current vehicle fleets and infrastructure. Often developing countries have fleet make-ups that are comprised of older and legacy vehicles, which can regularly experience problems if they utilise biofuels that are not at a compatible blend level. Also, existing infrastructure might not be ready and adapted to higher blends, and can pose economic risks if not retrofitted appropriately.

Therefore, it is recommended that governments take various steps to determine what blend level is appropriate for biodiesel and bioethanol.

- *Determine the economically sustainable supply of biofuels that can be utilised in the transport sector*
- *Estimate the achievable biofuel blend (contingent on supply and projected supply)*
- *Determine if the current fleet make-up is compatible with this blend level > if not, assess if there are policy instruments that can improve compatibility problems*
- *Determine if the current infrastructure is compatible with this blend level > if not, assess if there are policy instruments that can improve compatibility problems*
- *Structure appropriate blend level(s) and accompanying policy instruments*

Liquid biofuels in non-transport applications

The exemplary analysis of stationary applications of liquid biofuels indicates that village-based, decentralized rural electrification can be more effective than transport applications in reducing GHG and non-GHG emissions, without negative cost and employment impacts. The following are recommendations based on these findings:

- *Stationary biofuel options should be explored further and possibly implemented where energy access is a key issue of sustainable development.*

  In this, applications such as EtOH-based gelfuels for cooking and conversion of biogenic residues and bioenergy crops into biogas could offer additional options for clean cooking, and electricity generation, and biogas production could be integrated in many biofuel production systems which would help reducing CH4 leakage (e.g. in palm oil mills).

- *It is recommended to consider alternative uses of liquid biofuels during the evaluation of GEF project proposals, and to extend the available information on decentralized stationary uses of biofuels to more settings.*

  Furthermore, there might be opportunities to “modernise” provision of biomass-based energy services – especially traditional use in stoves – using liquid biofuels to replace firewood and charcoal, which could reduce pressure of forests, and respective negative impacts. These options should be explored in more detail, taking into account the cost and investment implications, and potential benefits on health, including effects on black carbon emissions.

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Annex: Definition of Biofuel Supply Chain System Components

HARVESTING

Efficient feedstock harvesting methods must match the unique requirements of each biomass source and site conditions. A wide range of new technology is being developed for harvesting short rotation woody crops (SRWC). Common felling methods include manual (chainsaws), feller-bunchers/ feller-bundlers, feller chippers, and swath cutters. Feller-bundlers and feller chippers convert the biomass into chips or bundles respectively, and significantly reduce biomass extraction costs. Other variations include the harvester forwarder, feller chipper, feller chipper forwarder, feller forwarder, feller skidder, harvester-multi-stem, tree puller, etc. For developing countries, manual motorised systems may be preferred due to availability of low cost labour.

Forwarding

Harvested biomass needs to be hauled to designated landing sites around the fields to enable roadside processing, storage or further transportation to central facilities. Forwarding or primary biomass transportation can be accomplished in many ways. The most basic form involves hand crews physically carrying material out of the stand when the extraction distance is relatively short. This is clearly very labour-intensive work and presents numerous safety and health issues. An alternative approach is to use a forwarder (a self-loading off-road truck) to drive through the stand collecting biomass from piles and transport piles to roadside where it is dumped or unloaded with a crane. Piled biomass could also be removed with a biomass bundler, which collects and compresses material into composite residue “logs” (CRLs) that are significantly more compact than loose woody biomass. The CRL’s can be transported on standard forwarders.

TRANSPORTATION

To determine the costs of transportation, transport requirements are related to the spatial distribution of biomass in each region, as well as subsequent transport to processing units and conversion plant. For first transport distance estimation, it is assumed that the distribution of biomass over an area is constant and that the biomass is transported over a marginal transport distance, represented by the radius of a circle in which the biomass is spread with the given distribution density (Dornburg et al. 2001). First transport from the field to local processing centres is by truck. Truck transport from the first processing units to the processing facility is “dedicated”, meaning that the trucks return empty. The main transportation modes are mainly road and rail. Long distance transportation is normally done by train and ships, but road truck transport can also be used. Truck transportation is the most expensive (and is advisable to limit to a few hundred kilometres. Water transportation is also possible along the coast where transfers are required to ports with facilities for sea going ships. International shipping is by the bulk carriers and tankers, and these can be chartered and dedicated also.

BIOMASS PRE-TREATMENT OPTIONS

Pretreatment of biomass is necessary to improve logistic efficiency. It includes sizing, drying and densification. Hence, an important logistical question is to identify combination(s) of pre-treatment options which can best upgrade biomass properties for optimal logistics. The following pretreatment options are normally considered.

Sizing:

The purpose of sizing is to meet subsequent step feedstock specifications and to improve handling. Appropriate technologies for sizing have to be selected; typically a Chipper or roll crusher is used for chipping logs to 30mm while a hammermill can be used to grind the chips to less than 10mm. A bales chipper can also be used when dealing with bundles or bales. Sometimes, a harvest chipper can also be employed, where chipping is done in the field during harvesting. It is important to note that chips decompose easily and moisture content increases in storage. Hence chips should be dried quickly or chipped as late as possible in the chain, otherwise biomass dry matter losses can lead to poor supply chain efficiency and costly biomass delivery.

Drying:

Moisture content of fresh biomass is about 50% and drying is necessary to meet feedstock criteria at conversion plant: e.g. gasification requires feedstock with moisture content of less than 8%. In addition, drying also helps in reducing decomposition risks, fire and health hazards as well as reducing biomass weight (not volume) – and thus reducing logistic costs. To allow efficient drying, it must always be preceded by a sizing step, so as to expose a greater biomass surface area. Usually, part of dried biomass can be used in the drying process, reducing the fossil energy requirements. Various drying technologies can be used e.g. the Rotary Drum dryer.

Densification:

Since untreated biomass is bulky, moist, fibrous, perishable and leads to expensive logistics, it is necessary to densify it. Densified biomass has high energy density, it is water resistant, easily crushed, does not rot and this results in cheaper logistics. Key technologies used for densification include baling, pelletising, briquetting, torrefaction and pyrolysis. Drying and sizing steps always precede densification, because of strict feedstock specifications. An important consideration for densification is the choice between small scale decentralised facilities and large scale centralised facilities. The former is suited to developing country conditions where small scale systems dominate, but the latter offers economies of scale which may be important in driving costs down.

(a)Pelletisation:

Pellets are made by compressing and extruding heated (pulverised) biomass. The high pressure melts the lignin and binds the biomass (otherwise a binder added). Pelletisation produces biomass with a consistent quality and size, with better thermal efficiency and higher energy density. The most common pellet technologies used include the Pellet press, the Piston Press, the Extruder and the Roller Press.

(b)Torrefaction:

Torrefaction is a thermochemical treatment of biomass at 200-320 ℃ (under atmospheric conditions and in the absence of oxygen) to give a dry, blackened material “bio-coal” final product. The process liberates water, volatile organic compounds (VOC’s), and hemicellulose (HC) from the cellulose and lignin. The VOC’s and HC are combusted to generate 80% of the torrefaction process heat. The remaining and warm lignin can act as a binder when the torrefied wood is pelletized. During torrefaction, biomass loses typically 20% of its mass (dry bone basis), and 10% of the energy content (in volatiles). Torrefied biomass can be densified (into briquettes or pellets) using conventional densification equipment, to further increase the density of the material and to improve its hydrophobic properties.

Torrefied biomass has a higher energy density (18 - 20 GJ/m3) which results in lower handling costs. It has more homogeneous composition and a wide variety of raw biomass feedstocks can be used to yield similar products. However, torrefied biomass is hydrophobic but this improves on densification. The process of torrefaction eliminates biological activity and thereby reduces the risk of fire and decomposition. It improves the grindability of biomass which leads to a reduction in energy demand for densification. Small scale and decentralised torrefaction is possible, which offers advantages for reducing logistical capacity early in the chain. Torrefied biomass can be used as a substitute coal in combustion or gasification feedstock.

(c)Pyrolysis:

Pyrolysis involves the thermochemical breakdown of organic material from 430-800 ℃, under pressure and in the absence of oxygen. It produces gas and liquid products and leaves a carbon rich solid residue (char). The composition of products depended on pyrolysis method, characteristic of biomass and reaction parameters, e.g. extreme pyrolysis (carbonization) leaves mostly carbon as the residue (used in industrial charcoal production). Higher efficiency is achieved by the so-called “flash pyrolysis” where pulverised feedstock is quickly heated to between 350 and 500 ℃ for less than 2 seconds. The resulting “bio-oil” has a high bulk density (1200 kg/m3) and a heating value of 15-18 MJ/kg. Pyrolysis oil can be used as a fuel, but also as a feedstock for gasification. Because of its corrosive nature, pyrolysis oil requires special lining in carbon steel tanks for storage and transportation (and this increases handling costs by about 14%).

Torrefied biomass densification (torrefied and pelletised biomass, TOPs)

Torrefied biomass is a porous product with a low density. It is fragile, which makes it relatively easy to grind. However, decreased mechanical strength and increased dust formation, in addition to low volumetric density, makes further densification desirable. This is especially important when long distance transport is considered. In the ECN Laboratories, the mass density of torrefied biomass pellet has been measured at around 22 MJ/kg, whereas the energy density reaches up to 18 GJ/m3. Although this energy density is less than that of coal (20.4GJ/m3), it is 20% higher than commercial wood pellets. Thus, torrefaction in combination with pelletisation (TOPs) offers significant advantages when the biomass logistics are considered. With torrefied biomass, the pressure required for densification could be reduced by a factor of 2 at 225 oC, while the energy consumption of densification could be reduced by a factor of 2 compared to biomass pelletisation. Torrefaction can reduce power consumption required for size reduction by up to 70–90% compared to conventional biomass pelletisation. A simpler type of size reduction, such as cutting mills and jaw crushers, can be deployed instead of hammer mills which are used for the conventional pelletising process.

Impact of pre-treated biomass on gasification systems

Torrefied biomass has several advantages; prior to gasification, electricity consumption for milling decreases significantly. The fibrous structure and the tenancy of biomass are reduced by hemicellulose decomposition together with the depolymeristation of cellulose during the torrefaction reaction. The power consumption in size reduction is decreased 85% when the biomass is first torrefied. The energy consumption required for milling biomass into 100 mm decreases from 0.08kWe/kWth(dry) to 0.01–0.02kWe/kWth when torrefaction is applied. Moreover the capacity of the mill increases in proportion to the particle size. When the 0.2mm particle size is considered, the chipper capacity for torrefied willow is up to 6.5 times the capacity of untreated willow. For both torrefied pellets and conventional pellets, drying is not needed.

In the case of bio-oil, the pre-treatment section needs to be adjusted depending on the bio-oil characteristics. Sizing is not necessary anymore and the feeding system can be similar to the liquid fuel feeding systems for CFB gasification instead of those that are suitable for solid fuel feeding.

Storage

Storage is required wherever there is difference in scale in adjacent supply chain steps, or when biomass is supplied seasonally. The main biomass storage types include open air, outdoor covered, bunker, container and silo. Harvested biomass can be stored in the field (open air) for four to six weeks to facilitate natural and low cost drying. After storage in the field, the moisture content of biomass is expected to fall from about 50% to about 30-35%. Further storage is expected at the roadside for logs and bales, at the conversion unit and at other transfer points in the chain. Storage facilities differ for each fuel type, i.e. open-air piles are assumed for logs and bales while pellets are housed in silos of capacity 5000m3. Pyrolysis oil is stored in special lined carbon steel tanks, which are 14% more expensive than conventional steel tanks.

Appendix A:

Life cycle energy and greenhouse gas assessment IFEU Heidelberg

A-1 Detailed descriptions of key issues for life cycle energy and greenhouse gas assessments

A-1.1 Functional unit

An LCA is always anchored in a precise, quantitative description of the function(s) provided by the analysed system, the so-called functional unit. The functional unit is supposed to reflect the goal and scope definition. The results of energy and greenhouse gas balances of biofuels are often related to functional units such as:

- 1 MJ of biofuel (absolute results, product basis)
- 1 hectare of cultivated land (absolute results, area basis)
- Percentage of energy / greenhouse gas (GHG) emission saving (relative results).

Due the large variety of questions addressed in LCA studies, there is no universal 'best choice'. Relative results are often considered more comprehensible and user-friendly. On the other hand, absolute values are more comprehensive and transparent.

It is impossible to directly compare the results of studies with different functional units because the chosen functional unit affects the interpretation of results. A biofuel performing best related to one functional unit might be worst related to another functional unit. Results for GEF case studies for different functional units are given in chapter A-2 (Figure A-8, Figure A-9 and Figure A-10.

A-1.2 Co-product handling

The assessment of co-products is one of the most important issues for energy and GHG assessment of biofuels. Being agricultural products, biofuels are characterized by a number of various co-products accruing during production and processing, e.g. press cakes, shells, or glycerine from biodiesel production. There are two main strategies to handle co-products in energy and GHG assessments (cf. Figure A-1):

- *Substitution:* A co-product usually supersedes an alternative product that would be used in case the co-product was not available. For example, glycerine as a co-product of biodiesel production can be used in the pharmaceutical industry. If no glycerine from this process was available, petroleum-based glycerine or similar chemicals would be used instead. The avoided environmental burden of the replaced product (in this case: petroleum-based glycerine) is subtracted from the analyzed system (in this case the biodiesel system).
- *Allocation:* The expenditures for a process are assigned to the different co-products by a defined allocation factor, e.g. by mass, volume, energy content or market price.

The substitution approach can be considered as preferable from a scientific point of view, but requires a lot more effort for calculations. Legally binding acts, therefore, often rely on allocation because it is easy to apply, predictable over time and indisputable. In this respect, allocation by energy content is the most robust approach. This approach is stipulated by the EU Renewable Energy Directive (RED) (CEC, 2009). The GEF calculation tool uses only allocation by energy content.

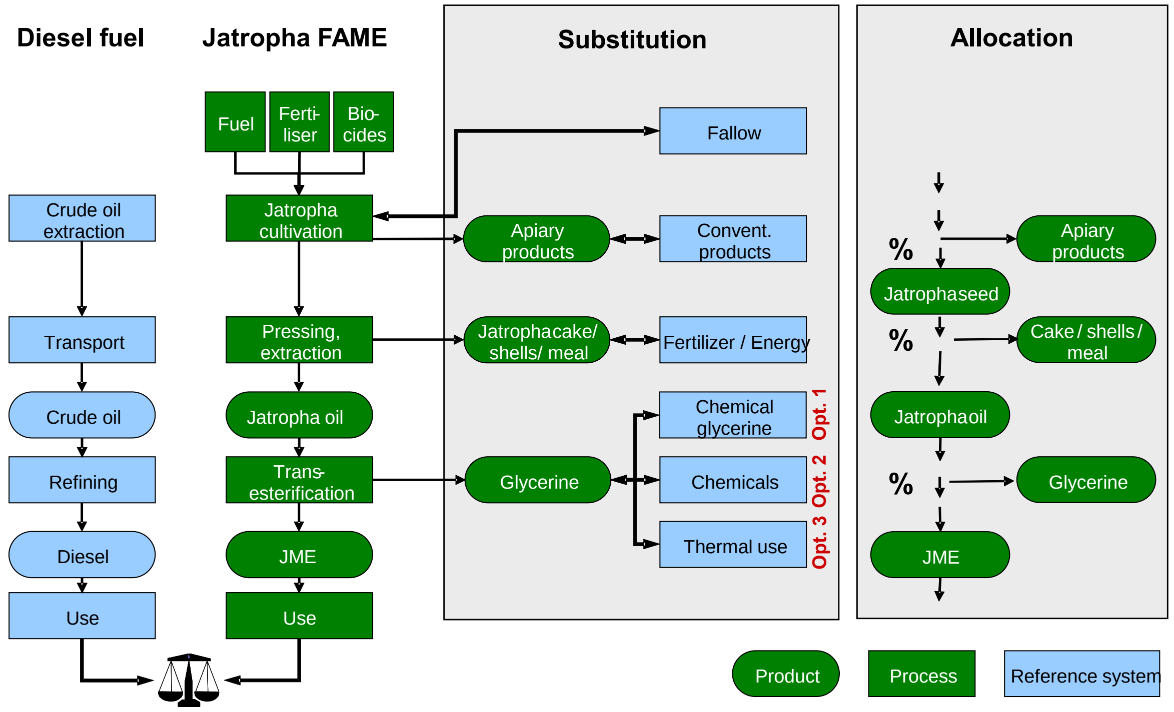

Figure A-1 Exemplary life cycle comparison between Jatropha FAME (Jatropha oil Methyl Ester, JME) and conventional diesel with two different approaches for co-product handling: Substitution or allocation.

Exemplary results for Jatropha FAME for different options in terms of co-product handling are given in the main text (chapter 3.1.1.3, Figure 3-4).

A-1.3 Land use change

Direct and indirect land use change

Land use change is a key issue for GHG assessment of biofuels. If ecosystems (e.g. forest or grassland) are cleared to obtain new agricultural land for fuel, feed or food production, the carbon stocks of the natural ecosystem, which are most often higher than the carbon stocks of an agricultural system, are decreased. The associated GHG emissions can actually overcompensate the emission savings from biofuel production and use and hence lead to a negative GHG balance. Therefore, the way land use change is accounted for is of very high relevance for the assessment of a GHG calculation methodology (cf.

Figure A-5). There are two types of land use change caused by biofuel production:

- Direct land use change (dLUC): Establishing a new plantation on land formerly not used for crop production (e.g. fallow, degraded land, forest, grassland).

- Indirect land use change (iLUC): Bioenergy production on fields or plantations formerly used for food, feed or fibre production. Provided that the demand for food and feed is constant, food and feed production is displaced to another area where again unfavourable land use changes might occur.

DLUC and iLUC are depicted in Figure A-2. Both direct and indirect land use change should be accounted for in GHG assessment of biofuels if possible. All available assessment methodologies include dLUC, while iLUC is only partly integrated (e.g. in the US RFS2 and the Californian LCFS, but not yet in EU RED). ILUC emissions are very difficult to quantify. In many cases, computable general equilibrium (CGE) or partial equilibrium (PE) models are used to assess the impact of an increasing production of a specific biofuel on land use patterns. (cf. chapter 6.2.3). Until now, the results produced by these models vary considerably depending on the underlying assumptions and parameters (cf. chapter 3.2.3). The ongoing scientific debate around these models has proven that none of them is mature enough to deduct an indisputable “iLUC malus” to be used in legal frameworks such as the EU RED.

Within the GEF greenhouse gas calculation tool, a simplified yet highly debated approach is taken: as a proxy for indirect land use change, the so-called ‘iLUC-factor’ developed by (Fritsche et al., 2010) can be included in the calculations (3.5 t CO2 eq per ha). In contrast to iLUC, direct land use changes are based on exact calculations on a separate sheet.

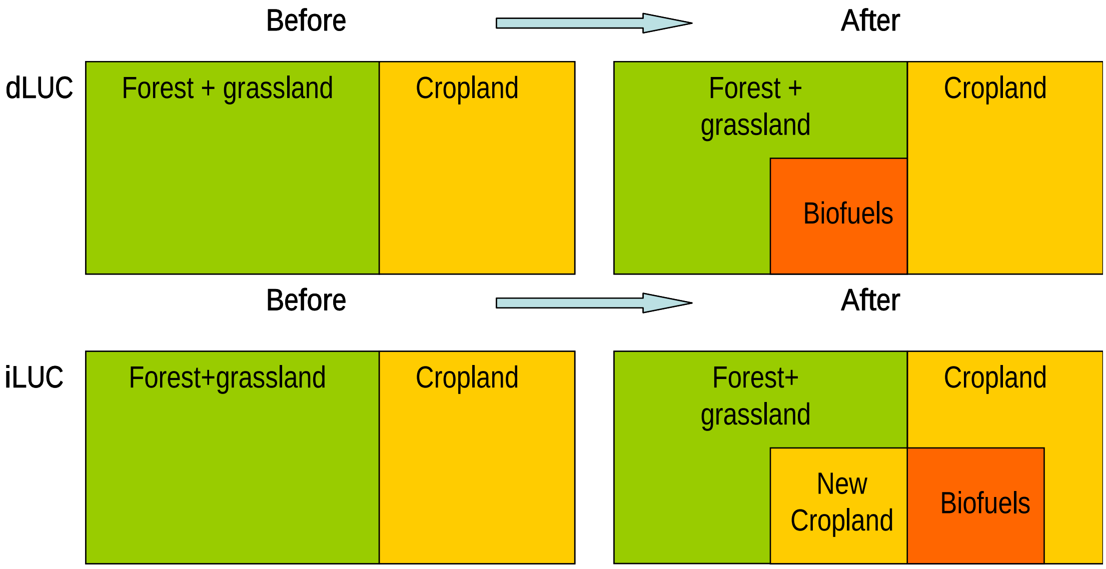

Figure A-2 Direct land use change (dLUC) and indirect land use change (iLUC).

Previous land use, subsequent land use and period under observation

Land use changes affect the carbon stock of above- and below-ground biomass, (living plant biomass and dead biomass as litter or dead wood) and soil organic carbon, The resulting release (or sequestration) of carbon – mainly in form of CO_2 – has to be accounted for in GHG balances. The magnitude of carbon stock changes depend on the previous land use system, the carbon stocks within the plantation and – if applicable – the carbon stocks in a subsequent land use system. Figure A-3 exemplifies how the organic carbon stocks may change over time. Figure A-4 gives some examples for previous and subsequent land use options.

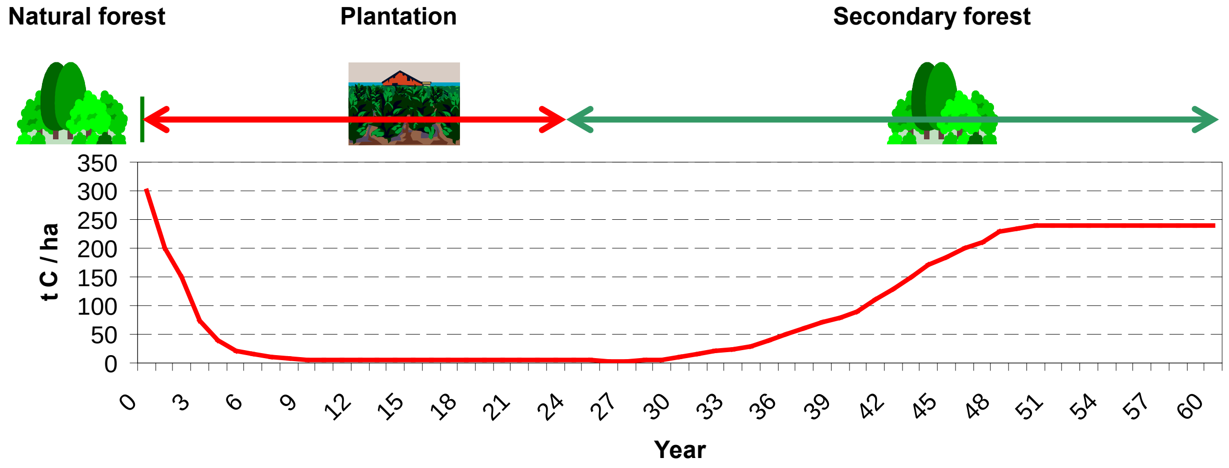

Figure A-3 Example: Carbon stock changes after clearing of natural forest (=previous land use) and establishment of a secondary forest by natural succession after leaving the plantation (=subsequent land use).

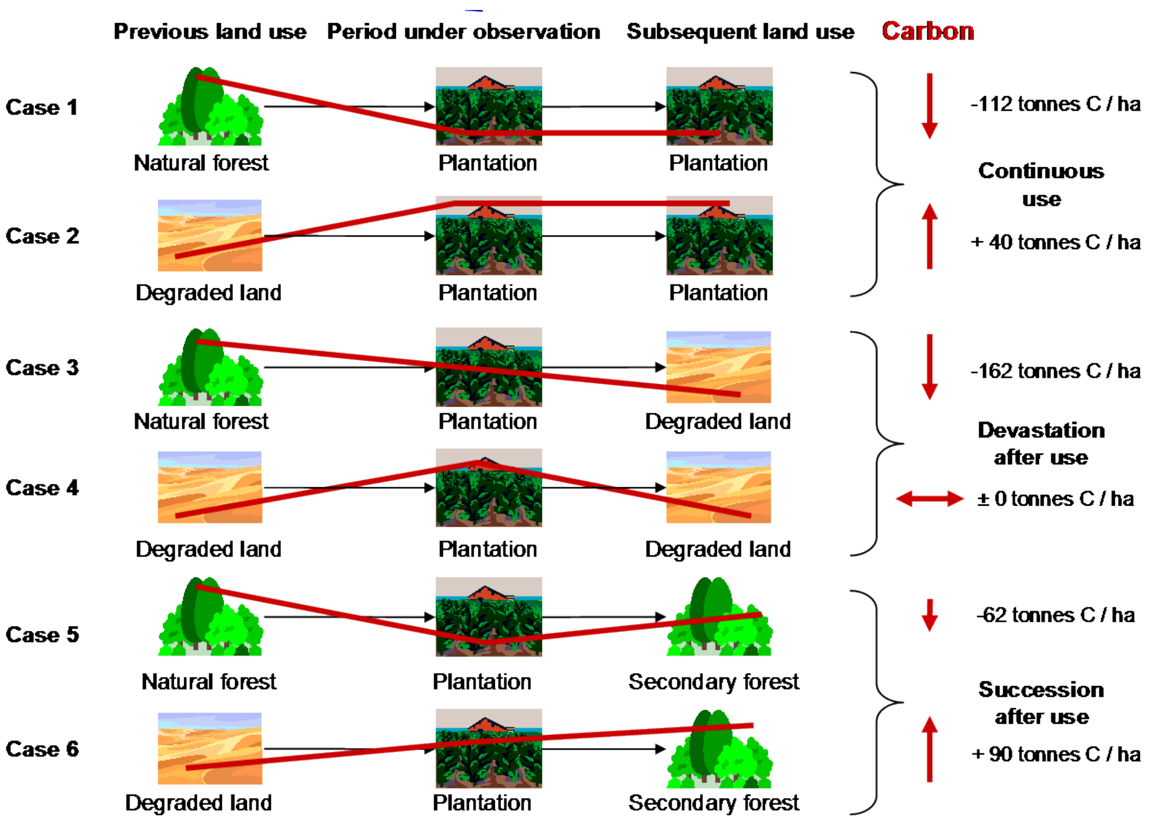

Figure A-4 Effects of previous land use and subsequent land use on C-release per ha.

Annualisation

Greenhouse gas emissions from land use changes can either result from singular events (e. g. clear-cutting a forest) or from continuous processes (e. g. peat oxidation) that prevail for many years after land conversion. Emissions from singular events require an annualisation, i.e. they must be assigned to a certain period of time, because the newly obtained cropland is usually cultivated for a longer time. Following (IPCC, 2006), annualised emissions from carbon stock changes caused by land use change are calculated by dividing total emissions equally over 20 years. A longer use of agricultural land is likely and may justify longer annualisation periods. For example, the typical cultivation period for an oil palm plantation is 25 years. In case of longer agricultural use or in case subsequent land use should be considered, longer annualisation periods as e.g. 100 or 500 years may be suitable. But it has to be considered that long annualisation periods and subsequent land use are linked with a high uncertainty. It is almost impossible to make a sound estimation of land use change systems in 100 or even 500 years. Furthermore, the need to mitigate GHG emissions in a short term to decelerate climate change favours short annualisation periods as recommended by IPCC.

Exemplary results

Figure A-5 shows how direct land use change may affect the GHG balance of GEF case studies. The potential GHG emissions caused by land use change are particularly high in tropical areas with a risk of clear-cutting of tropical forests. Product-related GHG emissions caused by land use change are lower for high-yielding crops like sugar cane compared to low-yielding crops like Jatropha. The table illustrates the GEF case studies and related best and worse case scenarios for GHG reductions (cf. Table A-1).

Table A-1 Greenhouse gas emissions connected to land use change for the different case studies (annualisation of 20 years).

Case study	THG best case		THG worst case		
	[kg CO_2 / GJ]	land use change	[kg CO_2 / GJ]	Land use change	C-content [t C / ha]
Jatropha – Tanzania	-52,43	no land use change	2224,22	Tropical forest	220
Soybean – Argentina	-57,29	no land use change	294,26	Subtropical savanna	50
Poplar – Ukraine	-74,58	no land use change	95,69	Temperate forest	75
Switchgrass – Argentina	-71,79	no land use change	170,48	Subtropical savanna	50
Sugar cane – Mozambique	-73,06	no land use change	151,27	Tropical forest	220
Cassava – Mozambique	-3,53	no land use change	1457,21	Tropical forest	220
Eucalyptus – Mozambique	-42,94	no land use change	704,46	Tropical forest	220
Switchgrass – Argentina	-64,44	no land use change	164,26	Subtropical savanna	50

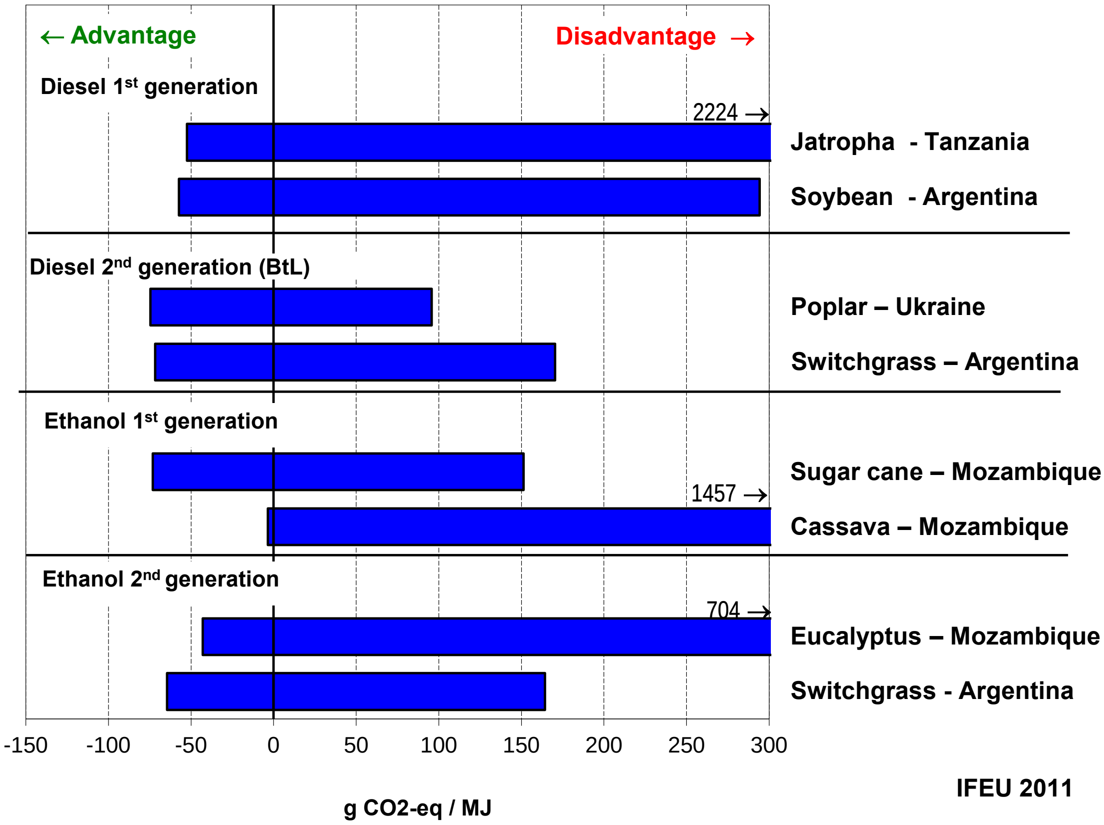

Figure A-5 Range of results of GHG balances for GEF case studies: Minimum and maximum value for different options in terms of direct land use change (all other settings: average of respective predefined scenarios in GEF tool).

A-1.4 Fossil reference product

To calculate GHG savings by biofuels, the emissions of a specific biofuel have to be compared to the emissions of the equivalent conventional fuel (the so called "fossil reference product" of "fossil fuel comparator"). For example, petrol is the fossil reference product for ethanol from sugar cane. The fossil reference product has to be defined in the goal and scope definition of a LCA study. Depending on the specific goal and scope, different fossil reference products might be chosen for the same biofuel:

- Geographical scope or time horizon determine fuel mixes. For example, the "average" diesel substituted by a biodiesel may differ between the US and the EU due to regional differences in petroleum origin and refinery technology.
- Depending on the goal of the study, different specifications of the replaced fuel might be set. Such specifications are e.g. if "average fuel mix", or "fuel from least efficient refinery" or "fuel from marginal crude oil reservoirs" is replaced.

The legally binding acts use the following emission factors for fossil fuels: 83.8 – 94.71 g CO_2 eq /MJ for diesel (min: EU RED, average fossil fuel mix; max: LCFS) and 83.8 –

95.85 g CO_2 eq /MJ for gasoline (min: EU RED, average fossil fuel mix; max: LCFS). Differences in fossil reference emissions may change overall results by up to 20 %. Here the figure illustrates the variability between settings and estimated GHG reductions or increases (cf. Figure A-6).

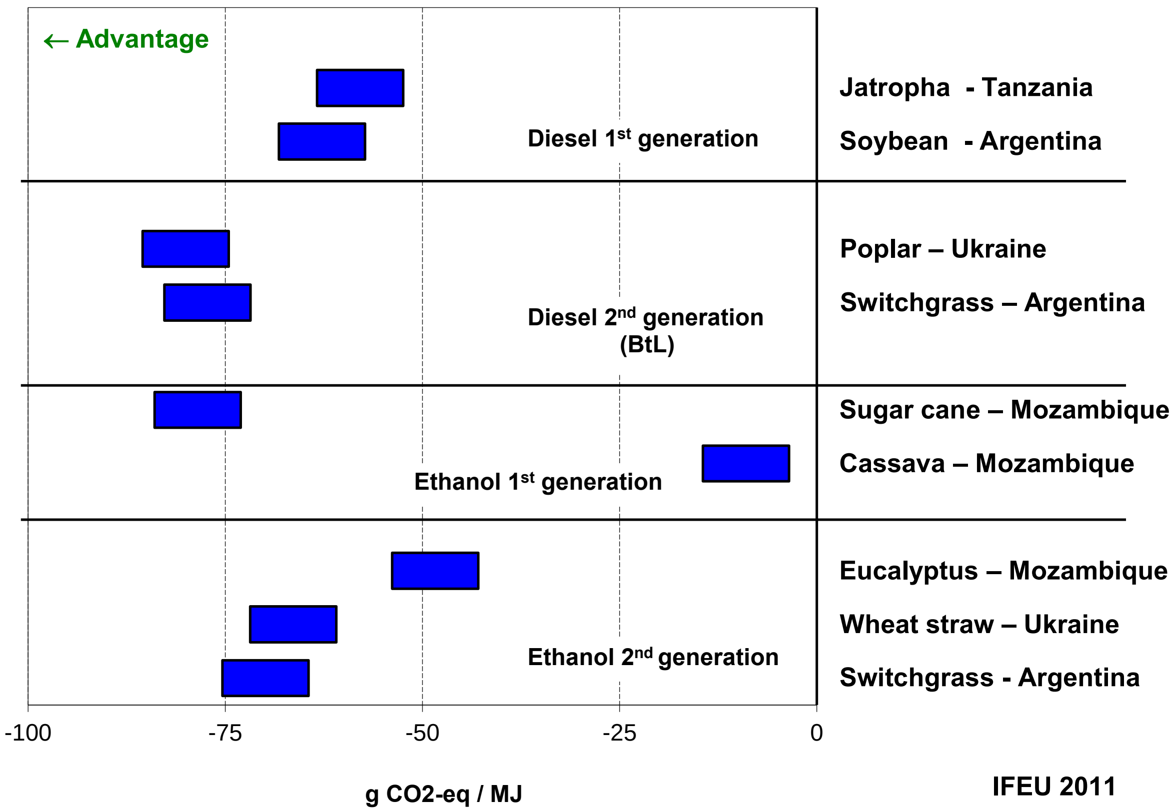

Figure A-6 Range of results of GHG balances for GEF case studies: Minimum and maximum value for different fossil reference products (all other settings: average of respective predefined scenarios in GEF tool).

A-1.5 Definition of primary energy (relevant for energy assessment only)

Non-renewable and total energy use

The depletion of energy resources is assessed in an environmental LCA because energy resources are a limited resource. This is in particular true for non-renewable energy carriers (uranium ore as well as fossil energy carriers such as coal, oil and gas). But also renewable energy is limited at a given point and place in time, e.g. the solar radiation available per hectare and year. Most LCA studies cover the non-renewable energy use, however, studies reporting total energy use can be found.

Strictly speaking, the depletion of energy resources is not an environmental impact per se. However, it correlates well with greenhouse gas emissions, unless carbon stock changes are included in the analysis and/or GHG other than CO2 play a significant role in the analysed system (e.g. CH4 and N2O) (cf. Figure A-7).

Cumulative primary energy demand

In LCA studies, the depletion of energy resources is usually expressed in terms of primary energy. Primary energy is defined as the energy content of primary energy carriers (e.g. fossil fuels, uranium ore, biomass etc.) and primary energy flows (e.g. wind, solar radiation) which have not been subjected to any transformation. The provision of primary energy carriers requires inputs of energy for extraction / mining, processing and transport to the place where the energy carrier is used. When calculating the cumulative primary energy demand associated with the use of a certain energy carrier, these expenditures have to be added to the primary energy carrier's energy content.
If only data on final energy use are available, the primary energy demand is calculated by multiplying the final energy demand (e.g. the amount of a fuel burned) by a so-called "primary energy factor", which covers the demands for extraction / mining, processing and transport of the primary energy carrier as well the efficiency of conversion of primary energy into the final energy (e.g. for conversion of kinetic or thermal energy into electricity).

Regarding biomass, there are different ways of calculating its primary energy content:

- Irradiated solar energy on the entire cultivation area
- Solar energy taken up by the plant
- Solar energy taken up by the plant less the plant's own consumption
- Net calorific value (LHV) of the harvested plant biomass

Most commonly, the primary energy content of biomass is defined as the lower heating value (LHV) of the harvested plant biomass. Figure A-7 exemplarily shows the non-renewable and total primary energy demand for the production of Jatropha FAME in Tanzania (bar 1 and 2). Bar 3 shows the irradiated solar energy per ha in Tanzania.

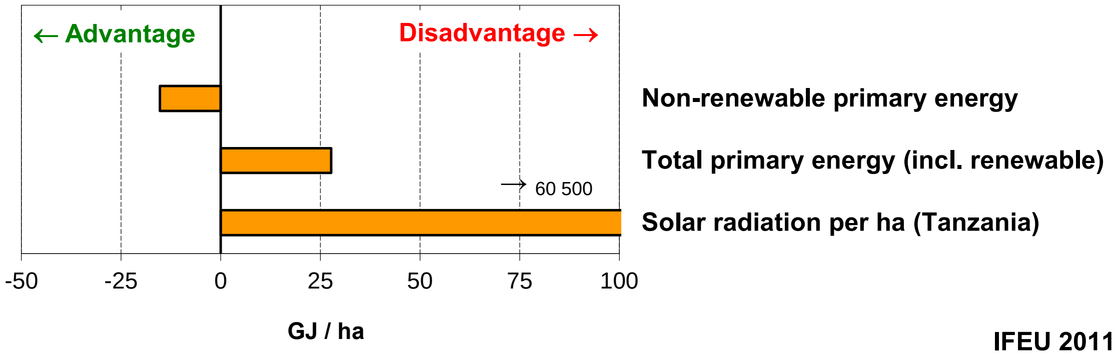

Figure A-7 Exemplary results for different types of area-related energy balances (GEF case study Jatropha, Tanzania): Use of non-renewable primary energy per hectare, total primary energy use per hectare and available solar energy per hectare.

A-1.6 Assessment of fossil and recent carbon (relevant for GHG assessment only)

Carbon dioxide (CO2) emissions can originate from either (recent) biogenic or fossil carbon stocks. In the case of biofuels, the amount of CO2 released into the atmosphere from direct biofuel combustion equals the amount of CO2 that recently has been taken up by

the plants (short carbon cycle). This release of biogenic CO2 is considered carbon neutral, i.e. it does not fuel climate change.
There are two approaches to handle recent and fossil carbon stocks in LCA studies:

(1) to distinguish between CO2 originating from fossil and recent carbon stocks and to include only emissions of fossil by the latter into the LCA.
(2) to assess all (fossil and biogenic) CO2 emissions but also all (biogenic) CO2 uptakes.

Both approaches should lead to identical results. The standard approach among LCA practitioners is to only take into account emissions of fossil CO2.

In some cases of biofuel production, (recent) biogenic carbon and fossil carbon are linked through chemical processes. For example, by producing biodiesel about 10 % of fossil methanol is added during the transesterification process which ends up in the biodiesel molecule. Hence, this biodiesel consists of 10% fossil carbon. If the emissions of biofuel use are set zero as in the EU RED, the fossil carbon originating from the methanol has to be accounted for in the term "emissions from processing" (ep).

A-2 Overview: LCA results for GEF case studies

In the following, the range of results of GHG balances for GEF case studies is shown (Figure A-8: product related; Figure A-9: area related; Figure A-10: relative savings). The results express the variability of GHG savings as a function of the type of farm, type of land, input intensity etc. Variables involving all methodological issues discussed above (land use change, co-product handling, fossil reference etc.) are kept constant. The results highlight the variability of farming and processing systems for different fuels and highlight the importance to gather project-specific data or at least on suitable default scenarios as given in the GEF greenhouse gas calculation tool. Results for primary energy savings are not presented here as they show very similar results as GHG savings (see e.g. Rettenmaier et al. 2010).

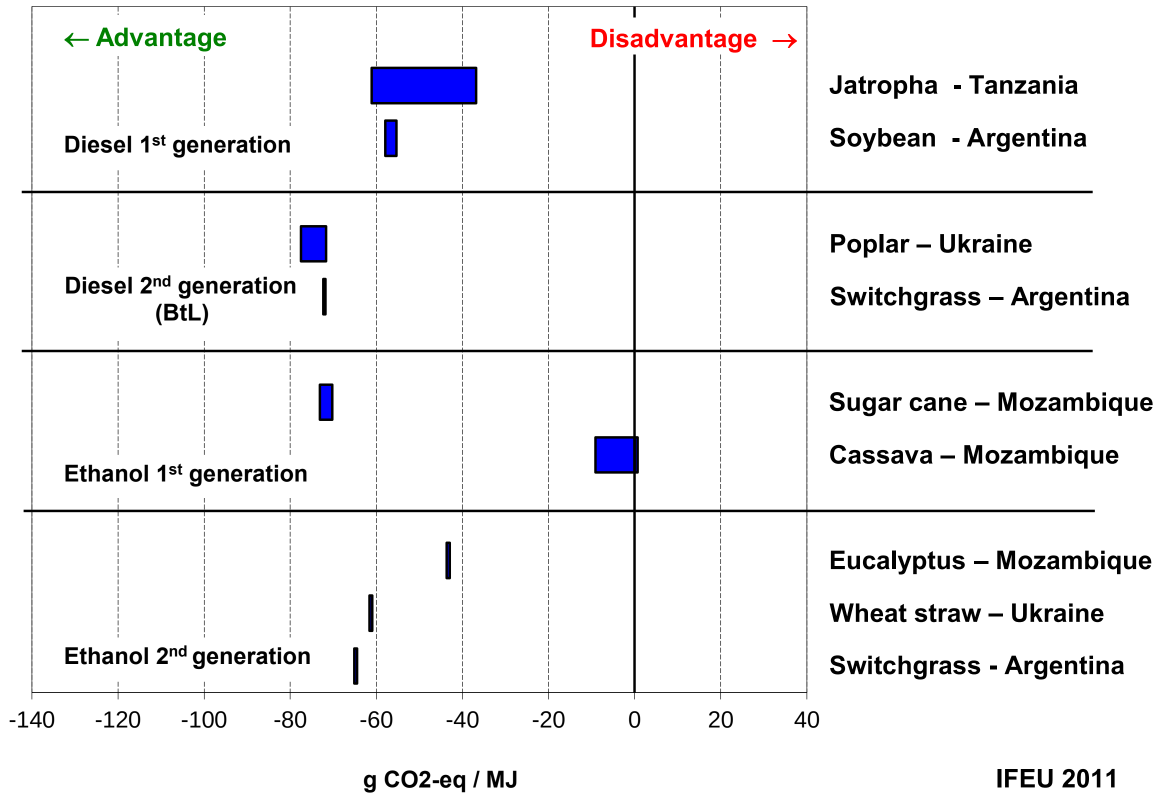

Figure A-8 Results of GHG balances for selected GEF case studies related to the unit product.

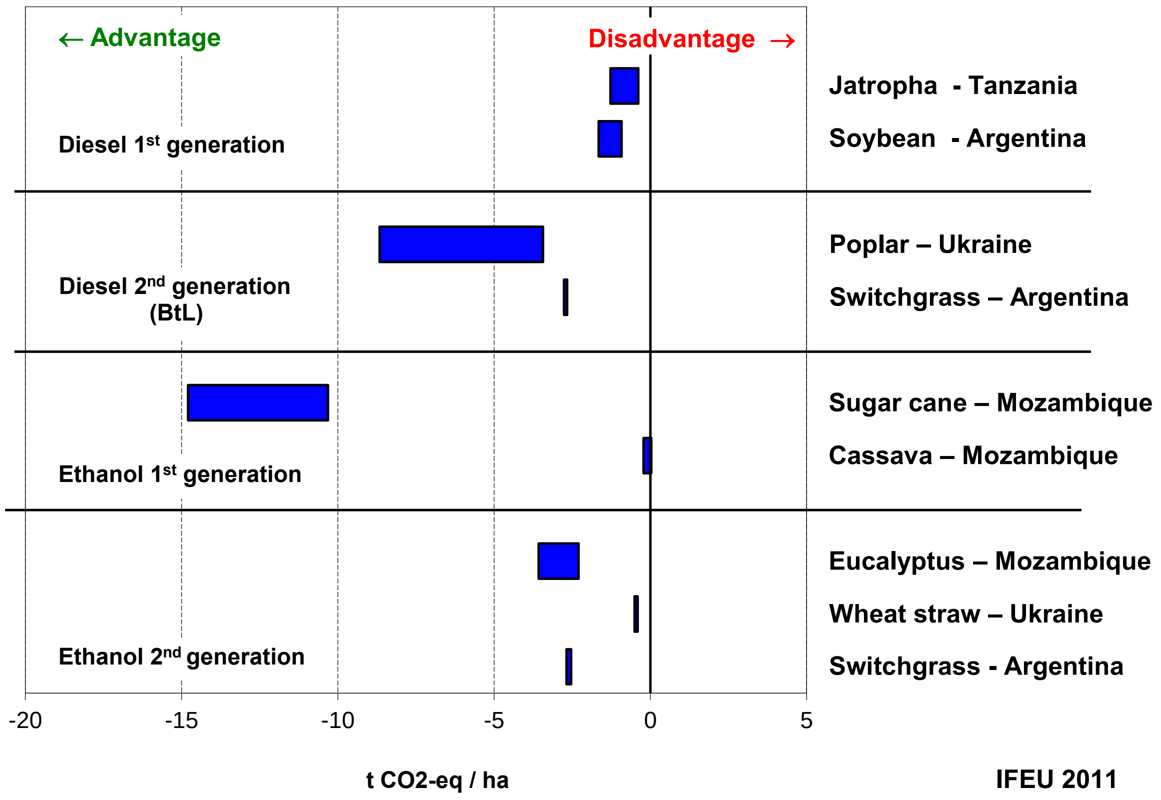

Figure A-9 Results of GHG balances for selected GEF case studies related to the unit area.

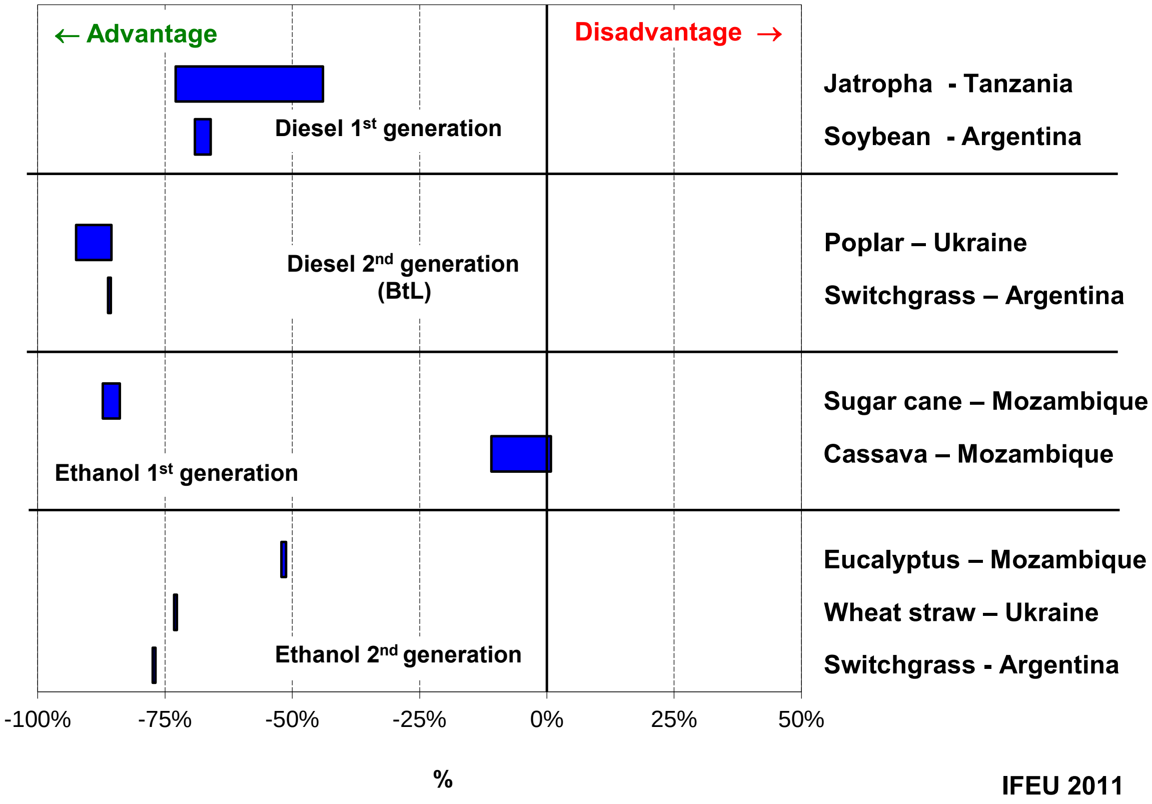

Figure A-10 Relative GHG savings for selected GEF case studies (% GHG savings compared to the fossil reference product).

Appendix B:

Evaluation of GHG calculation in certification systems in the context of GEF
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The following sections provide a detailed overview on the greenhouse gas calculation methodologies applied in international agreements (section C-1), regulatory frameworks (section C-2), and voluntary certification schemes (section C-3). The descriptions consist of three parts: a short description of the system, the role of greenhouse gas calculation within the system and a characterisation table that lists the most important elements of the greenhouse gas calculation methodology.

B-1 International agreements

B-1.1 UNFCCC – United Nations Framework Convention on Climate Change

Short description

The UNFCCC's Clean Development Mechanism (CDM) is one of the three market-based mechanisms included in the Kyoto protocol that are intended to help countries in limiting or reducing their greenhouse gas emissions. Its objective is to link the stimulation of sustainable development and emission reduction in developing countries with the flexibility for industrialised countries on how to meet their greenhouse gas emissions. The basic principle is that emission-reduction (or emission removal) projects in developing countries can earn Certified Emission Reductions (CERs), each equivalent to one tonne CO_2. CERs can be traded and used by industrialised countries to meet part of their emission reduction targets under the Kyoto Protocol. A share of proceeds is used for the UNFCCC Adaptation Fund.

Role of greenhouse gas emission calculations

Greenhouse gas calculation is the key element of CDM projects. In each project, the expected amount of greenhouse gas emissions saved compared to a baseline (business-as-usual) scenario has to be calculated and monitored. The emission reductions claimed are verified after the project phase and assured by a tradeable CER.

CDM provides guidelines, detailed (GHG calculation) methodologies and tools for various project types. In the field of biofuels, there is only one project type which can be approved by CDM: the production of biodiesel from waste oil or dedicated energy crops grown on degraded areas. Besides the specific project calculation methodology, CDM provides methodological tools that cover specific aspects, e.g. the calculation of emissions from the electricity grid. The latter are available for all projects where such aspects are dealt with.

Table B-1 describes the calculation methodology specifically for the above mentioned biodiesel projects. The supplementary methodological tools are mentioned at the corresponding place in the table.

Table B-1 Greenhouse gas calculation according to the CDM baseline and monitoring methodology for the production of biofuels

GENERAL DESCRIPTION	
Name	Approved consolidated baseline and monitoring methodology ACM0017 – Production of biodiesel for use as fuel (Version 02.0.0; EB 56)
Responsible body	UNFCCC (United Nations Framework Convention on Climate Change) Executive body: CDM (Clean Development Mechanism)
Website	http://cdm.unfccc.int/methodologies/DB/Z6UFHXTRQJ2PSZ1EOD21IT8FEF4AE7
Foundation (year, participants)	From 2001 CDM projects could be registered
Scope (products and feedstocks)	- Various methodologies in the field of GHG balancing within the CDM - In the field of biofuels, only this project type / methodology exists; it applies to biodiesel produced from: 1. waste oil/fat; and/or 2. oil crops that are cultivated on dedicated plantations established on lands that are degraded or degrading at the start of the project activity that is used in transport and stationary applications
Scope (geographic)	Developing countries
Type of system	- International agreement - one of the three flexibility mechanisms defined in the Kyoto Protocol
Objectives (mission etc.)	CDM shall stimulate the sustainable development and emission reductions in developing countries, while giving industrialised countries some flexibility in how they meet their emission reduction limitation targets
Biofuel goals	- Only biodiesel consumed in excess of mandatory regulations is eligible for the purpose of the project activity - ‘Additionality’ of project has to be proven, i.e. the methodology is only applicable for baseline scenarios with continuation of current practices with no investment in biodiesel production capacities and with continuation of petroleum diesel consumption
Eligibility of biomass towards goals	*See above*
Domestic / imported feedstock	- Only feedstocks / biodiesel produced and used in developing countries; no exports possible
LAND USE REQUIREMENTS	
Land use restrictions with relevance for GHG calculations	- Plantations shall not be established on peatlands - Area for plantation establishment shall be classified as ‘degraded’ (use of ‘A/R methodological tool for the identification if degraded or degrading lands for consideration in implementing CDM A/R project activities’)
GHG CALCULATION METHODOLOGY	
GENERAL	
Availability of calculation tool	No GHG calculation tool available; there are several so-called ‘methodological tools’, i.e. guidelines that support certain elements of the calculation: - Tool to calculate baseline, project and/or leakage emissions from electricity consumption; - Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion; - Tool to determine project emissions from flaring gases containing methane

Availability of calculation tool	- A/R methodological tool: tool for the identification of degraded or degrading lands for consideration in implementing CDM A/R project activities - Excel sheet for calculating GHG emissions from palm oil and jatropha cultivation
Feedstock sources included	- Waste oil / fat - Vegetable oil that is produced with oil seeds from plants that are cultivated on dedicated plantations established on lands that are degraded or degrading at the start of the project activity - Alcohol for esterification has to be methanol from fossil sources; if other sources (e.g. ethanol) are used, fuel cannot be counted
GHG thresholds	- There have to be GHG emission reductions due to the project activities - If leakage effects from alternative waste oil uses (see 'cultivation' section) leads to negative emission reductions, CERs (Certified Emission Reductions) are not issued until emission reductions from subsequent years have compensated the quantity of negative emissions
General methodology	- Project emissions caused by production and use of biodiesel are compared with baseline scenario emissions that considers fuel production, fuel consumption (i.e. fuel type), alternative use of waste oil / fat - Only the following baseline scenarios (i.e. developments in the absence of the project) are accepted: continuation of current practices with no investment in biodiesel production capacity (in terms of fuel production); continuation of petroleum diesel consumption; continuation of current land use, i.e. continued absence of agricultural and forestry activities on degraded or degrading lands - Emissions of CH_4 and N_2O is only taken into account for the cultivation step, and not in transportation, processing and fuel combustion due to insignificance; CH_4 emission are also taken into account for anaerobic wastewater treatment in crude vegetable oil production
Life cycle elements to be included	Baseline emissions: - Emissions of petrodiesel production and use for biodiesel from oil crops - For biodiesel from waste oils / fats, different baseline scenarios are possible: use of material for biofuel production, for production of substances other than fuel, for energy recovery through incineration, for incineration without energy recovery, disposal in an anaerobic or aerobic manner; if there are alternative uses, leakage effects have to be taken into account (see 'cultivation' section) Project emissions: - Cultivation of oil seeds (not to be taken into account if plantation is included in a CDM A / R (afforestation / reforestation) project) - Transportation of oil seeds / biomass residues from the field to oil production plant, vegetable oil and / or waste oil to biodiesel productsion plant, biodiesel to the site where it is blended with petrodiesel - Biodiesel production plant and vegetable oil production plant - Emissions from methanol that is used during esterification process (fraction of methanol carbon that is included in the biodiesel has to be counted as fossil carbon emission) - Production emissions of methanol (referred to as 'leakage') - Alternative use of waste oil / fats, i.e. displacement of existing uses of these oils that may result in increased demand for fossil fuel elsewhere (referred to as 'leakage'): project participants shall demonstrate that there is a surplus of waste/oil in the project region (definition provided), otherwise a leakage penalty shall be applied - 'Positive leakage' associated with the avoided production and transportation of petrodiesel
CO_2 equivalent factors (GWPs)	IPCC 1995 values - N_2O: 310 - CH_4: 21

Functional unit	t CO_2eq
Infrastructure	Is ignored
Electricity mix for external energy use	Several methodological tools provided by CDM for calculating emissions from electricity use from grid and off-grid power plants (see above); including default emission factors
Data sources for emission and conversion factors	- Several factors are provided in the methodology, others have to be gathered from own sources (e.g. from official data or own measurements) - Guidance on which values to be used is provided in the methodology
Actual / default values	- For palm oil and jatropha there are default cultivation emissions available which can be used instead of actual values - For all other feedstocks and process steps, actual values have to be calculated
Requirements for using default values	No
Requirements for using actual values	No, but only default values for oil palm and jatropha available
LAND USE CHANGE	
General	- Conversion of high carbon stock vegetation is excluded from the onset since only degraded soils may be used for plantations
Direct land use change	- Emissions resulting from changes in soil carbon stocks following land use changes or changes in the land management practices should be taken into account - For perennial plants only, if carbon stock in above and below ground biomass is higher in the project case than in the baseline these emissions are expected to be negligible and they are accounted for as zero - If carbon stocks in soil carbon pools increase as a result of the project activity, these increases should not be accounted as emission reductions but should be assumed as zero
Reference land use	Land use / land management before project start / without project activities
Cut-off date	Project start
Annualisation	Time dependence of the stock change factor for mineral soils: - 20 years for renewable crediting period - 10 years for single crediting period
Carbon stock included	Only soil carbon stocks (mineral and organic soils)
Calculation of carbon stocks	- IPCC 2006 Tier 1/2 approach Mineral soils: - IPCC Tier 1 approach - It is assumed that soil carbon stocks where in an equilibrium before the implementation of the project and change in a linear fashion during a transition period to a new equilibrium - Emissions are calculated based on difference between the soil organic carbon before and after implementation of the project activity and the duration of the transition period Organic soils: - Use of annual emission factor (IPCC default values) that estimates the losses of carbon following drainage
Indirect land use change	- Not included in GHG calculations - In project it shall be guaranteed that activities do not lead to a shift of pre-project activities outside the project boundary, i.e. the land under the proposed project activity can continue to provide at least the same amount of goods and services as in the absence of the project

Bonus for cultivation on degraded land	*Not applicable* - Project plantations have to be established on land classified as degraded or degrading
CULTIVATION / ACQUISITION OF RAW MATERIAL	
Processes to be taken into account	OPTION A: use of default values - for palm oil and jatropha conservative default values for two climate zones are available OPTION B: calculation based on actual data from cultivation process - Fossil fuel consumption for agricultural operations (use of 'Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion') - Electricity consumption for agricultural operations (e.g. irrigation; use of 'Tool to calculate baseline, project and/or leakage emissions from electricity consumption') - N_2O emissions from application of synthetic and organic fertilisers - CO_2 emissions from urea application - CO_2 emissions from application of limestone and dolomite - CH_4 and CO_2 emissions from field burning of biomass (e.g. after harvest) - N_2O emissions from land management at the plantation (e.g. drainage / management of organic soils) - Emissions from the production of synthetic fertiliser that is used in the plantation - CO_2 emissions resulting from changes in soil carbon stocks following land use changes or changes in the land management practices *For waste oils/fats:* if they are already used for energy or material purpose, project participants have to prove that there is a 25 % surplus in the project region; otherwise leakage emissions have to be calculated: - If oil was used for biofuel or energy production: most carbon intensive fuel oil in region is used as reference - If oil was used for material applications: the equivalent amount of fossil fuel which is necessary to replace the waste oil is calculated based on conversion coefficients
N_2O field emissions	- Direct N_2O emissions from synthetic and organic fertiliser application (1%) - Direct N_2O emissions from land management at plantation (crop residues returned to soil including N-fixing crops, soil emissions due to land use or land management changes such as drainage of organic soils) - Indirect N_2O emissions due to atmospheric deposition of nitrogen volatilised from the soil of the plantation and due to leaching / run-off
Use of average values	*Not applicable*
TRANSPORTS	
Processes to be taken into account	- Only need to be accounted if distances of more than 50 km are covered - Oil seeds to oil production plant - Vegetable oil and / or waste oil to biodiesel production plant - Biodiesel to the site where it is blended with petrodiesel
Calculation procedure	- OPTION 1: calculation based on distance and the average truck load (using an emission factor for vehicles transporting material) - OPTION 2: calculation based on actual quantity of fossil fuel consumed for transportation (using an emission factor for fuel type)

PROCESSING	
Processes to be taken into account	- Fossil fuel and electricity consumption; only electricity from grid is considered (using tools to calculate 'project or leakage CO_2 emissions from fossil fuel combustion' and 'baseline, project and/or leakage emissions from electricity consumption') - If applicable, methane emissions from anaerobic treatment of wastewater in oil production plant (also if methane is flared) - Fossil carbon in the biodiesel due to the use of methanol from fossil origin in esterification process - Emissions from methanol production (referred to as 'leakage')
Use of actual values	*Not applicable*
Excess electricity from cogeneration	*Not included*
CO-PRODUCTS	
General	- Glycerol has to be incinerated for energy production or used as raw material for industrial consumption - Project emissions are allocated between biodiesel and glycerol and, where applicable, emissions associated with the cultivation of land are allocated between the different products from the plants (see 'Draft guidance on apportioning of emissions to co-products and by-products')
Basis for allocation	Four approaches possible: - Allocation based on market price if transparent and reliable information on market price is available - Substitution - Allocation by energy content (only if all main, co- and by-products are fuels) - Attribution of all emissions to main product as a conservative approach; cannot be used for baseline emissions In exceptional cases, project participants may propose different allocation rules if they can justify that they are better suited.
Exemptions	- Residues / waste are not allocated (products that have no or negligible revenues) - If co- or by-products are not sold on the market and are not used / consumed, no emissions shall be apportioned - If a co- or by-product is currently not used in the market or is available in excess and project participants plan to use it under CDM project activities, no emissions shall be allocated
FUEL USE	
Emissions from combustion	- CH_4 and N_2O from fossil fuel use not included for simplification (assumed to be very small)
FOSSIL FUEL COMPARATOR	
	- Emissions from avoided production of petrodiesel are calculated (referred to as 'leakage') - Elements included: production of crude oil, oil refinery, long distance transport - Infrastructure not included, distribution to filling station not included (balances with emissions of biodiesel to blending facility) - Long distance transport: only transports within host countries are taken into account; international transports are not included since CDM projects cannot claim emission reductions from international bunker fuel consumption

B-1.2 GBEP – Global Bioenergy Partnership

Short description

The Global Bioenergy Partnership (GBEP) was launched at the G8 summit 2005 in Gleneagles to initiate an international discussion on the issues related to bioenergy. The objectives are to support bioenergy deployment particularly in developing countries, to work on biofuel best practices and to advance the sustainable development of bioenergy. At present there are 18 countries, 10 organisations and 20 observers participating in the partnership. Priority areas are to facilitate the sustainable development of bioenergy, to develop a common methodological framework on GHG emission reduction measurement from the use of bioenergy, to facilitate capacity building for sustainable bioenergy and to raise awareness and facilitate information exchange on bioenergy. Two task forces have been set up for developing sustainability indicators and for developing a GHG calculation framework. The task force on sustainability defined a set of 24 voluntary sustainability indicators for bioenergy which was endorsed by the Steering Committee in May 2011. One of the environmental indicators specifies that GBEP considers lifecycle GHG emissions relevant. They shall be based on calculation methodologies chosen nationally or at community level and reported using the GBEP methodological framework.

Role of greenhouse gas emission calculations

The task force on GHG balancing methodologies defined ‘The GBEP Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy’. Its main objective is to make greenhouse gas balancing more transparent and to facilitate the comparison between different bioenergy production systems and between different LCAs. Furthermore, it shall enable countries and organisations to evaluate bioenergy GHG emissions in a consistent manner. Consequently, it does not provide a strict calculation methodology, data standards or particular emission models but a checklist which can be applied to GHG balancing for communicating the details of the specific LCA methodologies applied.

The framework includes 10 ‘steps’:

1. Greenhouse gases covered
2. Source of biomass
3. Land use changes due to bioenergy production
4. Biomass feedstock production on farms and in forests
5. Transport of biomass
6. Processing into fuel
7. By-products and co-products
8. Transport of fuel
9. Fuel Use
10. Comparison with replaced fuel

For each step the framework presents a series of yes/no questions and checkboxes, with requests for further explanation where appropriate. With this checklist model, the framework can be used as guidance by many different target groups such as governments, biofuel producers or non-government organisations. Table B-2 provides a detailed description of the elements covered by the framework.

Table B-2 Greenhouse gas calculation according to the GBEP methodological framework for GHG lifecyle analysis

GENERAL DESCRIPTION	
Name	The GBEP Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy – Version Zero
Responsible body	Global Bioenergy Partnership; GBEP
Website	http://www.globalbioenergy.org
Foundation (year, participants)	2005, G8 + 5
Scope (products and feedstocks)	All bioenergy for transport and for stationary heat and electricity generation
Scope (geographic)	Global
Type of system	International methodological framework
Objectives (mission etc.)	- Facilitate emission comparisons between different bioenergy production systems and comparison of existing LCAS - Ensure that countries and organisations can evaluate bioenergy GHG emissions in a consistent manner
Biofuel goals	*Not applicable*
Eligibility of biomass towards goals	*Not applicable*
Domestic / imported feedstock	*Not applicable*
LAND USE REQUIREMENTS	
Land use restrictions with relevance for GHG calculations	No restrictions within the methodological framework; land use and land use change is part of the 24 sustainability indicators endorsed by GBEP
GHG CALCULATION METHODOLOGY	
GENERAL	
Availability of calculation tool	No calculations are made within the framework but qualitative information on specifications and settings are asked for
Feedstock sources included	To be reported by user; distinguishes between non-waste and residues / waste (a definition for the latter two is asked for)
GHG thresholds	*Not applicable*
General methodology	No LCA methodology but a framework with checklists to document qualitative information related to GHG calculations

Included life cycle elements	- Land use changes due to bioenergy production - Biomass feedstock production on farms and in forests - Transport of biomass - Processing into fuel - By-products and co-products - Transport of fuel - Fuel use - Comparison with replaced fuel
CO_2 equivalent factors (GWPs)	To be reported by user (CO_2, CH_4, N_2O, HCFs, PCFs, SF_6, others)
Functional unit	Mostly qualitative information is asked for; where quantitative data are to be provided, functional units have to be documented by the user
Electricity mix	User shall report whether GHG emissions from energy sources (including electricity) are taken into account; method used to account grid-related emissions shall be specified: e.g. average/marginal, national/regional, actual/future
Infrastructure	User shall report which sources of GHG emissions embodied in inputs were accounted for: - Emissions embodied in the manufacture of farm/forestry machinery - Emissions embodied in buildings - Other (to be specified)
Data source of GHG emission factors	To be reported by user whether methodologies and data used are publicly available
Actual / default values	*Not applicable*
Requirements for using default values	*Not applicable*
Requirements for using actual values	*Not applicable*
LAND USE CHANGE	
General	- To be reported by user whether direct or indirect land use changes or a combination of both are taken into account - Relevant key reference assumptions and characteristics need to be explained (e.g. system boundaries, omitted emission sources etc.) - User has to describe how the methodology attributes type of land use change to biofuel
Direct land use change	
Reference land use	To be reported by user; can choose between historic (specific year), business-as-usual (specific time frame), others (to be explained)
Cut-off date	To be reported by user
Annualisation	To be reported by user

Carbon stock included	To be reported by user which of the carbon stocks have been taken into account: living biomass, dead organic matter, soil, changes in carbon stocks in products
Calculation of carbon stocks	To be reported by user whether methodology and data are publicly available
Other	
Indirect land use change	Distinguishes between domestic and international indirect land use change and combinations of both; same procedure as for direct land use change
Bonus for cultivation on degraded land	*Not applicable*
CULTIVATION	
Processes to be taken into account	User shall report which of the following processes where taken into account: - Emissions from operating farm/forestry machinery - Emissions from energy used in irrigation - Emissions from energy used to prepare feedstocks (drying grains, densification of biomass, etc.) - Emissions from energy used in transport of feedstocks - CO_2 emissions from lime/dolomite applications - N_2O emissions resulting from the application of nitrogen fertilisers (direct; volatilisation; runoff/leaching) - CH_4 emissions from lands (especially wetlands) - Net changes in soil organic carbon (due to management practices, not land use conversion) - Emissions embodied in the manufacture of fertiliser inputs. - Emissions embodied in the manufacture of pesticide inputs - Emissions embodied in the production of seeds - Other (to be specified)
N_2O field emissions	To be reported by user (see above)
Use of average values	*Not applicable*
TRANSPORTS	
Processes to be taken into account	User shall report whether the following aspects are taken into account: - Transports from production site to use / processing plant and to the use site - Intermediate processing steps and its emissions - Emission from empty or otherwise utilised return runs
Calculation procedure	*Not applicable*
PROCESSING	

Processes to be taken into account	User shall report whether - GHG emissions associated with material inputs used in the conversion process (e.g. chemicals, water) are accounted for - GHG emissions associated with the energy used in the conversion process are accounted for (specify the method used to account for grid-related emissions (e.g. average/marginal, national/regional, actual/future)) - GHG emissions from wastes and leakages (including waste disposal) are accounted for. - Other GHG emissions from the process are accounted for (to be specified).
Use of actual values	*Not applicable*
Calculation procedure	*Not applicable*
Average emissions	*Not applicable*
Excess electricity from cogeneration	*Not applicable*
CO-PRODUCTS	
General	User shall specify which co-products are taken into account and how co-products are defined
Procedure	User shall report whether allocation or substitution or a combination or other methods have been applied
Basis for allocation	To be reported by user: mass, energy content, economic value, other; if substitution method is applied, user shall specify methodology used to determine the exact type of use / application of a co-product and method used to determine reference product
Exemptions	To be reported by user
FUEL USE	
Emissions from combustion	For stationary application, user shall report on specifications of plant where fuel is used (e.g. efficiencies etc.): - Efficiencies - Electricity sent to general grid - For CHP, method used to account for electricity and heat - Non-CO_2 emissions from combustion - Whether biomass is tainted with fossil material For transport fuels, user shall report on miles (km) per energy units and on tailpipe emissions

FOSSIL FUEL COMPARATOR	
	User shall report on all specifications applied for the calculation of the fossil fuel: - Methodology for LCA of replaced fuel / energy production system - Greenhouse gases covered - Whether an LCA has been performed on the replaced fuel / energy production system - Which sources of emissions embodied in infrastructure have been taken into account For replaced transport fuels, the following elements shall be reported: - Relevant characteristics of crude - Whether emission prior to extraction are accounted for - Emissions from extraction / production that are accounted for - Emissions from crude transport - Refinery emissions - Fuel transport prior to use - Fuel use emissions - Other emissions For stationary use, the following shall be reported: - Technologies, methodologies, data for calculating the extraction / production / transport of replaced energy source - Fuel emissions

B-1.3 International Standard – ISO 13065

The International Standardisation Organisation (ISO) works on developing sustainability criteria for the production, supply chain and application of bioenergy. This includes terminology and aspects related to the sustainability of bioenergy. The standard is currently under development by the ISO project committee, ISO/PC 248, Sustainability criteria for bioenergy.

The committee brings together international expertise and state-of-the-art best practice to discuss the social, economic and environmental aspects of bioenergy, and identify criteria that could prevent it from being environmentally destructive or socially aggressive. Some 29 countries are involved as participants or observers, including large markets such as China and the USA.

The standard also covers greenhouse gas calculation. However, it is not the aim of the standard to create a full GHG calculation methodology but rather to establish requirements to which GHG calculations must comply. These requirements are based on the life cycle assessment methodology as regulated by ISO 14040 and ISO 14044.

At present, there only a preliminary version of the standard exists and final results will not be available until late 2012. Therefore, no characterisation table is included here.

B-1.4 CEN Standard - prEN 16214-4

Within the European Committee for Standardisation (CEN9, the Technical Committee (TC) 383 Sustainability produced biomass for energy applications was created in 2008 in order to work on European standards dealing with sustainability principles, criteria and indicators including their verification and auditing schemes for biomass for energy applications. This includes green house gas emission and fossil fuel balances, biodiversity, environmental, economic and social aspects and indirect effects within each of the aspects.
The framework for the scope of the work of TC 383 is set by the European Renewable energy Directive (RED; see section B-2.3).
The standard prEN 16214-4 provides a detailed GHG calculation methodology that will allow any economic operator in a biofuel or bioliquid chain to calculate the actual GHG emissions associated with its operations in a standardised and transparent manner. The methodology strictly follows the principles and rules stipulated in the RED. Where appropriate these rules are clarified, explained and further elaborated.

Since the standard is still under development, no characterisation table included here. For the methodology as stipulated in the RED, refer to Table B-5.

B-2 Regulatory frameworks

B-2.1 RFS2 – US Renewable Fuel Standard

Short description

The Renewable Fuels Standard program was developed under the Energy Policy Act in 2005. It required gasoline to contain a minimum amount of fuel produced from renewable sources. The aim is the reduction of greenhouse gas emissions from the use of renewable fuels, reductions of imported petroleum and the expansion of the renewable fuel sector. A credit trading system was established to provide flexibility to the fuel producers.

In 2007, the Energy Independence and Security Act (ESIA) required changes to the RFS program and expanded it significantly (now referred to as RFS2). It now includes all transportation fuels and heating oil and requires the use of 9.0 billion gallons of renewable fuel in 2008, increasing to 36 billion gallons in 2022. There are four categories of biofuels (biomass-based diesel, cellulosic biofuels, advanced biofuels, renewable biofuel) for which annually specific volume standards were developed.

In order to qualify for these volume standards, the fuels must demonstrate that they meet certain minimum greenhouse gas reduction standards. There are four different reduction requirements for the four renewable fuel categories. In addition to the greenhouse gas reduction goals, renewable fuel has to be produced from feedstock that qualifies as 'renewable biomass'. It limits the types of biomass as well as the type of land from which the biomass can be harvested. The requirements apply to both US and imported biomass.

Role of greenhouse gas emission calculations

In order to qualify for the mandatory renewable fuel volumes, the fuels have to prove compliance with certain greenhouse gas emission thresholds. There are four different thresholds for the four different renewable fuel categories. However, in contrast to most other schemes presented here, no individual greenhouse gas calculations have to be made by market operators. Rather, the US Environmental Protection Agency (EPA) pre-calculated and modeled the life cycle greenhouse gas emissions for a range of renewable fuel pathways (combination of fuel type, feedstock, production process). The results from the directly modeled pathways can be extended to pathways covering the same fuel type and feedstock as a modeled pathway but with feedstock production sources that were not included in the analysis (e.g. corn ethanol produced in another country) as well to other feedstocks with low risks of not complying (e.g. waste). All pathways that comply with the GHG emission thresholds are included in so-called lookup tables (see Figure B-1 for an excerpt). They are assigned a certain code which is needed by fuel producers to generate so-called Renewable Identification Numbers (RINs). These numbers are used for credit trading and for compliance demonstration. For generating the appropriate number, the producer has to consider the type of feedstock used (e.g. cellulosic biofuel must be made from cellulosic feedstocks) and the process (biomass-based diesel cannot be produced from co-processing renewable biomass and petroleum).

Fuel type	Feedstock	Production process requirements	D-Code
Biodiesel, and renewable diesel.	Soy bean oil; Oil from annual covercrops; Algal oil; Biogenic waste oils/fats/greases; Non-food grade corn oil.	One of the following: Trans-Esterification Hydrotreating Excluding processes that co-process renewable biomass and petroleum.	4
Biodiesel, and renewable diesel.	Soy bean oil; Oil from annual covercrops; Algal oil; Biogenic waste oils/fats/greases; Non-food grade corn oil.	One of the following: Trans-Esterification Hydrotreating Includes only processes that co-process renewable biomass and petroleum.	5
Ethanol	Sugarcane	Fermentation	5
Ethanol	Cellulosic Biomass from agricultural residues, slash, forest thinnings and forest product residues, annual covercrops; switchgrass, and miscanthus; cellulosic components of separated yard wastes; cellulosic components of separated food wastes; and cellulosic components of separated MSW.	Any	3
Cellulosic Diesel, Jet Fuel and Heating Oil.	Cellulosic Biomass from agricultural residues, slash, forest thinnings and forest product residues, annual covercrops, switchgrass, and miscanthus; cellulosic components of separated yard wastes; cellulosic components of separated food wastes; and cellulosic components of separated MSW.	Any	7
Butanol	Corn starch	Fermentation; dry mill using natural gas, biomass, or biogas for process energy.	6
Cellulosic Naphtha	Cellulosic Biomass from agricultural residues, slash, forest thinnings and forest product residues, annual covercrops, switchgrass, and miscanthus; cellulosic components of separated yard wastes; cellulosic components of separated food wastes; and cellulosic components of separated MSW.	Fischer-Tropsch process	3
Ethanol, renewable diesel, jet fuel, heating oil, and naphtha.	The non-cellulosic portions of separated food wastes.	Any	5
Biogas	Landfills, sewage and waste treatment plants, manure digesters.	Any	5

Figure B-1 Excerpt from a lookup table in the RFS

If a pathway is not included in the tables, the producer can still generate a RIN if it falls within an exception (certain biofuels do not have to meet the 20% threshold) and if the fuel meets the definition of ‘renewable fuel’. If the pathway does not fall within an exception, the producer may petition the EPA for its assessment.

Table B-3 shows the major specifications of greenhouse gas balancing under the RFS2.

Table B-3 Greenhouse gas calculation in the RFS2

GENERAL DESCRIPTION	
Name	US Renewable Fuel Standard; RFS2
Responsible body	US Environmental Protection Agency (EPA)
Website	http://www.epa.gov/otaq/fuels/renewablefuels/index.htm
Foundation (year, participants)	The RFS program was expanded in 2007 under the Energy Independence and Security Act (ESIA) and became RFS2.
Scope (products and feedstocks)	Sets volumes of renewable fuels to be blended into transport fuel (diesel and gasoline) in road and non-road vehicles except for ocean going vessels; also renewable fuel used for heating and as jet fuel may be counted (so-called 'additional renewable fuel')
Scope (geographic)	Biofuel goals apply to the USA; specific requirements apply to domestic and imported biomass
Type of system	Law
Objectives (mission etc.)	- Achieve significant reduction of greenhouse gases from the use of renewable fuels (requires US EPA to calculate lifecycle greenhouse gas performances of the renewable fuels) - Reduce imported petroleum - Encourage the development and expansion of the renewable fuels sector
Biofuel goals	- Renewable fuel required to be blended into transportation fuel will increase from 9 billion gallons in 2008 to 36 billion gallons by 2022; total amount is translated into annual volume requirements - Specific annual volume requirements exist for four different renewable fuel categories (renewable fuel, advanced biofuel, biomass-based diesel, cellulosic biofuel)
Eligibility of biomass towards goals	- Only feedstock that meets the definition 'renewable biomass' may be counted: 1. Planted crops and crop residue from agricultural land cleared prior to December 19, 2007 and actively managed or fallow on that date 2. Planted trees and tree residue from tree plantations cleared prior to December 19, 2007 and actively managed on that date 3. Animal waste material and byproducts 4. Slash and pre-commercial thinnings from non-federal forestlands that are neither old-growth nor listed as critically imperiled or rare by a State Natural Heritage program 5. Biomass cleared from the vicinity of buildings and other areas at risk of wildfire 6. Algae 7. Separated yard waste and food waste - Only biofuel pathways that meet the GHG thresholds may be counted to-

	wards the volume (four specific GHG reduction thresholds for the four renewable fuel categories)
Domestic / imported feedstock	Requirements apply to feedstock produced outside and inside the US

LAND USE REQUIREMENTS	
Land use restrictions with relevance for GHG calculations	- No direct exclusion of land with high carbon stock - Indirectly since planted crops and trees only may be harvested from land that was cleared or cultivated prior to December 2007 and actively managed since then
GHG CALCULATION METHODOLOGY	
GENERAL	GHG reductions have been pre-calculated by US EPA for certain pathways (combination of fuel type, feedstock, production process) in order to determine which biofuels qualify for the four GHG reduction thresholds and renewable fuel categories established in EISA ➔ individual facilities are not required to demonstrate that they meet GHG thresholds
Availability of calculation tool	*Not applicable as no individual calculations are required by market operators*
Feedstock sources included	Biofuels that meet the GHG thresholds: - Ethanol produced from corn starch at a new natural gas, biomass, or biogas fired facility using advanced efficient technologies meets 20% threshold (coal fired will not) - Sugarcane ethanol (multiple pathways) meets 50% threshold - Biodiesel (soy, wastes, algae) meets 50% threshold - Butanol from corn starch meets 20% threshold - Cellulosic ethanol and diesel fuel (thermal and biochemical from stover, switchgrass) meets 60% threshold - Additional pathways: biodiesel and renewable diesel from canola oil and palm oil; ethanol from grain sorghum and biofuel from wood pulp - Results can be extended to the same fuel type and feedstock as a modeled pathway but with feedstock production sources that were not included in analysis (e.g. corn ethanol produced in another country) - Results can be extended to other fuel pathways with low risk of non-compliance: 1. Crop residues (e.g. corn stover, wheat straw, rice straw, citrus residue) 2. Forest material (including eligible forest thinnings and solid residue remaining from forest production) 3. Annual cover crops planted on existing crop land (e.g. winter cover crops) 4. Separated food and yard waste including biogenic waste from food processing 5. Perennial grasses including switchgrass and miscanthus
GHG thresholds	- Renewable fuel (ethanol from corn starch and any other qualifying renewable fuel that meets the threshold): 20% - Advanced biofuel (all biofuels other than corn starch that meet the threshold; includes biodiesel and cellulosic biofuel): 50% - Biomass-based diesel (all biodiesel): 50% - Cellulosic biofuel (fuel from cellulose, hemicellulose, lignin): 60%

General methodology	- Based on partial equilibrium models (FASOM for domestic agricultural sector, FAPRI-CARD for international agricultural sector): differences in total GHG emissions have been compared between two future volumes; determination of the overall impacts in response to a given volume change in the amount of biofuel produced - Changes in fertiliser, energy use, livestock are combined with GHG emission factors (both for domestic and international changes) Two settings for comparison: 1. 'Business-as-usual-scenario' compared to a second scenario with higher volumes of renewable fuels 2. Base yield case vs. high yield case
Life cycle elements to be included	Well-to-wheel, including direct emissions and indirect emissions such as emissions from land use changes Processes considered: - feedstock agriculture - feedstock transport - feedstock processing & biofuel production - biofuel transport and distribution - biofuel tailpipe emissions
CO_2 equivalent factors (GWPs)	IPCC 1995 values: N_2O: 310 CH_4: 21
Functional unit	g CO_2eq/mmBtu (= 293.071 kWh or 1055 MJ)
Infrastructure	Direct emissions from construction and infrastructure are excluded.
Electricity mix for external energy use	- national averages in country of consumption - marginal electricity mixes for surplus electricity (e.g. from bagasse)
Data sources for emission factors	- GHG emission factors for fuel and fertiliser production, for transportation, process energy, grid electricity: GREET - Livestock emission factors: IPCC guidance - Domestic impact of N_2O emissions from fertiliser application & land use changes: DAYCENT model
Actual / default values	*Not applicable*
Requirements for using default values	*Not applicable*
Requirements for using actual values	*Not applicable*
LAND USE CHANGE	
General	- Modeling of LUC based on o Amount of land converted and where o Type of land converted o GHG emissions associated with conversion (domestic and international) o Timeframe of emission analysis

General	- Distinction between domestic and international land use changes: o FASOM model for estimating changes in domestic agricultural sector - FAPRI-CARD model for estimating impacts on international agricultural and livestock production
Direct land use change	= domestic land use changes; FASOM models changes in total land use required for agriculture land use shifting between crops as well as interactions with pasture and forestry; output is combined with GHG emissions to generate domestic land use change GHG emissions
Reference land use	Land use in 2022; comparison of 'business as usual' scenario (without renewable fuels) with the production of a specific biofuel needed to meet the renewable fuel requirements for 2022
Cut-off date	Only future changes taken into account
Annualisation	Dividing total emissions equally over 30 years
Carbon stock included	Sum of changes in above- and belowground biomass carbon stocks, changes in soil carbon stocks on mineral soils, emissions from peat drainage, foregone forest sequestration
Calculation of carbon stocks	Regional and country level maps from different sources
Other	Non-CO_2 emissions (CH_4, N_2O) resulting from land clearing with fire are included where applicable
Indirect land use change	= international land use changes; emissions determined based on combining FAPRI–CARD output of crop acreage change with satellite data to determine types of land impacted by the projected crop changes and then applying emission factors of different land use conversions to generate GHG impacts
Bonus for cultivation on degraded land	*Not applicable*
CULTIVATION	
Processes to be taken into account	- Changes in fertiliser, energy use and livestock in whole national and international agricultural sector - Four main sources of GHG emissions are taken into account (besides LUC): agricultural inputs (e.g. fertiliser and energy use), fertiliser N_2O, livestock, and rice methane - Fuel use emissions from GREET include both the upstream emissions associated with production of the fuel and downstream combustion emissions.
N_2O field emissions	- Domestic: N_2O emissions from domestic fertiliser application and nitrogen fixing crops based on the amount of fertiliser used and different regional factors to represent the percent of nitrogen fertiliser applied that result in N_2O emissions; based on existing DAYCENT modeling with emission factors updated according to 2006 IPCC guidance - International: N_2O emissions from fertiliser application by applying IPCC default factors for different crops in different countries.
Use of average values	*Not applicable*
Other	GHG emissions from livestock (from enteric fermentation and manure management) and methane emissions from rice production are modelled
TRANSPORTS	

Processes to be taken into account	- Distance and modes of transport needed to ship feedstock from the field to the biofuel processing facility and the finished biofuel from the facility to end use
Calculation procedure	- Above mentioned information is combined with GREET factors to generate GHG emissions
PROCESSING	
Processes to be taken into account	- Energy use needed in the biofuel processing facility from industry sources, reports, and process modeling - Energy use is combined with emissions factors from GREET for process fuels and USA grid electricity to develop GHG impacts of the biofuel production process
Use of actual values	*Not applicable*
Excess electricity from cogeneration	*Not applicable since modeling of whole energy sector*
CO-PRODUCTS	
General	- Mainly system expansion (modeling of the whole agricultural system)
Procedure	- Co-products are used as biofuel feedstock (e.g. corn oil) or fuel (glycerine is combusted due to market saturation)
Basis for allocation	*Not applicable*
Exemptions	*Not applicable*
FUEL USE	
Emissions from combustion	- CO_2 emissions not included - CH_4 and N_2O from fuel use are included based on EPA MOVES Model
FOSSIL FUEL COMPARATOR	
	- Analysis to determine the lifecycle greenhouse gas emissions for petroleum; based on GREET model (Version 1.8b) - Petroleum baseline (2005) well-to-wheel: o Gasoline: 98205 g CO_2eq/mmBtu o Diesel (ultra-low sulfur): 97006 g CO_2eq / mmBtu
SENSITIVITY ANALYSES	
	- Quantification of uncertainty associated specifically with international indirect land use changes - Systematic sensitivity analysis with the GTAP Model for land use changes

B-2.2 LCFS – California Low Carbon Fuel Standard

Short description

The California Low Carbon Fuel Standard has been enacted in 2007 being the first low-carbon fuel mandate worldwide. Its specific criteria will take effect in January 2011. Its main aim is to reduce the greenhouse gas emissions from transportation fuels compared to conventional fuels, thus reducing the GHG emissions in Californian transportation as a whole. The directive calls for a GHG reduction of at least 10 % in California's transportation fuels by 2020. This overall reduction goal has been translated into annual so-called carbon intensities (CI) for diesel and gasoline as well as their substitutes. The requirements specify the amount of greenhouse gases one MJ diesel or gasoline (and blends) may emit in a given year up to 2020. The fuel providers have to ensure that the average CI of their fuel pool (including gasoline, diesel, and their blends and substitutes) meets these annual requirements. Emission trading has been established in California so that different market-based mechanisms are available for producers to meet these goals. One possibility is to blend in renewable fuels that substitute for diesel and gasoline. The regulations provide specific carbon intensities based on greenhouse gas balancing for each fuel used in California. The specific values can then be used to calculate the average carbon intensity of a given fuel pool.

Role of greenhouse gas emission calculations

The California Energy Commission and the California Air Resources Board (CARB) use well-to-wheel greenhouse gas balancing to generate individual carbon intensities (i.e. GHG emission values) for each fuel used in California. The values are modelled with the California-modified GREET model and presented in lookup tables (example see Figure B-2). This means that individual facilities do not have to perform their own calculations but can use the default values. The default values are presented without and with additional emissions from land use changes (direct and indirect). Land use changes have been modelled with a GTAP model.

The fuel provider has to look for the value that reflects his production conditions as precisely as possible. Under certain circumstances, he may apply for the modification of given values and/or for the modelling of totally new pathways in the GREET model.

Fuel	Pathway Identifier	Pathway Description	Carbon Intensity Values (gCO2e/MJ)		
			Direct Emissions	Land Use or Other Indirect Effect	Total
Gasoline	CBOB001	CARBOB - based on the average crude oil delivered to California refineries and average California refinery efficiencies	95.86	0	95.86
Ethanol from Corn	ETHC001	Midwest average; 80% Dry Mill; 20% Wet Mill; Dry DGS; NG	69.40	30	99.40
	ETHC002	California average; 80% Midwest Average; 20% California; Dry Mill; Wet DGS; NG	65.66	30	95.66
	ETHC003	California; Dry Mill; Wet DGS; NG	50.70	30	80.70
	ETHC004	Midwest; Dry Mill; Dry DGS, NG	68.40	30	98.40
	ETHC005	Midwest; Wet Mill, 60% NG, 40% coal	75.10	30	105.10
	ETHC006	Midwest; Wet Mill, 100% NG	64.52	30	94.52
	ETHC007	Midwest; Wet Mill, 100% coal	90.99	30	120.99
	ETHC008	Midwest; Dry Mill; Wet, DGS; NG	60.10	30	90.10
	ETHC009	California; Dry Mill; Dry DGS, NG	58.90	30	88.90
	ETHC010	Midwest; Dry Mill; Dry DGS; 80% NG; 20% Biomass	63.60	30	93.60
	ETHC011	Midwest; Dry Mill; Wet DGS; 80% NG; 20% Biomass	56.80	30	86.80
	ETHC012	California; Dry Mill; Dry DGS; 80% NG; 20% Biomass	54.20	30	84.20
	ETHC013	California; Dry Mill; Wet DGS; 80% NG; 20% Biomass	47.44	30	77.44
	ETHC014	2B Application*: Midwest; Dry Mill; Plant energy use not to exceed a value the applicant classifies as confidential; No grid electricity use; Coal use not to exceed 63% of fuel use (by energy); Coal carbon content not to exceed 48%	61.00	30	91.00
	ETHC015	2B Application*: Midwest; Dry Mill; Plant energy use not to exceed a value the applicant classifies as confidential; No grid electricity use; Biomass must be at least 5% of the fuel use (by energy); Coal use not to exceed 58% of fuel use (by energy); Coal carbon content not to exceed 48%	59.09	30	89.09

Figure B-2 Lookup table under the LCFS: carbon intensities for gasoline and fuels that substitute for gasoline

Table B-4 summarises the specification for greenhouse gas calculations under the LCFS.

Table B-4 Greenhouse gas calculation in the LCFS

GENERAL DESCRIPTION	
Name	Californian Low Carbon Fuel Standard; LCFS
Responsible body	California Air Resources Board (CARB)
Website	http://www.energy.ca.gov/low_carbon_fuel_standard/index.html
Foundation (year, partici-pants)	LCFS enacted in 2007; specific rules and carbon intensity reference values for the LCFS go into effect on January 2011
Scope (products and feedstocks)	- All transportation fuels used in California except liquefied petroleum gas, fuel used for interstate locomotives, ocean vessels, aircraft, military - GHG reference values for corn ethanol, sugarcane ethanol, CNG (different feedstocks), LNG (different feedstocks) and various fossil fuel pathways
Scope (geo-graphic)	For fuel sold in California
Type of system	Law
Objectives (mis-sion etc.)	- Reduce carbon footprint of transportation - Reduce the state's dependence on petroleum - Create a market for clean transportation technology - Stimulate the production and use of alternative, low-carbon fuels in California
Biofuel goals	- 10% reduction of GHG emissions in Californian transport sector by 2020 - Reduction goal is translated into yearly reductions that are expressed as an-nual carbon intensity (CI) requirements for diesel and gasoline; i.e. there is an annual reduction of GHGs (expressed in g CO_2 eq/MJ) allowed to be emitted by transportation fuels
Eligibility of biomass to-wards goals	- Not directly applicable - Specific 'carbon intensity' (CI) scores (i.e. GHG emission reference values) are assigned to each transportation fuel; additionally there are annual average carbon intensity requirements for diesel and gasoline that stepwise lead to a 10% reduction by 2020; the fuel provider's fuel pool (including gasoline, die-sel and its blends and substitutes) has to meet annual target CI for a given year (overall and fuel specific CIs are included in lookup tables in regulation)
Domestic / im-ported feed-stock	Requirements apply to imported and domestic feedstocks
LAND USE REQUIREMENTS	
Land use re-strictions with relevance for GHG calcula-tions	No direct exclusion of specific land types

GHG CALCULATION METHODOLOGY	
GENERAL	- Carbon Intensities for each transport fuel are generated with California-modified GREET model and used to calculate average carbon intensities for a fuel provider's fuel pool - Under certain circumstances, these values may be modified or new values may be generated with the GREET model
Availability of calculation tool	- No, lookup table for all relevant fuels that are in use in California and changes are possible only in special cases - Excel-based CA-GREET model can be downloaded and inputs can be modified, however, it cannot be used to make own LCFS relevant calculations
Feedstock sources included	- In lookup table CI values for corn (ethanol), sugarcane (ethanol), soybeans, used cooking oil, tallow (for biodiesel), dairy digester biogas, landfill gas (both LNG and CNG) - New pathways may be included under certain restrictions
GHG thresholds	- Annual carbon intensity requirements for transportation gasoline and diesel fuel are set forth starting January 1, 2011 that must be met by fuel providers - Stepwise decrease of carbon intensity and increase of GHG % reduction until 2020 for both gasoline and diesel o gasoline: 86.27 g CO_2eq/MJ in 2020 o diesel: 85.24 g CO_2eq/MJ in 2020
General methodology	- All GHG emissions are modeled with the California-modified GREET model plus a land use modifier (GTAP)
Life cycle elements to be included	Well-to-wheel (emissions from fuel use set to zero, emissions from seed production is excluded)
CO_2 equivalent factors (GWPs)	IPCC 2007 values N_2O: 298 CH_4: 25
Functional unit	Carbon intensities in lookup tables are provided in g CO_2eq/MJ
Infrastructure	Construction of infrastructure, plants and transport systems are not included
Electricity mix for external energy use	- Currently only sugarcane is regarded as non-US feedstock; Brasilian sugarcane ethanol production runs self-sufficiently (from bagasse burning) - Exported electricity in Brazil replaces Brazilian marginal electricity mix
Data sources for emission factors	- Default CA-GREET emission factors are used - For Brazilian sugar cane average US emission factors are used
Actual / default values	- Default GHG emission factors (with / without land use change) are included in lookup tables
Requirements for using default values	- Regulated party must use the default carbon intensity values in lookup table that most closely corresponds to the production process used to produce the regulated party's fuel - Under certain circumstances, default values can be modified and new pathways can be included in the model
Requirements for using actual values	*See above*

LAND USE CHANGE	
General	No differentiation between iLUC and dLUC; uses Global Trade Analysis Project (GTAP) model
Direct land use change	included
Reference land use	2020 Comparison of emissions for business as usual scenario with effects of increased biofuel production
Cut-off date	Only future changes taken into account
Annualisation	Dividing total emissions equally over 30 years
Carbon stock included	
Calculation of carbon stocks	GTAP model
Other	
Indirect land use change	Included
Bonus for cultivation on degraded land	*Not applicable*
CULTIVATION	
Processes to be taken into account	- Farming energy (diesel, gasoline, natural gas, LPG, electricity) and fertiliser use (N-, P_2O_5-, K_2O-, CaO-fertiliser, herbicide and insecticide use), soil N_2O emissions (direct from N-fertiliser); impact of lime added to soils on GHG emissions - for corn ethanol, share of corn stover removed (50%) is taken into account for calculating N in N_2O avoided per unit of N in stover removed - Sugarcane burning taken into account (emissions of CO_2, VOC, CO, CH_4, N_20)
N_2O field emissions	Direct field N_2O emissions from N-fertiliser application following IPCC values
Use of average values	*Not applicable*
TRANSPORTS	
Processes to be taken into account	Models every transport step with all relevant input data (distance, mode of transport, moisture content of biomass etc.)
Calculation procedure	Modeling
PROCESSING	
Processes to be taken into account	- Different processing pathways for each feedstock (e.g. dry and wet mill ethanol) - Energy use (process fuels, electricity, biomass), other process inputs (e.g. H_2 for hydrogenation), type and share of co-products - in all processes, direct emissions of VOC, CO, CH_4, N_20, CO_2 included

Use of actual values	*Not applicable*
Excess electricity from cogeneration	Exported to the grid replacing marginal national electricity for which a credit is given
CO-PRODUCTS	
General	- Different allocation methods used for different feedstocks (e.g. displacement method for ethanol, mass / energy based allocation for soybean) - In some pathways using the combination of different methods (e.g. mass based allocation for soybean meal/oil and energy based allocation for biodiesel/glycerine)
Basis for allocation	Mass, energy based and economic allocation depending on feedstock and scenario
Exemptions	No
FUEL USE	
Emissions from combustion	- CO_2 emissions set to zero - CH_4 and N_2O from fuel use not included
FOSSIL FUEL COMPARATOR	
	- Different references are given for different fossil fuels o gasoline: 95.86 g CO_2eq/MJ o ultra low sulphur diesel: 94.71 g CO_2eq/MJ) - Also values for different types of fossil CNG, LNG, hydrogen, electricity
SENSITIVITY ANALYSES	
	- In lookup tables different scenarios are calculated for the feedstocks covering different cultivation (e.g. manual vs. mechanical harvest for sugarcane) and processing (e.g. dry / wet ethanol, different process energy carriers) scenarios - Different options for changing scenarios in GREET model (e.g. including infrastructure, changing between allocation methods), however, not applicable for LCFS purposes

B-2.3 EU- RED – Renewable Energy Directive

Short description

The EU Directive on the Promotion of the Use of Energy from Renewable Sources (2009/28/EC; RED) was adopted in 2009 and promotes the use of renewable energy throughout Europe. It sets targets for the amount of renewable energies to be used: until 2020, at least 20% of the Community's gross final consumption shall be from renewable sources and at least 10% of the final energy consumption in transport. These overall targets are translated into national targets for each Member State.

The Directive also formulates sustainability criteria for biofuels and bioliquids. Only those shares of biofuels and bioliquids fulfilling the criteria can be counted towards the renewable energy targets. The sustainability criteria are mandatory for both imported biomass and those produced within the EU.

Role of GHG calculation within the RED

Among the sustainability criteria for biofuels and bioliquids there is one criterion on greenhouse gas emission savings: it shall be at least 35% (50% starting in 2017). The Directive offers the use of default values on GHG savings which are available for 34 biofuel production pathways. There are certain restriction for using the default values which may necessitate to performing individual calculations. For example, there are no default values for land use changes nor are there default values available for every possible biofuel. Furthermore, most (conservative) default values won't reach the 50% target in 2017 so that own calculations will be necessary for proving compliance. For performing own calculations the Directive provides a calculation methodology in the annex.

As part of the sustainability criteria, proving compliance with the greenhouse gas emission saving goals is mandatory for the biofuels and bioliquids amounts being counted towards the renewable energy goal. In some Member States compliance with the sustainability criteria is mandatory for receiving subsidies for energy production.

The approval of compliance with the sustainability criteria is realised with certification systems. This led to the establishment of new certification schemes and, in existing schemes, to the development of new standards that apply to those producers that want to gain access to the European market.

Table B-5 gives an overview on the greenhouse gas calculation methodology as stipulated in the RED.

Table B-5 Greenhouse gas calculation in the RED

GENERAL DESCRIPTION	
Name	Renewable Energy Directive (2009/28/EC); RED
Responsible body	European Commission
Website	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF
Foundation (year, participants)	April 2009 by the European Commission
Scope (products and feedstocks)	Sets renewable energy targets for energy and transport sector; includes mandatory sustainability criteria (including GHG reduction goals) for all (liquid) biofuels and bioliquids
Scope (geographic)	Renewable energy goals apply to Eureopean Member States; sustainability criteria apply to imported biomass and those produced within the EU
Type of system	Regulatory framework
Objectives (mission etc.)	Renewable energy goals shall - reduce greenhouse gas emissions - promote security of energy supply - promote technological development and innovation - provide opportunities for employment and regional development

Biofuel goals	10 % energy from renewable energy in transport by 2020; overall European target is translated into specific national targets for the EU Member States

Eligibility of biomass to-wards goals	Only biofuels and bioliquids that fulfill the sustainability criteria (including GHG emission reduction) may be counted towards the national (and thus European) renewable energy goals; biofuels from residues and waste only need to fulfill part of the sustainability criteria (including GHG reduction goals)
Domestic / imported feedstock	Sustainability criteria apply to feedstock produced outside and inside the Europe-an Union
LAND USE REQUIREMENTS	
Land use restrictions with relevance for GHG cal-culations	Biofuels and bioliquids shall not be made from feedstock obtained from land with high carbon stocks, namely - wetlands - continuously forested area - peatland
GHG CALCULATION METHODOLOGY	
GENERAL	
Availability of calculation tool	The BioGrace tool was developed specifically to harmonise RED-conform GHG calculations, however it may also be used for other certification systems ; for fur-ther details see section B-3.1
Feedstock sources in-cluded	- All biomass types that produce liquid biofuels / bioliquids - Default values for GHG savings are provided for 15 feedstocks (34 pathways)
GHG thresh-olds	- GHG emission savings shall be at least 35 %, from 2017 on at least 50%; for installations that started production on or after 2017, savings shall be at least 65 % starting in 2018 - For installations that were in operation on 23 January 2008, the 35 % reduction goal shall apply starting on 1 April 2013
General methodology	GHG emission savings are calculated by adding up emissions from the single life cycle steps. Negative emissions (=savings) are subtracted. GHG emissions are compared against a fossil reference value for fossil fuel. Balance needs to be positive and above GHG thresholds mentioned above.
Life cycle elements to be included	Well-to-wheel: - Extraction / cultivation of raw material - Carbon stock changes from land use changes - Processing - Transport and distribution - Use of fuel (set to zero emissions) - Savings from soil carbon accumulation via improved agricultural management - Savings from carbon capture and geological storage - Savings from carbon capture and replacement - Savings from excess electricity from cogeneration
CO_2 equiva-lent factors (GWPs)	IPCC 2001 values: N_2O: 296 CH_4: 23
Functional unit	- Gram CO2 equivalent per MJ of fuel: gCO2eq/MJ - For transport fuels, the functional unit may be adjusted to take into account dif-ferences between fuels in useful work done, expressed in terms of km/MJ
Infrastructure	Excluded

Electricity mix for external energy use	- Assumed to be equal to the average emission intensity of the production and distribution of electricity in a defined region - Alternatively, the average value of individual electricity production may be used, if that plant is not connected to the electricity grid
Actual / default values	Three possibilities for calculating the GHG emissions savings exist: 1) Using default values provided in the RED 2) Using actual values based on own calculation 3) Using the sum of disaggregated default values (provided for some of the processes along the value chain); these may also be combined with actual values
Requirements for using default values	Default values may only be used for biomass - cultivated outside the EU - cultivated within the EU and included in a list of areas in their territory where GHG emissions from crop cultivation can be expected to be at or below cultivation default values (to be prepared by each Member State) - that is waste or residues other than agricultural, aquaculture and fisheries residues - if emissions from land use change are equal or less than zero
Requirements for using actual values	Actual values have to be used - for biomass that does not fall under the above mentioned points - for those pathways where no default values are available - for emissions from land use changes Independently of the availability and applicability of default values every economic operator can decide to use actual values for own reasons.
LAND USE CHANGE	
General	Land that does not fall under the above mentioned restriction may be converted; however, if conversion took place after the reference date, associated emissions have to be calculated and included in the balance; only emissions from direct land use changes are included
Direct land use change	
Reference land use	Land use in January 2008 or 20 years before the raw material was obtained, whichever was the later
Cut-off date	1 January 2008
Annualisation	Annualised emissions from carbon stock changes caused by land-use change, shall be calculated by dividing total emissions equally over 20 years.
Carbon stock included	Soil and vegetation
Calculation of carbon stocks	Following the EU guidelines (CEC, 2009)
Indirect land use change	So far not included, however the Commission is developing a methodology
Bonus for cultivation on degraded land	- A bonus of 29 g CO2eq/MJ is attributed if the land was not in use for agriculture or any other activity in January 2008 and if it is severely degraded or heavily contaminated. - So far no definition for ‘severely degraded’ and ‘heavily contaminated’ land

CULTIVATION	
Processes to be taken into account	- Emissions from extraction or cultivation; from the collection of raw materials; from waste and leakages; and from the production of chemicals or products used in extraction or cultivation. - Capture of CO_2 in the cultivation of raw materials is not included.
N_2O field emissions	Only refers to N_2O emissions generally but subsumed under emissions from cultivation
Use of average values	Average values may be used instead of actual farm-level data if they have been calculated for smaller geographical areas than those used in the calculation of the default values (i.e. NUTS-2 level or more fine-grained)
Other	Emission savings from soil carbon accumulation via improved agricultural management is mentioned in the overall formula
TRANSPORTS	
Processes to be taken into account	Emissions from the transport and storage of raw and semi-finished materials and from the storage and distribution of finished materials are included.
Calculation procedure	For transports, no default value can be used at the economic operator’s level since the transport default value is one single value including all transport and distribution activities.
PROCESSING	
Processes to be taken into account	Emissions from the processing itself; from waste and leakages; and from the production of chemicals or products used in processing are included.
Use of actual values	*See above*
Excess electricity from cogeneration	- Emission savings can be taken into account except where the fuel used is a co-product other than an agricultural crop residue. - Size of the cogeneration unit shall be assumed to be the minimum necessary to supply the heat that is needed to produce the fuel. - GHG emission savings shall be equal to the amount of GHG that would be emitted when an equal amount of electricity was generated in a power plant using the same fuel as the cogeneration unit
Others	- Emission saving from carbon capture and geological storage: emissions avoided through the capture and sequestration of emitted CO_2 directly related to the extraction, transport, processing and distribution of fuel - Emission saving from carbon capture and replacement: emissions avoided through the capture of CO_2 of which the carbon originates from biomass and which is used to replace fossil-derived CO_2 used in commercial products and services.
CO-PRODUCTS	
General	Allocation is applied to all co-products emerging along the life cycle
Procedure	- The emissions to be divided shall include all emissions that take place up to and including the process step at which a co-product is produced. - If any allocation to co-products has taken place at an earlier process step in the

	life-cycle, then the fraction of those emissions assigned in the last such process step to the intermediate fuel product shall be used for this purpose instead of the total of those emissions.
Basis for allocation	- Lower heating value in the case of co-products other than electricity - The energy content of by-products that have negative energy content is defined as zero.
Exemptions	No allocation is applied to wastes, agricultural crop residues, including straw, bagasse, husks, cobs and nut shells, and residues from processing, including crude glycerine (glycerine that is not refined).
FUEL USE	
Emissions from combustion	Emissions from the fuel in use are taken to be zero.
FOSSIL FUEL COMPARATOR	
	- Biofuels: comparator shall be the latest available actual average emissions from the fossil part of petrol and diesel consumed in the Community as reported under Directive 98/70/EC. If no such data are available, the value used shall be 83,8 gCO2eq/MJ. - Bioliquids used for electricity production: 91 gCO_2eq/MJ - Bioliquids used for heat production: 77 gCO_2eq/MJ - Bioliquids used for cogeneration: 85 gCO_2eq/MJ

B-3 Voluntary certification schemes

B-3.1 BioGrace

Short description

BioGrace is an Intelligent Energy Europe (IEE) - funded project that shall support the implementation of the European Renewable Energy Directive (RED) by harmonising the calculation of biofuel greenhouse gas emissions as stipulated in that Directive. The RED was adopted in 2009 (see section B-2.3) and, among others, sets minimum targets for greenhouse gas emission savings. The Directive provides default savings for 35 current and future biofuel production pathways. For those economic operators that want or need to calculate their own GHG savings, the Directive describes a calculation methodology. This methodology is implemented by an excel-based calculation tool designed during the BioGrace project. The tool has two functions:

- Making the RED default values transparent: the tool contains dedicated excel sheets for 22 biofuel pathways that are already established at the market. The calculation steps in the excel sheets are already filled in thus making the calculation of default values traceable.
- Doing own harmonised calculations: the pre-filled excel sheets for the 22 pathways can be adapted to the user's needs by changing input data, adding specific standard values for existing inputs and adding new inputs in the process. There is also guidance on how to include additional fuel pathways. The tool also contains a uni-

form and transparent list of standard conversion values. These are, for instance, nitrous oxide or carbon dioxide emissions per kg of nitrogen fertiliser or per MJ of natural gas.

The standard values are also published as separate list and European policy makers are asked to refer to this list when implementing the RED into national legislation. Differences in conversion values are a major source for deviation between GHG results. Since such values are not specified in the RED, BioGrace fills this gap by publishing such a list.

Table B-6 gives an overview on the main greenhouse gas calculation principles covered by the BioGrace tool. Since it implements the RED methodology exactly, most elements reference that methodology (see section B-2.3).

Table B-6 Greenhouse gas calculation in BioGrace

GENERAL DESCRIPTION	
Name	Harmonised calculation of biofuel greenhouse gas emissions in Europe; BioGrace
Responsible body	Project funded as part of the Intelligent Energy Europe Program
Website	http://www.biograce.net/
Foundation (year, participants)	Project with nine European partners; project duration: 01/05/2010 – 31/03/2013
Scope (products and feedstocks)	Liquid and gaseous biofuels and bioliquids Pre-calculation of 22 RED pathways covering 16 feedstocks
Scope (geographic)	European
Type of system	Excel-based greenhouse gas calculator implementing the calculation methodology as stipulated in the European Renewable Energy Directive (RED)
Objectives (mission etc.)	Aims at harmonising calculations of biofuel GHG emissions at European leven and thus supports the implementation of the RED into national laws
Biofuel goals	*Not applicable*
Eligibility of biomass towards goals	*Not applicable*
Domestic / imported feedstock	*Not applicable*
LAND USE REQUIREMENTS	
Land use restrictions with relevance for GHG calculations	*Not applicable*
GHG CALCULATION METHODOLOGY	
GENERAL	
Availability of calcula-tion tool	*Not applicable*

Feedstock sources included	Pre-calculated GHG emissions for 22 RED pathways: - Ethanol: sugar beet, wheat (different processing options), corn, sugar-cane - FAME: rape seed, sunflower, soybean, palm oil (different options), waste vegetable or animal oil - HVO: rape seed, sunflower, palm oil (different options) - SVO: rape seed - CNG: biogas from MSW, wet manure, dry manure
GHG thresholds	*See RED*
General methodology (principles applying to all life cycle steps)	Exact implementation of the greenhouse gas calculation methodology required by the RED
Life cycle elements to be included / system boundaries	Well-to-wheel - Extraction / cultivation of raw material - Carbon stock changes from land use changes - Processing - Transport and distribution - Use of fuel (set to zero) - Savings from soil carbon accumulation via improved agricultural management - Savings from carbon capture and geological storage - Savings from carbon capture and replacement - Savings from excess electricity from cogeneration
CO_2 equivalent factors (GWPs)	Inconsistent use of GWPs in RED ➔ inclusion of two calculation options: 1) following GWPs described in RED (CH_4: 23; N_2O: 296) 2) using same GWPs as had been used for calculating default values (CH_4: 25; N_2O: 298)
Functional unit	- g CO2eq/MJ fuel - results of intermediary calculation steps are also per ha and per kg fuel provided
Infrastructure	Not included
Electricity mix	- Emissions calculated from grid electricity should be an national averages; averages are listed in the BioGrace tool - If a national average is not included in the list and cannot be obtained from other sources, it is allowed to use the average for the regional electricity mix in the BioGrace list. - Average emissions from a power plant can be applied only if the power plant is not connected to the grid. - Decreasing the GHG emissions of electricity used by buying green certificates from a Green certificate scheme is not allowed.
Data source of GHG emission factors	Emissoin factors are listed (together with all other necessary conversion factors) in the BioGrace tool and are published in a separate document
Actual / default values	The BioGrace tool allows the reproduction of RED default values calculation and allows for the calculation of actual values (either for the pre-

	defined pathways or for additional pathways); also combination of default and actual values possible
Requirements for using default values	*See RED*
Requirements for using actual values	*See RED*

LAND USE CHANGE	
General	Direct land use change included on extra sheet
Direct land use change	
Reference land use	The reference land use shall be the land use in January 2008 or 20 years before the raw material was obtained, whichever is later
Cut-off date	January 2008
Annualisation	Annualised emissions are calculated by dividing total emissions equally over 20 years.
Carbon stock includ-ed	Above- and below-ground vegetation and soil
Calculation of carbon stocks	The calculation in the tool follows and implements the Commission guide-lines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC (2010/335/EU) that draws on the 2006 IPCC Guide-lines for National Greenhouse Gas Inventories (volume 4).
Indirect land use change	*Not included*
Bonus for cultiva-tion on degraded land	A bonus of 29 g eCO2/MJ can be added if cultivation takes place on se-verely degraded or heavily contaminated land (for definition see RED). This can only be done from the moment that the European Commission has defined degraded land and heavily contaminated land.
CULTIVATION	
Processes to be taken into account	Yield, energy consumption (diesel fuel), agro-chemicals (pesticides, N-/CaO-/ K_2O-/ P_2O_5-fertiliser), seeds, by-products brought back to fields (for field emissions), field N_2O-emissions, CH_4 from trash burning (where appli-cable)
N_2O field emissions	N_2O data for the RED default values have been partly calculated with the DNDC model which takes into account direct and indirect emissions For own calculations, the tool includes a separate excel sheet follwing the IPCC guidelines for National Greenhouse gas Inventories, Volume 4, Chapter 11(2006), tier one.
Use of average val-ues	According to the RED, for cultivation it is permissible to use average values for geographical areas at the level of NUTS-2 areas or more fine-grained level. Reports had to be prepared in accordance with RED article 19.2 where member states have listed average GHG emission values at such levels (published on the EC transparency platform). Since the calculation of some values might not have been done in accordance with the BioGrace calculation rules, it is not allowed to use the GHG emission results from these reports directly. However, the input data, for example yield and amount of N-fertiliser, may be used if they are complete.

Other	There is a separate sheet in the tool for calculation of carbon stock accumulation thanks to improved agricultural management (e_{sca} according to RED). It calculates changes in soil carbon stock only following the Commission Decision of 10 June 2010 on guidelines for the calculation of land use carbon stocks for the purpose of Annex V of Directive 2009/28/EC Only may be used if no land use change occurs! If there is LUC, the LUC module should be used
TRANSPORTS	
Processes to be taken into account	Transport distance, type of transport, type of fuel used
Calculation procedure	
PROCESSING	
Processes to be taken into account	Yield, energy consumption (process energy, electricity), type and amount of by-products
Calculation procedure	
Emission factors	*See above* When calculating emissions from energy input of solid biomass or biomass derived fuels, it is recommended to apply the standard value for "average biomass" in the BioGrace list of additional standard values.
Average emissions	
Excess electricity	- If the process heat used in the biofuel / bioliquid facility is produced by a CHP process, emissions from excess electricity shall be subtracted from the total emissions of the biofuel, for all CHP process fuels except from co-products from the biofuel production process. - Excess electricity produced in a cogeneration plant (producing both heat and electricity) is considered to be the electricity produced in proportion to the heat needed in the biofuel production process. The size of the emissions saving should be the same as the life cycle emissions that would arise if the same amount of electricity was produced in a power plant with the same fuel.
CO-PRODUCTS	
General	- Emissions have to be allocated between the fuel and its co-product. - No emissions can be allocated to heat. - Emissions to be allocated are the emissions that arise up und until the process step where a co-product is formed. The allocation takes place after the process step directly after the forming of a co-product. When leaving a process, the co-product takes the allocated emissions with it. - If processing of co-products and/or the fuel is interlinked with feedback loops with earlier steps in the production process, the production process is defined as a refinery. Allocation from the emissions then takes place after the step where no more feedback loops interlink with earlier parts in the process.

Basis for allocation	Lower heating value for the whole product and not just the dry part of it (provided in BioGrace list of standard values); the wet content of the product shall be included. For products with a moisture content of 10% or lower, an approximation to dry product is allowed.
Exemptions	- Waste and residues used for biofuel production have zero GHG emissions up and until the point of collection. If the waste or residue need further processing before it can be used in the biofuel process, the emissions from that processing are to be allocated to that waste or residue. - Waste heat is considered to have an emission factor of zero. This is because the energy if not used in the biofuel production will in most cases not be used elsewhere.
FUEL USE	
Emissions from combustion	*Set to zero*
FOSSIL FUEL COMPARATOR	
	83.8 g CO_{2eq}/MJ
SENSITIVITY ANALYSES	
	Variations included regarding the different GWPs, however, not meant to be a sensitivity analysis

B-3.2 BSI – Bonsucro (former Better Sugarcane Initiative)

Short description

Bonsucro was founded under the name ‚Better Sugarcane Initiative'. It is a global multi-stakeholder association with sugarcane retailers, investors, traders, producers and NGOs. It developed a certification system for sugarcane producers with the aim of reducing the environmental and social impacts of sugarcane production. The Principles & Criteria apply to sugarcane producers as well as to sugarcane processing units (for sugar and ethanol production). The unit of certification is the sugar mill and audits are based on the assessment of the mill and the cane supply area. Certified sugarcane is available from April 2011 on. There are five principles in the 'Production Standard':

- Principle 1: Obey the Law
- Principle 2: Respect human rights and labour standard
- Principle 3: Manage input, production and processing efficiencies to enhance sustainability
- Principle 4: Actively manage biodiversity and ecosystem services
- Principle 5: Continuously improve key areas of the business

In addition to the five principles there is an additional section 6 for sugarcane ethanol intended to be put on the European market. The section covers the requirements of the EU RED (see section C-2.3), i.e. criteria on monitoring the global warming emissions and on protecting areas with high biodiversity value and with high carbon stocks. Section 7 of the ‘Production Standard’ covers Chain of Custody requirements.

In order to be entitled to the Bonsucro certificates, 80% of the indicators contained in Principles 1 to 5 and 7 must be met. Certain core criteria must also be fully satisfied. In order to obtain a ‘Bonsucro EU certificate’ the above mentioned minimum requirements have to be met. In addition, full compliance with the requirements listed under section 6 is mandatory. In 2011, the standard has been officially approved by the European Commission.

Role of GHG calculation within the system

Within the Bonsucro standard, there are two different requirements concerning GHG emission calculations. First, the general standard sets GHG emission thresholds for both sugar and ethanol in section 3 (criterion 3.2: To monitor global warming emissions with a view to minimising climate change impacts). It is not a core criterion but falls under the 80 % rule. The respective calculation instructions are described in detail in Appendix 3.

Additionally, section 6 lists the requirements for the EU scheme including a GHG emission threshold. This requirement is mandatory only for those users that wish to sell sugarcane ethanol to the European market. At present the use of RED default values (see also section C-2.3) is required which makes self calculation of greenhouse gas emissions obsolete. The default values are provided as disaggregated values (for cultivation, processing and transport / distribution) and as overall default values for the whole sugarcane ethanol life cycles. After the revision of section 6, however, the use of actual, i.e. self calculated values will be possible. The proposed methodology will follow the methodology stipulated in the RED.

In Table B-7, elements from both sections are listed. Their allocation to section 3 (main standard) and section 6 (EU RED standard) is indicated.

Table B-7 Greenhouse gas calculation in the Bonsucro scheme

GENERAL DESCRIPTION	
Name	Bonsucro – Better Sugarcane Initiative; BSI
Responsible body	
Website	http://www.bonsucro.com/welcome.html
Foundation (year, participants)	2005; international roundtable initiative; certification starts in 2011
Scope (products and feedstocks)	Sugarcane and sugarcane derived products ***Section 3:*** ethanol and sugar ***Section 6:*** only ethanol
Scope (geographic)	Global
Type of system	Certification system
Objectives (mission etc.)	- Improve the social, environmental, and economic sustainability of sugarcane by promoting the use of a global metric standard - Continuously improving sugarcane production and downstream processing in order to contribute to a more sustainable future
Biofuel goals	*Not applicable*

Eligibility of biomass towards goals	*Not applicable*
Domestic / imported feedstock	*Not applicable*
Land use restrictions with relevance for GHG calculations	***Section 3:*** no direct reference to land use restrictions; emissions from land use changes have to be calculated if they occur after January 2008 ***Section 6:*** excludes land with high biodiversity value, land with high carbon stocks and peat lands Land with high carbon stocks include - Wetlands - Continuous forests
GHG CALCULATION METHODOLOGY	
GENERAL	
Availability of calculation tool	*No own tool*
Feedstock sources included	Only sugarcane
GHG thresholds	***Section 3:*** < 24 gCO_{2eq}/MJ fuel (equals RED default value) ***Section 6:*** < 50 %
General methodology (principles applying to all life cycle steps)	***Section 3:*** - materiality threshold of 1% to ensure that very minor sources of life cycle GHG emissions do not require the same treatment as more significant sources. - also calculation of primary energy demand taking into account the efficiency of generation and supply of the secondary energy source e.g. using a conversion factor
Life cycle elements to be included / system boundaries	***Section 3:*** growing and processing of sugarcane; individual mills and growers are handled as units; if an external units provides steam and power to a mill from bagasse that has been provided by the mill, this unit is considered together with that mill. ***Section 6:*** default values given for cultivation, processing, transports
CO_2 equivalent factors (GWPs)	***Section3:*** IPCC 2001 values: N_2O: 296 CH_4: 23
Functional unit	***Section 3:*** specific functional units for each processing step; total net GHG emissions provided as g CO_2eq/L ethanol and/or g CO_2eq/MJ fuel ***Section 6:*** g CO_2eq/MJ fuel
Infrastructure	***Section 3:*** emissions from the manufacture of machinery and equipment shall not be taken into account since the inclusion of energy generally has an effect of less than 10% on calculated emissions.
Electricity mix	***Section 3:*** if surplus power is exported from bagasse combustion, a credit for the average national energy mix is given; in Annex, average emissions for 25 countries are provided
Data source of GHG emission factors	***Section 3:*** emission factors from various sources are listed in the annex (fertiliser, agricultural chemicals, primary energy carriers, process chemicals, national electricity mixes)

Actual / default values	***Section 3:*** only actual values may be used ***Section 6:*** only default values may be used
Requirements for using default values	***Section 6:*** Obligation to use disaggregated default values (based on RED): Overall default value (24 gCO_{2eq}/MJ) = cultivation (14 g CO_{2eq}/MJ) + processing (including excess electricity; 1 g CO_{2eq}/MJ) + transport and distribution (9 g CO_{2eq}/MJ). Default values may be used if the annualised emissions from land use change after January 2008 are zero. If they are not zero, the respective GHG emissions must be added to the default values.
Requirements for using actual values	***Section 6:*** The calculation of actual values is not permitted at present. The possibility of using actual or a combination of disaggregated default and actual values will be offered in future revisions. The methodology to calculate actual values will follow the rules established by the RED.
LAND USE CHANGE	
General	***Section 3 & 6:*** GHG emissions from land use changes after reference date must be calculated and added to all other emissions.
Direct land use change	
Reference land use	***Section 3 & 6:*** Land use before conversion
Cut-off date	***Section 3 & 6:*** January 2008
Annualisation	***Section 3:*** Not explicitly mentioned ***Section 6:*** Annualisation by dividing total emissions equally over 20 years
Carbon stock included	***Section 3:*** Not explicitly mentioned ***Section 6:*** Soil and vegetation
Calculation of carbon stocks	***Section 3:*** The table of IPCC default land use change values for selected countries published in the PAS 2050 are used in the calculation (BSI, 2008) ***Section 6:*** according to the guidelines published by the European Commission (CEC, 2009) based on IPCC 2006
Indirect land use change	*Not included*
Bonus for cultivation on degraded land	*Not included*
CULTIVATION	
Processes to be taken into account	***Section 3:*** direct (energy) inputs: fuel and power; indirect inputs: production of chemicals, fertilisers and other material used (except infrastructure) Farming operations covered are chemical applications, irrigation, tillage, harvesting. Additionally, emissions from lime application are included (both from production and field CO_2 emissions); IPCC factor is used
N_2O field emissions	***Section 3:*** emissions from fertiliser manufacture and field emissions are taken into account following IPCC (1.25% of N in nitrogen fertilisers) Following Macedo et al., 2008 1.225 % of N in filter cake, vinasse, and cane residues is emitted as N_2O

Use of average values for cultivation emissions	Not specified
Other	***Section 3:*** emissions from cane burning are included following IPCC's emission factor for burning biomass: 0.07 kg N_2O/t dry matter; 2.7 kg CH_4/t dry matter; changes in the carbon content of soils, either emissions or sequestration, other than those arising from direct land use change, are excluded.
TRANSPORTS	
Processes to be taken into account	***Section 3:*** all emissions arising from transport required during the product and raw materials life cycle are included (include emissions associated with creating and transporting the fuels required) Transport of products from the factory and transport of workers are not included.
PROCESSING	
Processes to be taken into account	***Section 3:*** direct and indirect inputs are included; direct: fuel and power inputs, indirect: production of chemicals and other materials used; includes export of electric power or bagasse. Non-CO_2 emissions from fossil and biogenic carbon sources are included (e.g. burning bagasse in sugar mill boilers) based on IPCC data for burning of biomass. CO_2 emissions arising from biogenic carbon sources are excluded. Emissions from anaerobic treatment of effluent based on IPCC values in the case that methane is not captured and used as a fuel
Excess electricity from cogeneration	***Section 3:*** credit is given for exporting power or bagasse according to the displacement of energy in that country (based on average national mixes); average emissions are provided for several countries in the annex
CO-PRODUCTS	
General	***Section 3:*** Use of both substitution / displacement and allocation, depending on product: - Export of power or bagasse: credit is provided for energy and emissions saved based on average national mixes - Production of only sugar and molasses: allocation based on the market value is applied - Production of both sugar and ethanol: emissions are allocated between both products based on energy content or mass - Production of ethanol: all emissions are allocated to ethanol (per liters or MJ)
Basis for allocation	***Section 3:*** see above; depending on products, allocation is based on energy content (lower heating value), mass or market value
Exemptions	***Section 3:*** *No comment*
FUEL USE	
Emissions from combustion	***Section 3:*** Non-CO_2 emissions arising from both fossil and biogenic carbon sources are included in the calculation of GHG emissions.
FOSSIL FUEL COMPARATOR	
	Section 3: 85 g CO_2eq/MJ (gasoline) ***Section 6:*** 83.8 g CO_2eq/MJ

B-3.3 GGL – Green Gold Label

Short description

The Green Gold Label (GGL) program is a certification system for biomass from forestry and agriculture. It was founded in 2002 by the Dutch energy company Essent and Skull International (now Control Union Certifications) and is now registered and owned by the Green Gold Label Foundation.

It covers all uses of biomass (energy/power production and material use in the chemical industry) and the whole supply chain (cultivation, processing, transportation, final use). There are specific standards for each element in the supply chain:

- GGLS1: Chain of Custody Processing Standard
- GGLS2: Agricultural Source Criteria
- GGLS4: Criteria for full supply chain from raw material to end user of biomass
- GGLS5: Forest Management Criteria
- GGLS6: Power company criteria
- GGLS7: Conservation stewardship criteria
- GGLS8: Green House Gas Balance

The producers in agriculture and forestry have to be certified with the Green Gold Label or another recognised certification system (see below) and additionally have to comply with GGLS1 (Chain of Custody) for being allowed to sell certified biomass. The following certification systems are accepted:

- Agriculture: Organic, EUREPGAP or alternatively GGLS2 (Agricultural Source Criteria)
- Forestry: FSC, PEFC, CSA-FSM SFI, FFCS; GGLS5 is valid only temporarily for up to four years, afterwards it has to be certified by one of the other listed systems.

Since GGLS5 for forestry is only valid as an interim solution, it is not explained in more detail. GGLS2 for agriculture, in contrast is a full certificate and comprises the following principles:

- Principle 1: The agriculture management system is part of an integrated long term planning program (either individually or organised in a group), aimed at development and sustainability.
- Principle 2: The agriculture management system is based on land-resource planning.
- Principle 3: The agriculture management is aimed at land conservation and rehabilitation.
- Principle 4: The agriculture management is aimed at the insurance of freshwater supply and quality for sustainable food production and sustainable rural development.
- Principle 5: The agricultural management system has implemented integrated pest management and control.
- Principle 6: The agricultural management system has implemented sustainable plant nutrition to increase food production

Certified processing facilities (energy companies, chemical industry) can only use biomass with the GGLS1 label and additionally have to comply with GGLS4 (all users) or GGLS6 (only power companies). Furthermore, there are greenhouse gas emission reduction goals that have to be met. These goals and the greenhouse gas calculation methodology are described in GGLS8.

Besides these standards, GGLS7 addresses those producers who want to convert or restore an agricultural or forestry crop into an area of higher conservation value and who want to trade the removed crop.

Role of GHG calculation within GGL

GGLS8 describes the greenhouse gas calculation methodology as a basis for the certification and gives saving thresholds both for greenhouse gas emissions and for the use of fossil energy. If these thresholds are not met, then the biomass or biofuel cannot be certified as GGL material. This makes the calculation of energy and greenhouse gas emissions mandatory.

The methodology takes over elements of both the RED (see section C-2.3) and the NTA (see section C-3.5) and thus guarantees compliance with both schemes.

Table B-8 shows the main elements of greenhouse gas balancing according to the GGL methodology.

Table B-8 Greenhouse gas calculation in the Green Gold Label scheme

GENERAL DESCRIPTION	
Name	Green Gold Label; GGL
Responsible body	Registered and owned by the independent Green Gold Label Foundation
Website	http://www.greengoldcertified.org/index.php?id=5
Foundation (year, participants)	2002 by the Dutch energy company Essent and Skall International (now Control Union Certifications); inclusion of GHG balancing in 2009
Scope (products and feedstocks)	Covers all agricultural and woody biomass for energy, power production and chemical purposes Covers production, processing, transport and final energy transformation
Scope (geographic)	Global
Type of system	Certification system
Objectives (mission etc.)	Is committed to supporting the development of sustainable biomass for energy, power production and chemical purposes.
Biofuel goals	*Not applicable*
Eligibility of biomass towards goals	*Not applicable*
Domestic / imported feedstock	*Not applicable*

LAND USE REQUIREMENTS	
Land use restrictions with relevance for GHG calculations	No specific restrictions related to land with high carbon stocks
GHG CALCULATION METHODOLOGY	
GENERAL	
Availability of calculation tool	*No own tool*
Feedstock sources included	All agricultural and woody biomass as well as residues
GHG thresholds	Thresholds both for greenhouse gas and energy savings. The GHG savings are adopted from NTA 8080 (see section C-3.5): -Biomass for electricity and heating: 50% reduction when referring to natural gas -Biomass for electricity and heating: 70% when referring to the Dutch electricity mix -Biogas: 60% -Biofuels: 50% Minimum levels of energy savings: -Biomass for electricity and biofuels: 35%
General methodology	The fossil GHG from the production of the biomass are calculated by adding up the emission from the single life cycle steps processes (may be broken into subsections with separate calculations to be made). Negative figures (i.e. emission savings) are subtracted. The GHG emissions are compared against a reference value for the fossil fuel (mix) that the biomass will replace. The balance needs to be positive and above the GHG thresholds. The fossil reference values are listed in the annex and are based on NTA 8080.
Life cycle elements to be included	Well-to-wheel: - Extraction / cultivation of raw material - Carbon stock changes from land use changes - Processing (separates between processes on intermediate products and of the final biomass product) - Transport and distribution - Use of fuel (set to zero emissions) - Savings from soil carbon accumulation via improved agricultural management - Savings from carbon capture and geological storage (no details on calculation are given) - Savings from carbon capture and replacement (no details on calculation are given) - Savings from excess electricity from cogeneration (no details on calculation are given) Following NTA, residual products (with only a 10% value of the main product, and having no other useful applications or which is included on the exceptions list of the NTA 8080; named in the NTA list of exceptions) have to comply with a limited number of criteria: production of the final biomass

	products, transport / storage / transshipment, final use of biomass.

CO_2 equivalent factors (GWPs)	IPCC 2001 values: N_2O: 296 CH_4: 23
Functional unit	CO_2 equivalent per MJ of fuel: g CO_2eq/MJ
Infrastructure	GHG emissions for the production of equipment and tools used in the process as well as of packaging materials, infrastructure, building factories, processing units and offices are not included.
Electricity mix	Appendix 5 lists 73 national / regional energy mixes
Data source of GHG emission factors	Appendices provide emission factors and default values (from various sources): - CO_2 emission factors and densities for all relevant fuel and transport types, default fuel uses for transports, CO_2 emissions of fossil reference chains of electricity and heat for solid and liquid biofuels, GWPs, carbon stocks and carbon fractions of aboveground forest biomass, emission factors for drained organic soil in managed forests, overall reference values of soil and vegetation carbon stocks (Appendix 1) - 73 national / regional power mixes (Appendix 5)
Actual / default values	Actual or default values may be used (however, actual values will be preferred); different default values (e.g. for fossil references, carbon stocks) are included in the annex as alternative to actual values, however, no default values in the sense of the RED defaults (i.e. emission savings for whole biofuel pathways)
Requirements for using default values	Default values and emission factors listed in the appendices can be used if the specific information is not available; report has to include an explanation on why the actual value could not been used Exception: for fertiliser and waste management actual values always have to be used (see below)
Requirements for using actual values	No default values are given for fertilisation and waste management because they can deviate between enterprises from the best practices applied. Only actual and most recent figures from the process should be used.
LAND USE CHANGE	
General	- The change in carbon stock as a result of land use should be taken into account when the land use change happened less than 20 years ago. - Positive changes in carbon stocks (e.g. inundation of peatland or reforestation) should also be taken into account. - Energy used in land change and land preparation shall not be taken into account in the energy balanced.
Direct land use change	
Reference land use	Average carbon storage per hectare before the change
Cut-off date	20 years ago
Annualisation	The change in carbon stock shall be calculated as emission and divided over 20 years
Carbon stock included	- Carbon storage in vegetation and in the soil - Emissions from drained organic soils are not included

Calculation of carbon stocks	Default values for the calculation of soil and vegetation carbon stocks are listed in Appendix 1: - Above- and below-ground rations / root-to-shoot ratio for merchantable wood - IPCC 2006 reference values for aboveground forest biomass - IPCC 2006 emission factors for drained organic soils in managed forests - EU reference values for carbon stocks in soil and vegetation for different vegetation types (CEC, 2004)
Indirect l and use change	*Not included*
Bonus fo r c ulti-vation on de-graded land	*Not included*
CULTIVATION	
Processes to be taken into ac-count	Emissions from land maintenance, harvesting and cultivation of raw materi-als, as well as the emissions from fertilising, waste and leakages; includes fossil fuel and fossil energy use of equipment; only fossil fuel is counted, renewable fuel / energy is assumed to produce zero GHG (also applies to fuel / energy mixes of fossil and renewable energy); emissions and energy used for production of auxiliary materials (e.g. fertilisers) Waste: only direct process related waste is taken into account (i.e. waste of materials used for land preparation, maintenance, harvesting, cultivation); appendix 4 shows list of wastes that should not be included. The organic (sub) products of the plants or trees left on the field after harvesting in a system cycle that is steady state shall not be taken into account in the GHG, energy and allocation calculations. Emissions from cultivation do not need to be calculated for the biomass product from the NTA 8080 list of residual products.
N_2O field emis-sions	For fertiliser and waste, CH_4 and N_2O emissions are included. No guideline on field emissions is included.
Use of average values	Annual average figures on fertiliser and waste should be used.
Other	Carbon changes in the soil are included if the process has direct influence on it (e.g. taking material containing carbon from the ground)
TRANSPORTS	
Processes to be taken into ac-count	Distance, fossil fuel use per km, GHG emission factor of fuel used, amount of feedstock transported
Calculation pro-cedure	Allocation rule when the means of transport is hauling more than 1 cargo: fuel use may be allocated between the different cargos on relative amount of holds; if a hold contains more than one product the part of the hold is allo-cated relative to the volume of the different products in the hold.

PROCESSING	
Processes to be taken into account	- Includes the fossil fuel and fossil energy use of equipment; only fossil fuel is counted, renewable fuel / energy is assumed to produce zero GHG (also applies to fuel / energy mixes of fossil and renewable energy) - Emissions and energy used for production of auxiliary materials and (product) additives are included
Excess electricity from cogeneration	- The annual electricity produced from co-generation (included electricity excess delivered to the grid) from biofuels shall be subtracted from the total annual electricity use prior to performing the calculation for the GHG emission from electricity. - The annual excessive heat delivered to third parties produced by burning part of the raw materials shall be subtracted from the total annual fossil fuel used for production prior to performing the calculation of GHG emission.
CO-PRODUCTS	
General	Allocation is applied for the processes where more products are made from the raw material
Procedure	Only the relative amount of the emissions of the biomass raw material to all the raw material for all products shall be allocated to the biomass. The same allocation rules apply for one or more products being manufactured from a half-made product(s).
Basis for allocation	Caloric value
Exemptions	Auxiliary materials (like manure) and (product) additives that are residual products of another process and which commercial value are less than 10% of the main product or other products are excluded.
FUEL USE	
Emissions from combustion	Renewable fuel / energy is assumed to produce zero GHG
FOSSIL FUEL COMPARATOR	
	Fossil references are adopted from RED: - Petrol and diesel: 83.8 g CO_{2eq}/MJ - Bioliquids used for electricity production: 91 g CO_{2eq}/MJ - Bioliquids for heat production: 77 g CO_{2eq}/MJ - Bioliquids for cogeneration: 82 g CO_{2eq}/MJ

B-3.4 ISCC – International Sustainability and Carbon Certification

Short description

The International Sustainability and Carbon Certification (ISCC) is an international third-party certification system and was founded in January 2010. It applies primarily to all kinds of biomass in bioenergy applications (biofuels and bioliquids for electricity production), however, on a voluntary basis it may also be applied to food and chemical applications of biomass. More than 250 international stakeholders contributed to its development. The requirements cover a broad range of environmental, economic and social sustainability aspects.

Several documents regulate different aspects of the certification system. The certification criteria that must be complied with fall into three categories:

1. Sustainability criteria to be complied with in biomass production
2. Requirements concerning greenhouse gas emission savings and its calculation methodology
3. Requirements concerning the traceability and mass balance to provide consistent evidence of the provenance of the biomass

The sustainability criteria for biomass production are described in the document ISCC 202 (Sustainability Requirements for the Production of Biomass). There are six principles:

1. Principle 1: Biomass shall not be produced on land with high biodiversity value or high carbon stock and not from peat land (according to Article 17, 3. of the Directive 2009/28/EC and § 4 to 6 of the German BioSt-NachV and BioKraft-NachV). HCV areas shall be protected.
2. Principle 2: Biomass shall be produced in an environmentally responsible way. This includes the protection of soil, water and air and the application of Good Agricultural Practices.
3. Principle 3: Safe working conditions through training and education, use of protective clothing and proper and timely assistance in the event of accidents
4. Principle 4: Biomass production shall not violate human rights labour rights or land rights. It shall promote responsible labour conditions and workers' health, safety and welfare and shall be based on responsible community relations
5. Principle 5: Biomass production shall take place in compliance with all applicable regional and national laws and shall follow relevant international treaties
6. Principle 6: Good management practices shall be implemented

Not all criteria and indicators have the same weight but they are divided into “Minor Musts” and “Major Musts”. Of the latter, 60% have to be fulfilled for a successful auditing.
The second pillar, the greenhouse gas emission savings, are regulated in document ISCC 205 (GHG Emissions Calculation Methodology and GHG Audit) giving detailed instructions for the calculation procedure along the whole value chain.
ISCC 203 (Requirements for Traceability) is for the third part and ISCC 201 (System Basics for the Certification of Sustainable Biomass and Bioenergy) describes the basic functions and processes of the ISCC system.
There is no extra guidance or set of criteria for compliance with the European market since all relevant criteria have been integrated into the ISCC system from the outset. ISCC

has submitted its scheme to the EU Commission for recognition. It was approved by the Commission in July 2011.

Role of GHG calculation within ISCC

GHG balancing is a mandatory part of the ISCC system which claims proving sustainability and greenhouse gas savings for biomass. It is not embedded in the sustainability requirements described in ISCC 202 but an equal stand-alone part of the certification scheme. ISCC 202 only contains requirements regarding the land with high carbon stocks that cannot be used for biomass cultivation. GHG reduction goals are embedded in ISCC 201 whereas GHG balancing is regulated in ISCC 205. It almost exactly follows the EU RED methodology so that compliance with ISCC automatically leads to compliance with the EU RED. In 2011, ISCC has been officially recognised by the European Commission.

Table B-9 includes the most important elements of the greenhouse gas calculation methodology as stipulated by ISCC.

Table B-9 Greenhouse gas calculation in the ISCC scheme

GENERAL DESCRIPTION	
Name	International Sustainability and Carbon Certification; ISCC
Responsible body	ISCC Association (e.V.)
Website	http://www.iscc-system.org/index_eng.html
Foundation (year, participants)	ISCC association founded in January 2010; certification starts in 2010
Scope (products and feedstocks)	Certification of all biomass and bioenergy (bioliquids, biofuel)
Scope (geographic)	Global
Type of system	Certification system
Objectives (mission etc.)	ISCC is oriented towards - reduction of greenhouse gas emissions, - sustainable use of land, - protection of natural biospheres, - social sustainability
Biofuel goals	*Not applicable*
Eligibility of biomass towards goals	*Not applicable*
Domestic / imported feedstock	*Not applicable*
LAND USE REQUIREMENTS	
Land use restrictions with relevance for GHG calculations	Biomass shall not be produced on land with high carbon stocks, namely - wetlands - forested area - drained peatland

GHG CALCULATION METHODOLOGY	
GENERAL	
Availability of calculation tool	No tool available
Feedstock sources included	Covers all relevant raw materials / types of biomass
GHG thresholds	The produced liquid biomass respectively biofuel must grant greenhouse gas emission savings of 35%.
General methodology	GHG emission savings are calculated by adding up emissions from the single life cycle steps. Negative emissions (=savings) are subtracted. GHG emissions are compared against a fossil reference value for fossil fuel. Balance needs to be positive and above GHG thresholds mentioned above.
Life cycle elements to be included	Well-to-wheel: - Extraction / cultivation of raw material - Carbon stock changes from land use changes - Processing - Transport and distribution - Use of fuel (set to zero) - Savings from soil carbon accumulation via improved agricultural management - Savings from carbon capture and geological storage - Savings from carbon capture and replacement - Savings from excess electricity from cogeneration
CO_2 equivalent factors (GWPs)	IPCC 2001 values: N_2O: 296 CH_4: 23
Functional unit	g CO_2/MJ final product
Infrastructure	Emissions from the manufacture of machinery and equipment shall not be taken into account (it is not necessary to include inputs which have little or no effects on the result, i.e. those that have an impact on overall emissions that is lower than 5% of the total emissions)
Electricity mix	If external electricity is used, the emission factor for electricity from the regional electricity mix shall be used (emission factor must be taken from the 'ISCC list of emission factors'); either EU average or national averages for third countries
Data source of GHG emission factors	The following factors must be taken from the 'ISCC list of emission factors': - Emission factors diesel used in agricultural machinery or for transport, fertiliser production, fertiliser emissions from the field, for regional electricity mixes - Emission factors for fuel (for processing), wastewater and wastes, operating supplies
Actual / default values	There are three possibilities for calculating the GHG emissions savings: 1) Using default values provided in the RED (provided either as overall default value for the sum of emissions for the final product or as disaggregated default values for cultivation, processing, transport / distribution); disagreggated default values can also be taken from the BioGrace project (see section C-3.1) 2) Using actual values based on individual calculation based on the methodology provided in the RED 4) Combination of default and actual values

Requirements for using default values	There is no default value for land use change. If land use change took place, the respective emissions have to be calculated and added to the default values for cultivation if these are used.
Requirements for using actual values	Actual values for specific elements of the supply chain can be used regardless of whether there exists a default value for the biofuel/bioliquid in question.
LAND USE CHANGE	
General	- The issue of an ISCC certificate is not possible if the conversion of some of the above mentioned areas with high carbon stock has taken place. - Land that is not excluded from cultivation can be converted if the net GHG emissions from the land use change are calculated and added to the other emission values. - Emissions from LUC need not be calculated if it took place before the time reference point.
Direct land use change	
Reference land use	Land use in January 2008 or 20 years before the raw material was obtained, whichever is the later
Cut-off date	1 January 2008
Annualisation	Annualised emissions from carbon stock changes caused by land-use change shall be calculated by dividing total emissions equally over 20 years.
Carbon stock included	Soil and vegetation
Calculation of carbon stocks	Should follow the EU guideline for the calculation of land carbon stocks (EU, 2009)
Indirect land use change	Not included
Bonus for cultivation on degraded land	The entitlement of the bonus of 29 gCO_2eq/MJ for cultivation on degraded land is not possible until final definitions from the European Commission of degraded land are available.
CULTIVATION	
Processes to be taken into account	Emissions from cultivation itself, harvest, processing, emissions from production of the inputs (chemicals and others, e.g. diesel) necessary for cultivation CO_2 fixation during feedstock cultivation not considered. Elements included in the formula provided: - Yields - Fertiliser (production and field emissions) - Diesel - Electricity - Other inputs
N_2O field emissions	Emission factor is provided in the ‘ISCC list of emission factors’; an appropriate way to take into account N2O emissions from soils is the IPCC methodology (including direct and indirect emissions)

Use of average values	Average values may be used instead of actual farm-level data if they have been calculated for smaller geographical areas than those used in the calculation of the default values (i.e. NUTS-2 level or more fine-grained). Member States can use lists of such values which are published at the EU Transparency Platform. If such lists are not available, most recent available data from official sources can be used. Fertiliser inputs must be adapted to the yield data used.
Other	Emission savings from soil carbon accumulation via improved agricultural management is mentioned in the overall formula, however, no calculation guidance is provided.
TRANSPORTS	
Processes to be taken into account	All transport steps (distance loaded / empty) GHG emissions already accounted for in feedstock production and harvest need not to be considered.
Calculation procedure	The GHG emissions from transport always need to be documented and included into the GHG calculations by the element in the value chain that is receiving the product.
PROCESSING	
Processes to be taken into account	GHG emissions from processing, GHG emissions from wastes (wastewater) and from the production of all inputs
Calculation procedure	The following data needs to be collected on-site (annual average figures can be used): - Annual total electricity consumption from external sources, i.e. not produced in an internal combined heat and power production (CHP) plant, - Type of fuel used for steam production, e.g. heating oil, natural gas, crop residues, - Annual total fuel consumption for heat production, e.g. heating oil, natural gas, bagasse, - Further inputs (operating supplies) - Annual yield main product, e.g. rape oil, - Yield of co-products, - Annual amount of wastewater and wastes (e.g. POME), - Feedstock inputs (amounts, conversion rates, and GHG value of feedstock inputs); if wastes are used, their GHG emissions are considered to be zero - GHG emissions from wastes
Excess electricity from cogeneration	Only CHP production from fossil and bioenergy (not produced from co-products from the same process) is taken into account. It is assumed that the size of the CHP plant is that of the minimum size necessary to supply the needed amount of heat for the production of the liquid fuel (notional reduction may be necessary). The amount of GHG emission savings from excess electricity equals the amount of GHG emissions from the production of an equivalent amount of electricity in a power plant using the same fossil fuel as the CHP plant. This is the only case where for the treatment of co-products (excess electricity) the substitution method and, not as for all other by-products, the allocation method based on lower heating values of the main product and the by-products is being used.

Others	If palm oil mills are operating methane capture devices, the following aspects need to be checked and fulfilled: - Absorption of total wastewater in a closed system (only short-term storage of fresh POME) and supply to a biogas plant, - Use of the produced biogas for energy purposes, or in the worst case flaring of the biogas and - The biogas plant is in good condition, leakages are nonexistent, and the producer provides a guarantee about the maximum methane leakage that does not exceed the current state of the technology Emission saving from carbon capture and geological are emissions avoided through the capture and sequestration of emitted CO_2 directly related to the extraction, transport, processing and distribution of fuel. Emission saving from carbon capture and replacement are emissions avoided through the capture of CO_2 of which the carbon originates from biomass and which is used to replace fossil-derived CO_2 used in commercial products and services.
CO-PRODUCTS	
General	Allocation is applied to co-products emerging along the life cycle.
Procedure	Allocation takes place at every element in the value chain that in addition to the main product also produces co-products. All emissions up to that point can then be distributed between the main product and the co-products. The GHG value after this allocation product is passed on within the value chain. For the calculation of the share of GHG emissions that are allocated to the different products, total GHG emissions up to the production process where the by-product is produced need to be summed up and multiplied with the allocation factor
Basis for allocation	Lower heating value in the case of co-products other than electricity (that of the entire (co-)product, not only of the dry fraction). For nearly-dry products, the LHV of the dry fraction could be used as adequate approximation. The energy content of co-products that have negative energy content is defined as zero
Exemptions	No emissions should be allocated to agricultural crop residues and processing residues nor to waste. Those products from a production process the owner wants to or must get rid off are not considered as by-products but as waste. All co-products are accounted for in the calculation, except for crop residues (straw, bagasse, husks, cobs, nut shells) or processing residues (crude glycerine).
FUEL USE	
Emissions from combustion	Emissions from the fuel in use are not taken into account to balance the fact that carbon dioxide fixation during feedstock cultivation is not considered.
FOSSIL FUEL COMPARATOR	
	The following fossil comparators must be used: - Biofuels for transport: 83,8 g CO_2eq/MJ fossil fuel, - Bioliquids used for electricity production: 91 g CO_2eq/MJ fossil fuel, - Bioliquids used for electricity production in CHP plants: 85 g CO_2eq/MJ fossil fuel and - Bioliquids used for heat production: 77 g CO_2eq/MJ fossil fuel.

B-3.5 NEN NTA 8080 – Dutch Technical Agreement

Short description

The sustainability requirements set down in the European Renewable Energy Directive (EU RED, see also section C-2.3) require the establishment of a certification system to prove compliance. To fill this gap in the Netherlands, the NTA 8080 certification scheme has been developed taking into account the RED and the Cramer sustainability criteria. The latter have been formulated by the Dutch project group 'Sustainable production of biomass' for the use of biomass for energy applications and the chemical industry as a response to the increasingly critical view on biomass for bioenergy use. The criteria have been published in the Cramer report (Cramer, 2007).

The third-party certification scheme NTA 8080 is owned by NEN (Nederlandse Norm), the Dutch institute for standardisation.

NTA 8080 goes beyond the RED and may be applied to all types (solid, liquid, gaseous) of biomass for energy applications. The NTA can be applied to producers of primary biomass as well as at organisations that want to produce, convert, trade, transport and / or use sustainable biomass for energy purposes. For small-holders, a slimmed-down and more practical approach is applied.

The sustainability requirements cover the following topics:

- Greenhouse gas emission
- Competition with food and local applications of biomass
- Biodiversity
- Environment (soil, water, air)
- Prosperity
- Social well-being

In the NTA a list with exceptions is included for residual flows that represent a negligible economic value. For these materials, a reduced list of criteria applies: they only need to comply with the requirements with respect to greenhouse gas balance and the preservation and improvement of soil quality.

Since the standard specifically implements the RED sustainability criteria, there is an automatic compliance with them. In the foreword of the standard it is stated that requirements in the NTA which are not included in the EU RED have a voluntary character for biofuels for transportation.

Role of GHG calculation within NTA

Greenhouse gas balancing is a mandatory part of the NTA. There are requirements to achieve certain emission reduction goals that have to be met by all actors of the biomass value chain. Areas with high carbon stocks are excluded from use. Regarding the greenhouse gas calculation methodology, no own guidelines are provided but reference is made to the EU RED methodology that shall be applied. There is also reference to a GHG calculation tool that has been developed by SenterNovem. However, the information in the document is slightly outdated. Currently, a harmonised GHG calculation tool is under development at a European level (the BioGrace tool, see section B-3.1). NEN stated that they will follow this tool as soon as it becomes available.

Table B-9 lists the main elements of the NTA greenhouse gas calculation methodology. Only those items named in the standard and its guiding document are listed. For all other elements of the calculation, refer to RED (section B-2.3) or BioGrace (section B-3.1).

Table B-10 Greenhouse gas calculation in the NTA scheme

GENERAL DESCRIPTION	
Name	NEN NTA 8080 (Dutch Technical Agreement)
Responsible body	The Dutch Standardisation Institution NEN (Nederlandse Norm)
Website	http://www.sustainable-biomass.org/publicaties/3892
Foundation (year, participants)	2009; Cramer criteria served as basis for technical agreement with the support of NEN
Scope (products and feedstocks)	All biomass (solid, liquid, gaseous) for all energy uses (power, heat & cold and transportation fuels)
Scope (geographic)	Europe
Type of system	Certification system based on the Dutch technical agreement NTA 8080
Objectives (mission etc.)	Providing a certification scheme for sustainably produced biomass for energy purposes based on European and Dutch sustainability criteria, thus implementing the European sustainability requirements in the Netherlands
Biofuel goals	*Not applicable*
Eligibility of biomass towards goals	*Not applicable*
Domestic / imported feedstock	*Not applicable*
Land use restrictions with relevance for GHG calculations	Areas excluded for the planning of new production units for biomass: - areas in which the loss of above-ground carbon stock cannot be recovered within a period of 10 years of the intended biomass production; - areas with a high risk of significant carbon losses from the soil, such as certain grasslands, peat areas, mangroves and wet areas (wetlands) If activities are within the scope of the RED, then the following areas are excluded for biomass production: a) wetlands b) continuously forested areas c) land spanning more than one hectare with trees higher than five metres and a canopy cover of between 10 % and 30 %, or trees able to reach those thresholds in situ d) peatlands, unless evidence no drainage is necessary.

GHG CALCULATION METHODOLOGY	
GENERAL	
Availability of calculation tool	*Will use the BioGrace tool (see section B-3.1)* If own calculations or another tool is used, evidence needs to be provided that the same calculation methodology has been applied.
Feedstock sources includ-ed	All biomass feedstock for energy purposes
GHG thresholds	- Electricity and heat: at least 70 % in case of reference of Dutch mixture of electricity or coal, or at least 50 % in case of reference of natural gas. If in the chain of biomass innovative preparation technology or technologies is or are demonstrably used to enlarge the availability and/or the applicability of sustainable biomass, a minimum of 50 % applies; - Biogas: at least 60 %; - Transportation biofuels: at least 50 %; for those flows of biomass, for which in the RED a 'typical greenhouse gas emission saving' of less than 50 % is in-cluded a transition period till 2012 applies with a minimum of 35 %
General meth-odology (princi-ples applying to all life cycle steps)	*Follows the methodology of the EU RED*
Life cycle ele-ments to be included / sys-tem boundaries	*See RED*
CO_2 equivalent factors (GWPs)	*See RED*
Functional unit	*See RED*
Infrastructure	*See RED*
Electricity mix	*See RED*
Data source of GHG emission factors	*See RED*
Actual / default values	*See RED*
Requirements for using default values	If the activities are within the scope of the RED, the default values as included in this Directive may only be used if the raw materials meet one of the following conditions: a) the raw materials are cultivated outside the European Community b) the raw materials are cultivated in the European Community in areas in-cluded in a list that are formulated by the European member states as part of this European Directive (reports with lists are published on the EC transparency platform; http://ec.europa.eu/energy/renewables/transparency_platform/transparency_platform_en.htm) c) the raw materials are waste or residues other than agricultural, aquacul-ture and fishery residues.

Requirements for using actual values	- If no default values can be used, then actual values shall be used. - If actual values shall be used or are used for own reasons, these values shall be validated by an independent authority. When determining actual values, the basis of the information shall be clearly indicated. - In the case of energy consumption either actual measurements or technical specifications of the installations in operation shall be used. If a range is given, the most conservative value shall be used.
LAND USE CHANGE	
General	a) Loss of carbon stocks in the vegetation and in the soil through the planning of a production unit shall be established preceding the planning of the new production unit b) establish whether these losses will be compensated through cultivation of the intended biomass during the next 10 years; c) take measures to reduce the emission of greenhouse gases from the soil during cultivation; d) monitor, measure and analyse the measures; e) document the results.
Direct land use change	
Reference land use	*See RED*
Cut-off date	January 2007 Note: The RED applies 1 January 2008 as reference date, but the reference date of NTA precedes it.
Annualisation	*See RED*
Carbon stock included	*See RED*
Calculation of carbon stocks	Calculation shall follow the EU guidelines (CEC, 2009)
Indirect land use change	Reference to future work of Dutch government
Others	A bonus is attributed if restored degraded land is used. As long as the European Commission has not defined what is meant by degraded land, this bonus may not be attributed.
CULTIVATION	
Processes to be taken into account	*See RED*
N_2O field emissions	*See RED*
Use of average values	If values from scientific research are used when determining the emissions of cultivation, the values used shall be within the average range for the region in which the cultivation occurs. For fertilisers it applies that the crop and type shall be considered when using averages of the region in which the cultivation occurs.

TRANSPORTS	
Processes to be taken into account	*See RED*
Calculation procedure	*See RED*
PROCESSING	
Processes to be taken into account	*See RED*
Use of actual values	*See RED*
Calculation procedure	*See RED*
Emission factors	*See RED*
Average emissions	
Excess electricity	*See RED*
Others	
CO-PRODUCTS	
General	*See RED*
Basis for allocation	*See RED*
Exemptions	*See RED*
FUEL USE	
Emissions from combustion	*See RED*
FOSSIL FUEL COMPARATOR	
	See RED

B-3.6 RSB – Roundtable on Sustainable Biofuel

Short description

The Roundtable on Sustainable Biofuel (RSB) is a roundtable initiative coordinated by the Energy Center at EPFL in Lausanne. Since 2007, it brings together all kinds of stakeholders which include farmers, company representatives, NGOs and governments. The RSB is open to any organisation that is related to the field of biofuel sustainability.

Past work focused on getting a broad consensus on sustainability with regard to biofuels. Based on these requirements, a third-party certification system has been established which applies to the production and processing of biofuel feedstocks and raw materials as well as for the production, use and transport of liquid biofuels. The standard covers environmental, economic and social aspects. Four types of operators have been identified which are subject to different sustainability requirements within the standard: feedstock producer, feedstock processor, biofuel producer and biofuel blender.

Version 2 of the RSB Principles & Criteria for Sustainable Biofuel Production has been consolidated in November 2010 and can be used for certification from 2011 on. The following principles can be found in the RSB Principles & Criteria:

- Principle 1: Biofuel operations shall follow all applicable laws and regulations.
- Principle 2: Sustainable biofuel operations shall be planned, implemented, and continuously improved through an open, transparent, and consultative impact assessment and management process and an economic viability analysis.
- Principle 3. Biofuels shall contribute to climate change mitigation by significantly reducing lifecycle GHG emissions as compared to fossil fuels.
- Principle 4. Biofuel operations shall not violate human rights or labour rights and shall promote decent work and the well-being of workers.
- Principle 5. In regions of poverty, biofuel operations shall contribute to the social and economic development of local, rural and indigenous people and communities.
- Principle 6. Biofuel operations shall ensure the human right to adequate food and improve food security in food insecure regions.
- Principle 7. Biofuel operations shall avoid negative impacts on biodiversity, ecosystems, and conservation values.
- Principle 8: Biofuel operations shall implement practices that seek to reverse soil degradation and/or maintain soil health.
- Principle 9. Biofuel operations shall maintain or enhance the quality and quantity of surface and ground water resources, and respect prior formal or customary water rights.
- Principle 10. Air pollution from biofuel operations shall be minimised along the supply chain.
- Principle 11. The use of technologies in biofuel operations shall seek to maximise production efficiency as well as social and environmental performance, in addition to minimising the risk of damages to the environment and people.
- Principle 12. Biofuel operations shall respect land rights and land use rights.

Besides the general RSB Principles & Criteria, an adapted set of standards has been developed for compliance with the EU RED (‘RSB standard for EU market access’; for the EU RED, see section C-2.3). It is also available as Version 2. The relevant documents have been submitted for recognition to the European Commission in December 2010 and were approved in July 2011.

Role of GHG calculation within the system

GHG balancing is a mandatory part both of the general RSB Principles & Criteria as well as of the Standard for EU market access. In the main Principles & Criteria there is one explicit principle describing the reduction of greenhouse gas emissions (Principle 3: Biofuels shall contribute to climate change mitigation by significantly reducing lifecycle GHG emissions as compared to fossil fuels). It is further detailed by three criteria for the compliance with existing regulations, for the GHG calculation methodology to be used and for GHG reduction goals:

- Criterion 3a: In geographic areas with legislative biofuel policy or regulations in force, in which biofuel must meet GHG reduction requirements across its lifecycle to comply with such policy or regulations and/or to qualify for certain incentives, biofuel operations subject to such policy or regulations shall comply with such policy and regulations and/or qualify for the applicable incentives.
- Criterion 3b Lifecycle GHG emissions of biofuel shall be calculated using the RSB lifecycle GHG emission calculation methodology, which incorporates methodological elements and input data from authoritative sources; is based on sound and accepted science; is updated periodically as new data become available; has system boundaries from Well to Wheel; includes GHG emissions from land use change, including, but not limited to above- and below-ground carbon stock changes; and incentivises the use of co-products, residues and waste in such a way that the lifecycle GHG emissions of the biofuel are reduced.
- Criterion 3c: Biofuel blends shall have on average 50% lower lifecycle greenhouse gas emissions relative to the fossil fuel baseline. Each biofuel in the blend shall have lower lifecycle GHG emissions than the fossil fuel baseline.

The participating operator reporting the life cycle GHG emissions is a minimum requirement under Criterion 3b. The calculation of GHG emissions is also necessary to prove that the emission saving goals has been met according to Criterion 3c. The GHG calculation methodology is described in a separate document ('RSB GHG Calculation Methodology').

The RSB Standard for EU market access closely reflects the requirements as stipulated in the EU RED. This means that there is a certain GHG reduction goal for which compliance has to be proven by GHG balancing. The GHG calculations have to follow the RED methodology which is included in the Annex of the standard. In general the methodology is exactly the same as described in the RED.

For the greenhouse gas calculation under RSB, a calculation tool has been developed which is available online as a Beta Version (http://buiprojekte.f2.htw-berlin.de:1339/user). Besides calculating GHG emissions, the tool assists in performing a self-evaluation against the RSB standards. It can be used for both the main standard and the standard for EU market access. Where there are major discrepancies between both standards (e.g. regarding the reference for co-product allocation), the tool offers the possibility to choose between both versions. In contrast to the RSB Standard for EU Market Access, the tool has not yetbeen submitted to the EC Commission and thus has not yet been approved for doing official RED conform calculations.

The relation between both standard types is clearly regulated in the RSB Standard for EU Market Access. It states that the participating operators have to comply with this standard in addition to all other RSB standards. In cases where both standards specify requirements on the same or similar issues, the participating operator shall ensure compliance with the more rigorous requirement and at minimum with the requirement of the EU market access standard. This concerns for example the GHG reduction objective: whereas the EU standard requires a 50% reduction from only 2017 on (until then a 35% reduction applies), the main standard already requires it.

Table B-11 provides the basic principles of greenhouse gas calculation within the RSB systems. Both the general standard (referred to as 'RSB general') and the specific EU standard (referred to as 'EU-RSB') are included.

Table B-11 Greenhouse gas calculation in the RSB scheme

GENERAL DESCRIPTION	
Name	Roundtable on Sustainable Biofuel; RSB
Responsible body	Coordinated by the Energy Center at EPFL in Lausanne
Website	http://rsb.epfl.ch/
Foundation (year, participants)	Founded in 2006; roundtable initiative with international stakeholders; certification starts in 2011
Scope (products and feedstocks)	Liquid biofuels; tool contains a limited list of biofuels (to be extended in future)
Scope (geographic)	Global
Type of system	Multi-stakeholder initiative that developed a certification system
Objectives (mission etc.)	Provides and promotes the global standard for socially, environmentally and economically sustainable production and conversion of biomass
Biofuel goals	*Not applicable*
Eligibility of biomass towards goals	*Not applicable*
Domestic / imported feedstock	*Not applicable*
LAND USE REQUIREMENTS	
Land use restrictions with relevance for GHG calculations	***RSB general:*** only indirectly through Principle 7 – Conservation (Criterion 7.a Conservation values of local, regional or global importance within the potential or existing area of operation shall be maintained or enhanced); however, emissions occurring from land use change have to be calculated ***EU-RSB:*** primary producers of biomass shall ensure and provide evidence that no land with high carbon stock was converted for production of raw material (biomass) for biofuels/bioliquids: - Wetland - Continuously forested land - Peatland (unless drainage is not necessary)
GHG CALCULATION METHODOLOGY	
GENERAL	
Availability of calculation tool	A beta version of the RSB tool is available that among others includes GHG calculations; performs calculations both for main RSB standard and for RSB-EU standard (http://buiprojekte.f2.htw-berlin.de:1339/user)
Feedstock sources included	All types of feedstocks for liquid biofuels may be certified ***EU-RSB:*** lists default GHG savings for 15 feedstock sources (35 life cycles)

GHG thresholds	***RSB general:*** Biofuel blends shall have on average 50% lower lifecycle greenhouse gas emissions relative to the fossil fuel baseline. The minimum lifecycle GHG reduction of the biofuel blend, starting at 50%, shall increase over time. ***EU-RSB:*** the GHG emissions savings of the final biofuels/bioliquids product are at least: - 35 %, or - 35 % on 1 April 2013, if the production of the biofuels/bioliquids involved facilities which were in operation on 23 January 2008, or - 50% on 1. January 2017, or - 60% on 1. January 2018, if the production of the biofuels/bioliquids involved facilities which started operation on or after 1 January 2017
General methodology	***RSB general & EU-RSB:*** GHG emissions from single life cycle steps are added up; savings are subtracted. GHG emissions are compared against a fossil reference value for fossil fuel. Balance needs to be positive and above GHG thresholds mentioned in the standards.
Life cycle elements to be included	***RSB general:*** well-to-wheel; fuel in use excluded ***EU-RSB:*** Well-to-wheel - extraction or cultivation of raw materials; - carbon stock changes caused by land-use change; - processing; - transport and distribution; - the fuel in use (set to zero); - savings from soil carbon accumulation via improved agricultural management; - savings from carbon capture and geological storage; - savings from carbon capture and replacement; and - savings from excess electricity from cogeneration
CO_2 equivalent factors (GWPs)	***RSB general:*** all greenhouse gases based on the ReCiPE method **EU-RSB:** only N_2O and CH_4 based on IPCC 2007: N_2O: 298 CH_4: 25
Functional unit	***RSB general & EU-RSB:*** Grams of CO_2 equivalent per MJ of fuel: g $CO2_{eq}$/MJ. ***EU-RSB:*** emissions of a participating operator: kg CO_2eq/kg of product The final operator transforms the value in kg CO_2eq/MJ by using conversion factors. For transport fuels, values may be adjusted to take into account differences between fuels in useful work done, expressed in terms of km/MJ.
Electricity mix	***RSB general & EU-RSB:*** RSB tool includes national averages from ecoinvent data base[1] ***EU-RSB:*** regional (e.g. national) mixes shall be used for electricity not produced within the fuel production plant; average values for an individual electricity production can be used if that plant is not connected to the electricity grid.
Infrastructure	***RSB general:*** included (from ecoinvent data base) ***EU-RSB:*** emissions from the manufacture of machinery and equipment are not taken into account.

[1] http://www.ecoinvent.ch/

Data source of GHG emission factors	***RSB general & EU-RSB:*** emission factors taken from the ecoinvent database[1] are included in the tool
Actual / default values	***RSB general:*** only actual value; operator-specific data shall be entered in tool ***EU-RSB:*** two possibilities for calculation GHG emission: - default values or - calculated based on disaggregated default values and/or actual values (combination is possible); for actual values the tool can be used
Requirements for using default values	***EU-RSB:*** Default values shall only be used if 1) a default value exists, and 2) the biofuel was produced using the specified characteristics of the conversion process indicated in the annex , and 3) no net emissions from carbon stock change due to land use change where caused in primary production occur, and 4) biofuels/bioliquids were produced from raw materials which complied with the following characteristics: - Cultivated outside the EU - Cultivated within the EU and included in a list of areas on their territory where GHG emissions from crop cultivation can be expected to be at or below cultivation default values (to be prepared by each Member State, published on the EC Transparency Platform) - That is waste or residues other than agricultural, aquaculture and fisheries residues
Requirements for using actual values	***EU-RSB:*** Actual values shall be used if disaggregated default values are not available, if raw materials do not comply with the characteristic listed above and may be used instead of disaggregated default values where available.
LAND USE CHANGE	
General	***RSB general:*** no exclusion of land types, however, changes in carbon stocks due to land use changes have to be included in the GHG calculations; only direct land use changes included ***EU-RSB:*** land that does not fall under the above mentioned restriction may be converted; however, if conversion took place after the reference date, associated emissions have to be calculated and included in the balance; only emissions from direct land use changes are to be included
Direct land use change	
Reference land use	***RSB general:*** land use at the reference date (1 January 2009) ***EU-RSB:*** land use in January 2008 or 20 years before the raw material was obtained, whichever is the later
Cut-off date	***RSB general:*** 1 January 2009 or earlier, if another sustainability standard (operational or currently under development) with an earlier cutoff date applied to the project ***EU-RSB:*** 1 January 2008
Annualisation	***RSB general & EU-RSB:*** Annualised emissions from carbon stock changes shall be calculated by dividing total emissions equally over 20 years.

Carbon stock included	***RSB general & EU-RSB:*** Soil organic carbon, dead organic matter and vegetation (above-ground and below ground) ***RSB general:*** takes into account foregone sequestration, i.e. carbon sequestration avoided by land transformation
Calculation of carbon stocks	***RSB general & EU-RSB:*** tool includes Tier 1 data from IPCC 2006 (except for peat, based on Hooijer et al., 2006) ➔ implements European Commission guidelines (EC, 2009)
Other	***RSB general:*** possibility to include emissions from fire use for land clearing calculated based on IPCC 2006; takes into account N_2O emissions associated with loss of soil organic carbon
Indirect l and u se change	***RSB general & EU-RSB:*** not included
Bonus for cultivation on degraded land	***EU-RSB:*** A bonus of 29 gCO_2eq/MJ shall be attributed if the land was not in use for agriculture or any other activity in January 2008 and if it is severely degraded or heavily contaminated. However, the bonus shall not be included in the calculation until guidance is provided by the Commission on the definition of degraded lands.
CULTIVATION	
Processes to be taken into account	***RSB general & EU-RSB:*** Emissions from the extraction or cultivation process itself; from the collection of raw materials; from waste and leakages; and from the production of chemicals or products used in extraction or cultivation. Capture of CO_2 in the cultivation of raw materials shall be excluded.
N_2O field emissions	***RSB general*** **:** modeling of direct and indirect N-emissions from mineral and organic fertiliser based on different models: ammonia, N_2O NO_X, nitrate ***EU-RSB:*** direct and indirect N_2O emissions from soils are taken into account according to the IPCC methodology.
Use of average values	***EU-RSB:*** average values may be used instead of actual farm-level data if they have been calculated for smaller geographical areas than those used in the calculation of the RED default values (i.e. NUTS-2 level or more fine-grained). For agricultural management it is allowed to use either measured or statistical average / so-called aggregate values; for the latter there are quality requirements (e.g. statistics have to be official, fertiliser use has to be adjusted to crop type)
Other	***EU-RSB:*** emission savings from soil carbon accumulation via improved agricultural management is mentioned in the overall formula, however, no calculation guidance is provided

TRANSPORTS	
Processes to be taken into account	***RSB general & EU-RSB:*** Emissions from transport of the feedstock, the biofuel and intermediary products as well as from the storage of finished materials; losses of products during transport
PROCESSING	
Processes to be taken into account	***RSB general & EU-RSB:*** production of chemicals, energy used for production as well as possible emissions from the process itself (e.g. methane emissions from ponds in the palm oil production)
Use of actual values	***EU-RSB:*** actual values for emissions from processing in the production chain must be measured or based on technical specifications of the processing facility. When the range of emissions values for a group of processing facilities to which the facility concerned belongs is available, the most conservative number of that group shall be used.
Calculation procedure	***EU-RSB:*** emissions shall be calculated for each processing step individually and summed up.
Average emissions	***EU-RSB:*** the RED requires the use of average emission intensities for a defined region. In the case of the EU the most logical choice is the whole EU. In the case of third countries, where grids are often less linked-up across borders, the national average could be the appropriate choice.
Excess electricity from cogeneration	***EU-RSB:*** emission savings can be taken into account if the fuel used is not a co-product other than an agricultural crop residue. Size of the cogeneration unit shall be assumed to be the minimum necessary to supply the heat that is needed to produce the fuel. GHG emission savings shall be equal to the amount of GHG that would be emitted when an equal amount of electricity was generated in a power plant using the same fuel as the cogeneration unit.
Others	***EU-RSB:*** Emission saving from carbon capture and geological storage (emissions avoided through the capture and sequestration of emitted CO_2 directly related to the extraction, transport, processing and distribution of fuel) Emission savings from carbon capture and replacement (emissions avoided through the capture of CO_2 of which the carbon originates from biomass and which is used to replace fossil-derived CO_2 used in commercial products and services)
CO-PRODUCTS	
General	***RSB general & EU-RSB:*** allocation is applied to all co-products emerging along the life cycle.
Procedure	***RSB general & EU-RSB:*** allocation should be applied directly after a co-product is produced at a process step. This can be a process step within a plant after which further "downstream" processing takes place. If downstream processing of the (co-) products concerned is interlinked with any upstream part of the processing, the system is considered a "refinery" and allocation is applied at the points where each product has no further downstream processing that is interlinked by material or energy feedback-loops with any upstream part of the processing.

Basis for allocation	***RSB general:*** economic allocation ***EU-RSB:*** allocation based on lower heating value (that of the entire (co-) product, not of only the dry fraction of it).
Exemptions	***RSB general:*** all co-products taken into account; the definition of waste, and how to treat waste in GHG accounting, still is to be defined. ***EU-RSB:*** wastes, agricultural crop residues, including straw, bagasse, husks, cobs and nut shells, and residues from processing, including crude glycerine (glycerine that is not refined) are not allocated. Since heat does not have a lower heating value no emissions can be allocated to it on that basis. Co-products that have a negative energy content shall be considered to have an energy content of zero for the purpose of the calculation.
FUEL USE	
Emissions from combustion	***RSB general & EU-RSB:*** Emissions from the fuel in use shall be taken to be zero for biofuels and bioliquids.
FOSSIL FUEL COMPARATOR	
	RSB general: - Gasoline : 90 gCO_2eq/MJ - Diesel: 90 g CO_2eq/MJ - Kerosene-based Jet: 90 gCO_2eq/MJ. The fossil fuel baseline is re-calculated periodically every 5 years to reflect the changing carbon intensity of fossil fuels. The fossil fuel baseline is a global, average baseline. ***EU-RSB:*** - Biofuel: fossil fuel comparator shall be the latest available actual average emissions from the fossil part of petrol and diesel consumed in the Community. If no such data are available, the value used shall be 83.8 gCO_2eq/MJ. - bioliquids used for electricity production: 91 gCO_2eq/MJ - bioliquids used for heat production: 77 gCO_2eq/MJ - bioliquids used for cogeneration: 85 gCO_2eq/MJ

B-3.7 RTRS – Round Table on Responsible Soy

Short description

The Roundtable of Responsible Soy was founded in 2006. It is a global multi-stakeholder initiative with members covering producers, industry and civil society actors. The RTRS certification standard covers economic, social and environmental issues as well as all types of soy production and soybeans for all type of use applications. The ‚RTRS Standard for Responsible Soy Production Version 1.0' covers five principles:

- Principle 1: Legal Compliance and Good Business Practice
- Principle 2: Responsible Labour Conditions
- Principle 3: Responsible Community Relations
- Principle 4: Environmental Responsibility
- Principle 5: Good Agricultural Practice

In addition to the main standard, a RTRS EU RED scheme was developed which allows soybean producers and processors to meet the EU RED requirements. There are two documents covering different actors of the soybean value chain: the 'RTRS EU RED Compliance Requirements for Producers' that is mandatory for all producers (growers) and the 'RTRS EU RED Compliance Requirements for the Supply Chain' for all other supply chain operators (processors etc.). These requirements have to be met in addition to the main standard. Wherever both documents deal with the same issue which could lead to conflicts, guidance is given in the RTRS EU RED scheme on how to proceed. The RTRS EU RED scheme has been officially approved by the European Commission in 2011.

Role of greenhouse gas calculation

In the main standard, greenhouse emissions are addressed indirectly under principle 3 (Environmental Responsibility). There is a general requirement to make efforts to reduce emissions and increase sequestration of greenhouse gases on the farm. However, there are no reduction goals, and thus the calculation of greenhouse gas emissions is not necessary.

In contrast, under the RTRS EU RED scheme, greenhouse gas calculations are mandatory to prove compliance with the 35% reduction goal set by the EU RED. Details on the calculation methodology are given in the scheme (specifically for producers and the rest of the value chain). However, the methodology is only described as an indication as it is not planned that any producer has to perform their own calculation. In the future, RTRS will develop an own GHG calculator or will approve an existing GHG calculator for use. Table B-12 gives an overview on the greenhouse calculation methodology stipulated in RTRS. The table includes elements from both the main standard (referred to as 'RSB general') and the EU specific standard (referred to as 'RTRS EU').

Table B-12 Greenhouse gas calculation in the RTRS scheme

GENERAL DESCRIPTION	
Name	Roundtable on Responsible Soy; RTRS
Responsible body	RTRS Association
Website	http://www.responsiblesoy.org/
Foundation (year, participants)	2006; international multi-stakeholder platform; certification starts in 2011
Scope (products and feedstocks)	Soybeans and derived products
Scope (geographic)	Global
Type of system	Certification system
Objectives (mission etc.)	Encourage that current and future soybean is produced in a responsible manner to reduce social and environmental impacts while maintaining or improving the economic status for the producer.
Biofuel goals	*Not applicable*
Eligibility of biomass towards goals	*Not applicable*
Domestic / imported feedstock	*Not applicable*
LAND USE REQUIREMENTS	
Land use restrictions with relevance for GHG calculations	***RTRS general:*** land use restrictions only related to biodiversity conservation ***RTRS EU:*** Exclusion of high carbon areas (no conversion of high carbon stock areas since January 2008): - Land that is covered with or saturated by water permanently or for a significant part of the year - Peatland - Continuously forested areas - Land spanning more than one hectare with trees higher than five meters and a canopy cover between 10 % and 30 %, or trees able to reach those thresholds in situ, unless evidence is provided that the GHG emissions for the whole supply chain meet the 35% savings threshold.
GENERAL	
Availability of calculation tool	***RTRS EU:*** RTRS will either develop a GHG calculator, or will assess and approve an existing GHG calculator for use with the RTRS EU RED requirements
Feedstock sources included	Only soybeans

GHG thresholds	***RTRS general:*** Efforts are made to reduce emissions and increase sequestration of Greenhouse Gases (GHGs) on the farm. ***RTRS EU:*** 35% savings (reference is made to the EU RED)
General methodology	***RTRS general:*** no GHG calculation methodology is required ***RTRS EU:*** the GHG calculation methodology strictly follows the methodology as stipulated in the EU RED The methodology has been included as reference for the RTRS RED Indicators. In practice, GHG calculations will not normally be undertaken by a farmer but will be done with computer software. Any formal approval of a specific calculator by the RTRS will use the methodology set here. Any calculator used by the RTRS will be independently verified against the following methodology prior to approval. These options are available for GHG calculations: - Using default emission values - Using an RTRS approved RED GHG calculator. This is a software tool where input data is entered and the computer calculates the GHG emissions. - Using manual calculations following the methodology provided here
Life cycle elements to be included	***RTRS EU:*** Well-to-wheel: - Extraction / cultivation of soy - Carbon stock changes from land use changes - Processing - Transport and distribution - Use of fuel (set to zero) - Savings from soil carbon accumulation via improved agricultural management - Savings from carbon capture and geological storage - Savings from carbon capture and replacement - Savings from excess electricity from cogeneration
CO_2 equivalent factors (GWPs)	***RTRS EU:*** Not explicitly mentioned, however, will have to follow the RED
Functional unit	***RTRS EU:*** CO_2 equivalent per MJ of fuel: gCO_2eq/MJ Records along value chain should be expressed in kg CO_2eq per tonne of the batch of sustainable soy product received
Infrastructure	***RTRS EU:*** Not included
Electricity mix	***RTRS EU:*** the emission factor for electricity is calculated according to the GHG emissions of the regional or national electricity network. In the case of the EU the EU average can be applied.

Data source of GHG emission factors	***RTRS EU:*** The following data is considered to be accurately measured if it is taken from a scientifically recognised literature source (including statistical data from government bodies): - Calorific values of the main and by-products, - Emission factor of fertilisers, diesel in agricultural machinery, chemicals, electricity, thermal energy, for example and - Emission factor of nitrous oxide (N_2O) from the use of nitrogen fertilisers Examples of emission factors are provided in the standard based various sources
Actual / default values	***RTRS EU:*** Default values listed in RED for soy do not meet the 35% savings ➔ actual values and calculations should be used at least in some elements of the value chain to show the minimum 35% savings is met
Requirements for using default values	See above
Requirements for using actual values	***RTRS EU:*** Producers: advice to use actual values even though bigger savings compared to the default values are expected further down the value chain. However, since the producer does not know whether actual values will be used downstream, he should use actual values. Actual values from land use changes must be communicated regardless. Processor: default value for processing can only be used if actual values are used for cultivation and land use change, otherwise the minimum 35% GHG savings will not be met
LAND USE CHANGE	
General	***RTRS EU:*** GHG emissions from land-use change shall only be calculated if the land use change was a permitted change of land status. Only emissions from direct land use changes included
Direct land use change	
Reference land use	***RTRS EU:*** Carbon content of the land before conversion or 20 years before the production of the raw material, whichever date is the later.
Cut-off date	***RTRS EU:*** 1 January 2008
Annualisation	***RTRS EU:*** Annualised emissions from carbon stock changes caused by land-use change shall be calculated by dividing total emissions equally over 20 years.
Carbon stock included	***RTRS EU:*** Soil and vegetation
Calculation of carbon stocks	***RTRS EU:*** options for GHG calculations: - Using an RTRS approved RED GHG calculator. This is a software tool where input data is entered and the computer calculates the GHG emissions. - Using manual calculations for land use change, according to the Commission Decision of 10 June 2010 on guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC (notified under document C(2010) 3751).

Indirect land use change	*Not included*
Bonus for cultivation on degraded land	***RTRS EU:*** Bonus of 29 g CO_2eq/MJ soy biodiesel for degraded land cannot be included until the EU Commission has defined degraded land Producers can already measure and record soil carbon measurements and contamination levels
CULTIVATION	
Processes to be taken into account	***RTRS EU:*** - Yield data - Electricity consumption - Fertiliser use - Pesticide use - Soybeans used for planting are measured - Fuel use
N_2O field emissions	***RTRS EU:*** included
Use of average values	***RTRS EU:*** It is estimated that the GHG emissions from cultivation can also be derived from average values, which are calculated for geographical areas smaller than those used to calculate the default values. However, these values are not yet available.
Other	***RTRS EU:*** Emission savings from soil carbon accumulation via improved agricultural management; 'improved agricultural management' could include practices such as: - shifting to reduced or zero-tillage; - improved crop rotations and/or cover crops, including crop residue management; - improved fertiliser or manure management; - use of soil improver (e.g. compost). Evidence needs to be provided that the soil has increased carbon or that it can reasonably be expected to have increased over the period in which the raw materials concerned were cultivated (through measurements of soil carbon)
TRANSPORTS	
Processes to be taken into account	***RTRS EU:*** - distance between the farmer and the next economic operator, including the (empty) return run, - type of transport used to transport the crop, - quantity of soybean transported in the particular means of transport (mass of the dry crop) - for soy beans, the moisture content of the transported crop Additional values needed (stated or taken from a scientific literature source): - emission factor for fuel, - fuel consumption of the particular means of transport per km when full - fuel consumption of the particular means of transport per km on an empty run (return run)

Processes to be taken into account	This includes certification outsourced activities to independent third parties (e.g. subcontracts for storage, transport or other outsourced activities). If the RED default value is used it will prevent the use of actual values for transportation in the entire supply chain because it includes the sum of all transport in the supply chain ➔ not possible to add actual values to the default value.
Calculation procedure	***RTRS EU:*** The reference unit for transport of intermediate products is kg of intermediate product. GHG emissions from transport should not be added to GHG emissions from cultivation & land use change, or processing for this requirement but listed separately.
PROCESSING	
Processes to be taken into account	***RTRS EU:*** GHG emissions from waste (effluent) and GHG emissions from the manufacture of all resources necessary for the process are included in the calculation of the GHG emissions - Product yield data (including subsidiary products) - Electricity consumption - Where the processing facility co-generates electricity (CHP), surplus electricity is measured, fuel type is recorded and type of CHP plant is recorded - Heat generation for processing - Fuel used in processing - Operating materials used in processing - Effluent quantities from processing
Use of actual values	***RTRS EU:*** If the RED default value is used for one consignment it will prevent the use of actual values for processing in the entire supply chain of that consignment because the default value includes the sum of all processing in the supply chain. It is therefore not possible to add actual values to the default value later in the supply chain. A default value for processing can only be used if actual values are used for cultivation and land use change, otherwise the minimum 35% GHG savings will not be met.
Excess electricity from cogeneration	***RTRS EU:*** The general allocation rule does not apply for electricity from CHP when the CHP runs on - fossil fuels; - bioenergy, where this is not a co-product from the same process; or - agricultural crop residues, even if they are a co-product from the same process. Instead, the following rule applies: - Where the CHP supplies heat also for other purposes, the size of the CHP should be reduced on paper to the size that is necessary to supply only the heat necessary for the biofuel/bioliquid process. The primary electricity out-

	put of the CHP should be reduced in proportion. - To the amount of electricity that remains a greenhouse gas credit should be assigned that should be subtracted from the processing emissions. The amount of this benefit is equal to the life cycle emissions attributable to the production of an equal amount of electricity from the same type of fuel in a power plant. - The GHG emission saving from the surplus electricity is the GHG quantity that would be emitted when generating an equivalent quantity of power in a power plant that uses the same fossil fuels as the CHP plant.
Others	***RTRS EU:*** as soon as the European Commission finalises the method for calculating the emission savings from carbon capture and geological storage as well as from carbon capture and replacement, it will be incorporated into the administrative instruction. Until then possible changes of total GHG emissions will provisionally be calculated as zero.
CO-PRODUCTS	
	RTRS EU**:** if co-products and by-products are produced, actual values for GHG emissions shall be allocated to the soy products in proportion to the energy content of the co-products and by-products, including: - actual processing values - actual transportation values - actual cultivation and land use change value
GENERAL	
Procedure	**RTRS EU**: where default values are used, no allocation shall be applied. Allocation shall be applied to actual cultivation and land use change values at each processing step even if a default value for processing is used. The emissions that take place up to and including the process stage where a co-product is produced shall be divided between the main and the co-products. If any allocation to co-products has taken place at an earlier process step in the life-cycle, the fraction of those emissions assigned in the last such process step to the intermediate fuel product shall be used for the purpose of allocation. Allocation shall be applied directly after a co-product and biofuel/bioliquid /intermediate products are produced at a process step. However, if downstream processing of the (co-) products concerned is interlinked (by material or energy feedback loops) with any upstream part of the processing, the system is considered a 'refinery' and allocation is applied at the points where each product has no further downstream processing that is interlinked by material or energy feedback-loops with any upstream part of the processing.
Basis for allocation	**RTRS EU:** lower calorific value of the entire (co-)product, not only of the dry fraction of it. In case of nearly-dry products, the lower calorific value of the dry fraction can be used. Since heat does not have a lower calorific value no emissions can be allocated to it on that basis.
Exemptions	**RTRS EU:** no emissions are allocated to wastes and agricultural crop and processing residues. - *Wastes*: any substance or object which the holder discards or intends or is required to discard, including materials that have to be withdrawn from the market for health and safety reasons. Examples include straw, bagasse, husks, cobs and nut shells. Raw materials that have been intentionally modified to count as waste are not considered wastes. - *Residues*: include agricultural, aquaculture, fisheries and forestry residues and processing residues. A processing residue is a substance that is not the end product(s) that a production process directly seeks to produce. It is not a primary aim of the production process and the process

	has not been deliberately modified to produce it. Examples are crude glycerine, tall oil pitch and manure.
FUEL USE	
Emissions from combustion	**RTRS EU*:*** emissions from the fuel in use are taken to be zero.
Fossil fuel comparator	**RTRS EU*:*** 83.8 gCO_2eq/MJ for biodiesel

B-4 Summary of GHG calculation in the systems assessed

Table B-13 provides a summary on the main features of the above described systems as well as the main specifications of greenhouse gas balancing within the systems.

Table B-13 Summary of greenhouse gas calculation methodologies

Name	**Biomass covered by GHG calculation**	**Performer of calculation**	**Purpose of GHG calculation**	**Overall methodology used**	**Data used**	**Land use change**	**Co-products**
International agreements							
UNFCCC	Only biodiesel	Applicants to CDM projects	Amount of GHG saved due to a biodiesel project				
GBEP	All biomass for energy applications	Guideline for all types of users	Component of sustainability criteria (no thresholds)	No specific GHG calculation methodology but framework	No data	Essential element, no specific method	No prescription
ISO 13065	All biomass for energy applications	Guideline for all types of users	Component of sustainability criteria (no thresholds)	Widely compliant with ISO 14040/44 and 14067	No data	Essential element, no specific method	List of accepted approaches
Laws							
LCFS	Most common biofuels in California	CARB (California Air Resources Board)	Ex-ante modeling for providing default GHG values	Model-based	Data bases, scientific literature, GREET and GTAP model	Direct and indirect LUC modeled	Substitution and allocation (different references)
RFS2	Most common biofuels in US	EPA (Environmental Protection Agency)	Ex-ante modeling for application under RFS	Model-based	Data bases, scientific literature, different models	Direct and indirect LUC modeled	Substitution
RED	All liquid biofuels / bioliquids	Market operators	Proving compliance with GHG thresholds	Well-to-wheel calculation	Default values provided; operator-specific values may be used		Allocation based on LHV except agricultural residues

Name	Biomass covered	Performer of calculation	Purpose of GHG calculation	Overall methodology used	Data used	Land use change	Co-products
Voluntary certification systems							
RSB – main	All liquid biofuels	Certified party	Proving compliance with GHG thresholds for achieving certification	Same methodology as in RED; some minor variations	Operator-specific values shall be used	Same as RED	Economic allocation, all coproducts
RSB – EU		Certified party	See above	Same as RED	Same as RED	Same as RED	Same as RED
BSI – main	Sugar-cane	Certified party	See above	Well-to-Wheel	Only operator-specific values may be used	Same as RED	Substitution and allocation (different references), all co-products
BSI – EU		Certified party	See above	Same as RED	Only default values may be used	Same as RED	Same as RED
GGL	All biomass for fuel, power and material use	Certified party	See above	Same as RED	Operator-specific values should be used	Same as RED	Same as RED

Name	Biomass covered	Performer of calculation	Purpose of GHG calculation	Overall methodology used	Data used	Land use change	Co-products
Voluntary certification systems							
ISCC	All biomass for energy uses	Certified party	Proving compliance with GHG thresholds for achieving certification	Same as RED	Same as RED	Same as RED	Same as RED
NTA	All biomass for energy uses	Certified party	See above	Same as RED	Same as RED	Same as RED	Same as RED
RTRS – main	Soy	Certified party	See above				
RTRS – EU		Certified party	See above	Same as RED	Combination of default values and operator-specific values should be applied	Same as RED	Same as RED
BioGrace tool	25 biofuel/bioliquid pathways	Different users possible	See above	Exact implementation of RED calculation methodology	Operator-specific values may be included	Same as RED	Same as RED

Appendix C:

Assessment of Next Generation Biofuel Production in the Xinjiang Uyghur Autonomous Region, P.R. China

Jiao Jian, Jiaerheng Ahati, Zhang Ming, Gao Qingguo, He Tian, Peng Xiaowu, Zhang Zhang, Wei Bangyi

Xinjiang Academy of Environmental Protection Science, Urumqi, PR China
No. 38, Beijing South Road, Urumqi, Xinjiang, 830011, PR China

C-1 Project objective and scope

The project objective is to assess the potential of second generation bio-liquid fuel in Xinjiang in 2030 and to evaluate the impact of second generation bio-liquid fuel development on the environment. Starting with the natural conditions in Xinjiang, national and local Xinxiang policies and regulations, the amount of biomass production, resistance to drought and resistance to salinity of biological capacity are evaluated. Next , suitable materials for bio-liquid fuel development in Xinjiang are selected and investigated in more detail. China’s first second-generation biomass liquid fuel demonstration projects and case studies are analyzed and the status of available technology is determined. Three energy plants are ultimately chosen from plants growing properly in Xinjiang and three f scenarios are chosen to estimate the impact of second generation bio-liquid fuel development on the environment in Xinjiang by 2030 according to the maturity of the technology and technology trends.

C-2 Potential of bio-liquid fuel feedstock

C-2.1 Overview of Xinjiang

The Xinjiang Uygur Autonomous Region is located in the northwest of China, the hinterland of Eurasia at longitude 73°40' to 96°23', latitude 34°25' to 49°10'. The area of Xinjiang is 166 million hectares and accounts for one-sixth of China's land area making it the largest provincial-level administrative region in China. Xinjiang has 14 regions, prefectures and cities, including five autonomous prefectures, seven regions, two prefecture-level cities, and 68 counties [1].

The terrain is varied in Xinjiang, the landscape contour features are three mountains clipping two basins. The Altai Mountains are located in the North, the Kunlun Mountains in the South, central Tianshan Mountains in the middle divides Xinjiang into two parts, the southern area from Tianshan Mountain is called as Southern Xinjiang, the northern area from Tianshan Mountain as Northern Xinjiang, Hami and Turpan Basin as Eastern Xinjiang. The Tarim Basin is located between Kunlun Mountain and Tianshan Mountain while the Junggar Basin is located between Tianshan Mountain and Altai Mountain. There are some rivers in Xinjiang, watering the oasis along Tianshan Mountain. The melted snow from the mountain areas forms more than 500 rivers including three main rivers, the Tarim river, Ili river and Irtysh river. Oasis' are scattered among the basin edges and river basins. The total area of the oasis' is about 5% of the region [2]. Farmland accounts for 63 million hectares or 38% of total land area; the forest coverage rate is 4.0% [1].

In 2010, the GDP in Xinjiang was 427.705 billion Yuan, GDP per capita was 19,942 Yuan, and the primary industry output value was 75.974 billion Yuan, accounting for 17.8% of GDP. Although primary industry output value is not large, it plays an important role to provide employment opportunities for a sizeable number of the workforce. Since the reform and opening up, the proportion of primary industry output value in Xinjiang has been reducing overall and the proportion of the employed population in it had been is also dropping. The second industry and tertiary industry output value ratio has been rising and the proportion of the employed population has been rising in them [1].

The total population in Xinjiang was 21.6 million in 2009, made up from a total of 47 ethnic groups, including an ethnic minority population of 13.2 million, which is 61% of the total population. The employed population was 8.7 million, of which 4.3 million are in the primary industry, accounting for 49.4% of the total proportion [1]. In 2009, 2.5 million people in Xinxiang's total population were in poverty [3], mainly in four regions or prefectures of Hotan, Kashgar, Aksu and Kizilsu, and the areas along Tianshan Mountain and Altay Mountain. For the poor a minimum subsistence allowance system has been implemented in Xinjiang to ensure the guarantee of basic livelihood of the poor, on this basis other relief measures including health, education, housing, heating and others have also been developed to support the allowance system [4].

According to the Statistical Yearbook, Xinxiang's annual primary energy production was 127 million tonnes SCE in 2008, made up of 67 million tonnes SCE of raw coal, 27 million tons of crude oil and 24 billion cubic meters of natural gas; annual energy consumption was 71 million tonnes SCE, consuming 57 million tons of coal, 19 million tons of crude oil and 7 billion cubic meters of natural gas. Energy production and consumption diagrams are shown in Figure C-1 and Figure C-2.

Table C-1 Fundamental condition of population and economy

Item	Unit	Value	Year
Population	million persons	21.6	2009
Population growth rate	‰	12.9	2009
GDP	million Yuan	427,700	2009
GDP per capita	Yuan	19,942	2009
Number of the poor	million persons	2.49	2009
Poverty rate	percent	11.54	2009
Energy production	million tonnes SCE [a)]	127	2008
Energy consumption	million tonnes of SCE [a)]	71	2008

a) SCE = standard coal equivalent; 1 tonne (Mg) of SCE = 29.3 GJ

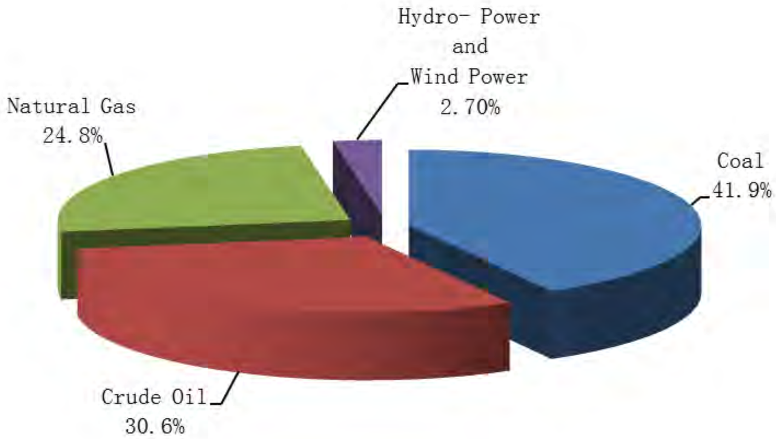

Figure C-1 Energy production in Xinjiang by source (2008)

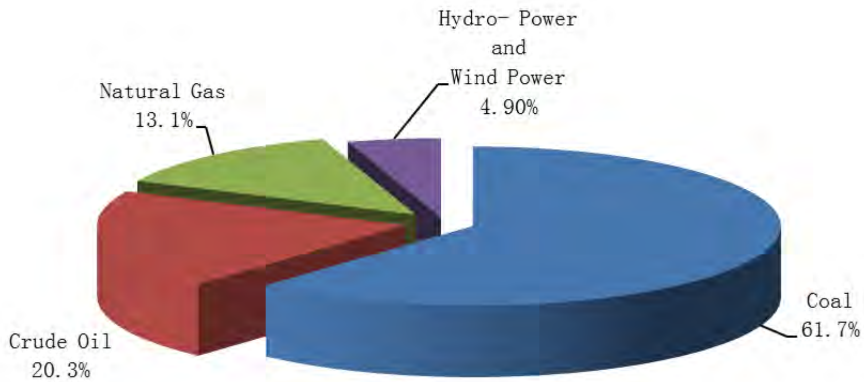

Figure C-2 Energy consumption in Xinjiang by source (2008)

C-2.2 Natural conditions of bio-fuel feedstock production

Xinjiang is located in the center of the Eurasian continent far from the sea. It belongs to a temperate continental arid climate zone, with rare precipitation, which causees the non-development of surface runoff and a large area without any flow. Due to westerly air stream, the rain fall in Northern Xinjiang is more than that in Southern Xinjiang, and that in Western Xinjiang is more than that in Eastern Xinjiang, that in the mountains is more than that in the plains and basins, that in windward slope is more than that in leeward slope, with the basin and valley being the center of dry land. Basic types of topography in Xinjiang are mountains and basins, the mountains account for 42.7% of total land area, while basins account for 57.3%. Arid climate and the landscape “Three mountains clipping two basins links and interacts with each other to form three distinctive ecological systems of the mountain, oasis and desert. The mountains are covered with snow, forest and grasslands from the top to the edge of the basin, the oasis’ are scattered among the basin edge and midstream of the rivers. There is vast wilderness from the edge of the basins to the inner basins and vast deserts in the central basin. Oasis area is about 5% of total area in

Xinjiang, almost all of the crops are located in the oasis and the agriculture in Xinjiang is also called oasis agriculture [5].

Since there is very little natural rainfall and strong evaporation, the precipitation is almost not practically significant for existence and development of natural oasis'. Water on the surface and underground in the oasis is the lifeline that maintains an oasis' survival, accounting for the core position in entire ecosystem of the oasis. Oasis agriculture has made great progress with the arable land Xinjiang having increased from 120 million hectares at its liberation period to a current 400 million hectares. The corresponding water consumption has also increased from 160 billion cubic meters to 52.822 billion cubic meters. The total water resources in Xinjiang are 80.26 billion cubic meters [1], with 65.8% of it has being exploited and utilized. In case of deducting water resources outflow from the border and necessary ecological water consumption, water utilization has reached its limit causing the expansion of the agricultural production scale in Xinjiang to be constrained [6].

The annual sunshine time ranges from 2500 to 3360 hours in Xinjiang and the annual overall solar radiation per square meter ranges from 5400 to 6300 MJ. Plenty of sunshine provides sufficient heat energy, while the annual accumulated temperature in the northern Junggar Basin and few mountainous areas is below 2800 °C, the value for the southern Junggar Basin is between 3000 to 3600 °C, in the Tarim Basin is over 4000 °C, and in the Turpan Basin ranges from 4500 to 5500 °C. About 200 days in the Tarim Basin are frost-free, 220 days in Turpan Basin and 185 days in western and southern Junggar Basin, providing sufficient light and heat resources for crops and pasture growth [7].

The soils are regularly distributed in Xinjiang. The soils in the basin are brown desert soil, gray-brown desert soil, gray desert soil calcium and other typical saline soils. The soils in the mountain are mainly meadow soil, mountain chernozem and mountain chestnut soil, but brown forest soil develops in the forest zone of mountain shady slope. In general the soil quality in Xinjiang is not high, characterized by little nitrogen, average phosphorus and excessive potassium. While the organic contents of the soil in Altay, Tacheng, and Yili Prefecture are higher, the organic contents of the soil in southern Junggar Basin and Tarim Basin as well as in Eastern Xinjiang are at a medium level [8]. Large areas in Xinjiang have high soil salinity, total area of arable land in oasis was 5 million hectares according to the survey in 2005, including arable salinized land of 1.6 million hectares, occupying 32% of total area of cultivated land in the oasis. On the whole, the proportion of mild salinity is the largest, followed by moderate and severe salinity. Soil salinity has a negative impact on agricultural production [9].

C-2.3 Agriculture and forestry planting status

(A) Land utilization status

In 2008, agricultural land was 63 million hectares, accounting for 38% of total land area; construction land was 1.2 million hectares (0.74%); unused land was 102 million hectares (61%). The land utilisation rate was 38.64%. Other agricultural land was 717,500 hectares or 0.43% of the agricultural land area. Unused land was mainly alpine, wilderness, Gobi land and desert which are difficult to utilise [1].

The pasture land was the largest in agricultural land, which was 51 million hectares, accounting for 81% of agricultural land area; followed by woodland which was 6.8 million hectares, accounting for 10.7% of agricultural land area; arable land was 4.1 million hectares, accounting for 6.5% of agricultural land area of which 3.8 million hectares was irrigated land which accounts for 92.4% of arable land; 2.0 million hectares of dry land, accounting for 5.0% of arable land. Most of the arable land in Xinjiang is used for irrigated agriculture; 364,200 hectares of garden area was the least, accounting for 0.58% of agricultural land area [1].

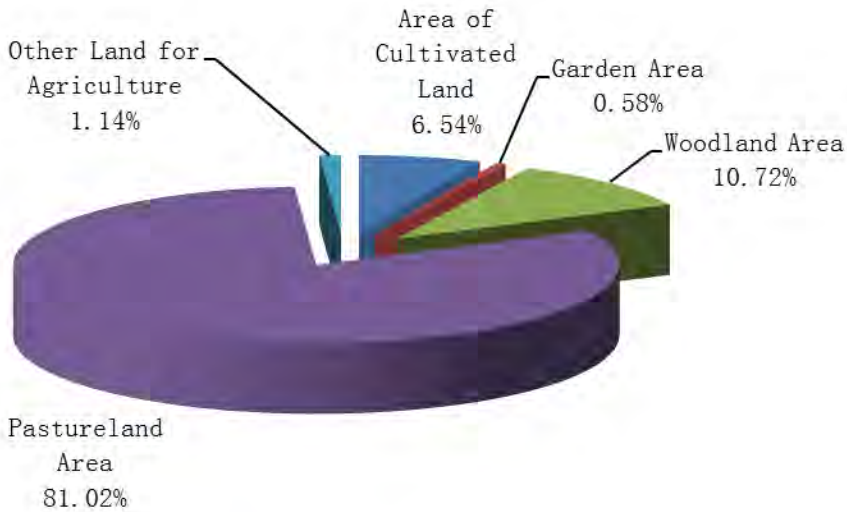

Figure C-3 Agricultural land utilisation in Xinjiang (2008)

(B) Crops and tree planting situation

In 2009, the total sown area for crops was 4.7 million hectares in Xinjiang, of which cotton, wheat and corn accounted for 1.4 million hectares, 1.1 million hectares and 0.6 million hectares, respectively, totalling 67% of total acreage. The planting areas and yields are summarized in Table C-2.

Table C-2 Crop area, yield and crop yield of unit acreage

Crop varieties	Planting area (thousand ha)	Planting proportion	Yield (1000 tonnes)	Crop yield (tonnes/ha)
Rice	73	1.56%	583	7.9
Wheat	1,153	24.49%	6,307	5.5
Corn	598	12.70%	4,394	7.3
Barley	31	0.67%	143	4.5
Beans	126	2.67%	322	2.6
Potato	38	0.80%	1,261	33
Cotton	1,409	29.92%	2,524	1.8
Rape	77	1.63%	157	2.0
Sunflower	156	3.31%	414	2.7

According to the results of the fifth review of continuous inspection on forest resource in Xinjiang in 2006, woodland area was 6.6 million hectares in Xinjiang, total wood volume was 339 million cubic meters, woodland volume was 301 million cubic meters, the forested area was 2.0 million hectares and shrub area was 4.6 million hectares (see census results in Table C-3).

Table C-3 Forest planting area (in 1,000 hectares)

	Forested land	**Shrub land**	**Total**
Shelter forest	1,531	4,472	6,003
Special forest	140	109	249
Timber forest	12		12
Firewood forest	9.6		9.6
Economic forest	324	19	343
Total	**2,016**	**4,601**	**6,617**

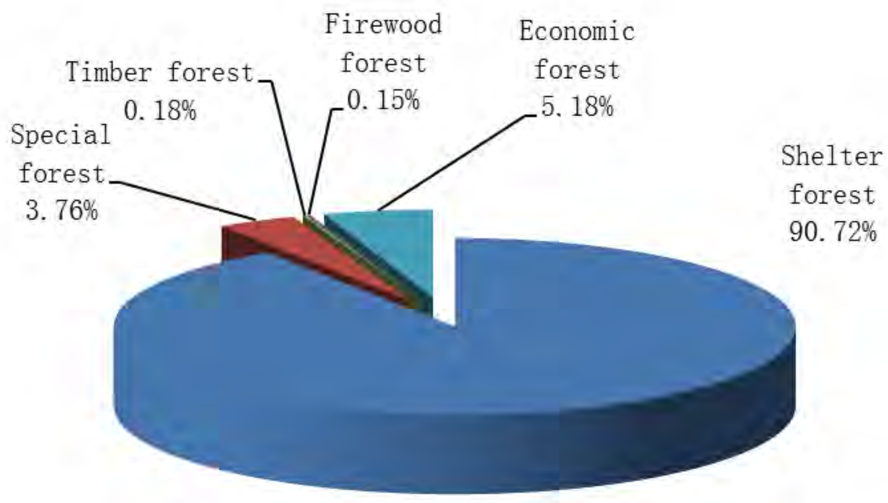

Figure C-4 Forest resources in Xinjiang (2006)

C-2.4 Major impact factors on biomass liquid fuel feedstock

The cultivation of biomass liquid fuel feedstock is mainly affected by the land utilisation structure since China has implemented a system where land ownership belongs to the state and other collective (i.e. public) ownerships, whereby contracting rights and operating rights belong to the farmers. Change of land usage (e.g. agricultural land transformed into construction land) are authorised mainly by the central government and local governments, where the central government has the highest decision-making power, and local governments act as the decision-maker and implementer of the local planning and policy process. In general, local governments are key decision-makers for land use changes; specific methods of land use (planting wheat instead of cotton, vegetables, fruit trees, etc.) are finally decided by the individuals based on individual rational choice and preferences.

Therefore, the cultivation is mainly affected by planning scheme, policies and regulations of central government and local governments and individual planting choices.

(A) China's industrial policy and planning

1) National Forestry Industry Development Plan (2010-2012)

It was proposed to establish a number of biomass energy forest bases in the southwest and northwest provinces.

2) Eleventh Five-Year Establishment Program on Forestry Bio-diesel Feedstock Forest Base

It was proposed to plant 133,000 hectares of *Xanthoceras sorbifolia* in Inner Mongolia, Liaoning, Xinjiang and other provinces.

3) Agricultural Biomass Energy Industrial Development Plan (2007-2015)

The protection of national food security is the highest priority in the agricultural development; thus the development of energy crops should not occupy the production land of food, cotton and other strategic materials and the grasslands should not be reclaimed. Wasteland, saline-alkali soil and fallow fields of grain or other unsuitable and underutilized land resources should be fully used to avoid the struggle for land between energy crops and grain or cotton crops. Energy crops should be moderately developed to meet the country's feedstock demand for bio-liquid fuel.

During the Eleventh Five-Year Plan period, the use of saline and other marginal land in Heilongjiang, Shandong, Inner Mongolia, Xinjiang, Hebei and other provinces will be focused to develop and promote sweet sorghum varieties and advanced cultivation techniques.

(B) Regional Policy of Converting Cultivated Land into Forest and Grassland

In 2000, the State Council issued the “State Council’s Opinions on Further doing Experimental Work of Converting Cultivated Land into Forest and Grassland (Guofagai [2000] No. 24)”. To carry out experimental work of converting cultivated land into forest and grassland, the country provided free grain cash and seed to the farmers who converted cultivated land and the country made the provisions on the proportion of ecological forest and economic forest that the ecological forest should generally be about 80%. The implementation of this policy has had a significant effect. Xinjiang completed a total of 138,464 ha of cropland conversion according to the Provincial Land and Resources Statistics 2001-2008, data for complete ecological restoration in summarized in **Fehler! Verweisquelle konnte nicht gefunden werden.** However, the table also shows that land area conversion subject to ecological restoration has decreased in recent years, indicating that difficulties of converting cultivated land have increased.

Table C-4 Ecological restoration area

Year	2001	2002	2003	2004	2005	2006	2007	2008
Ecological restoration area (ha)	4,999	52,952	61,855	11,704	4,339	1,979	636	0

C) Land Utilization Planning in Xinjiang [10]

1) Principle

To strictly protect the cultivated land; implement the principle of protecting grain planting, reducing cotton planting, managing fruit planting and promoting animal husbandry, adjust and optimize the structure of agricultural land; implement the principle of deciding the land area according to water resource, adjusting the measures to suit local conditions.

2) Land utilisation goal by 2020

The target amount of cultivated land will be more than 4.6 million hectares; garden land will reach 0.61 million hectares; 0.83 million hectares of forest land will increased from 6.8 million hectares in 2005; grassland area will be 50 million hectares.

(D) Impact of population

Demographic factors are an essential element driving changes in the use of land resources. Population growth inevitably leads to an increased demand on residential land, public facilities, transportation, urban construction land and other construction land. The result is the reduction of agricultural land, especially arable land. Meanwhile, the population growth directly leads to demand increase in grain production, increasing the demand for arable land. In 2001-2009, the population in Xinjiang has grown from 18.8 million in 2009 to 21.6 million, an annual average population growth rate of 15.1% [1].

(E) Impact of socio-economic development

The socio-economic development will lead to an increase in the economic activity and the changes in industrial structures, while the proportion of the secondary and tertiary industries and the associated land consumption will continue to increase. The population movement to the secondary and tertiary industries, the urbanization increase as well as the infrastructure construction increase will lead to pressures on agricultural land, affecting the land utilization structure. According to Xinjiang Provincial Land and Resources Statistics, a total of 16,264 hectares of arable land has been occupied for construction land between 2001 and 2008 (see Table C-5).

Table C-5 Arable land occupied for construction land

Year	2001	2002	2003	2004	2005	2006	2007	2008
Arable land occupied for construction land (ha)	1,334	3,624	2,409	1,914	2,588	1,577	1,545	1,273

(F) Choice of farmers planting structure

The planting structure is a function of economic interests: when arable land is limited, farmers will choose to plant crops with high returns. Since the economic efficiency of grain crops is very low, crop acreage has gradually been reduced prior to 2005. China began to adopt a series of food production policies to support grain production in 2004, such as the abolition of agricultural tax, implementation of food subsidies and special subsidies increase for seed, large grain farmers and farm machinery and other measures, in order to enlarge the farmers' initiative for growing grain. Followed by a rebound trend in grain acreage in Xinjiang, the use of arable land for restructuring of agriculture has decreased according to Xinjiang Provincial Land and Resources Statistics between 2001 and 2008 (see Table C-6).

Table C-6 Arable land occupied for agricultural restructuring

Year	2001	2002	2003	2004	2005	2006	2007	2008
Arable land occupied for agricultural restructuring (ha)	5,809	36,014	53,139	18,149	14,152	5,276	341	1,083

(G) Available land

In case of sufficient water supply in 2030, developable reserve land resources in Xinjiang will be expected to be 3.3 million hectares [11]. In the natural ecological suitability and appropriateness of economic conditions, the reserve land resource in Xinjiang was 1.5 million hectares in 2000 [12]. According to the 2008 Land Resources Bulletin of Xinjiang Uygur Autonomous Region, land use increased in Xinjiang to 25.8 million hectares from 2001 to 2008; 70% of increased land was obtained by land exploitation.

(H) Demand analysis of liquid biofuels

According to the Xinjiang Statistical Yearbook, the annual production of crude oil in Xinjiang in the year 2008 was 27 million tonnes, while consumption accounted for 8.9 million tonnes [1], indicating that Xinjiang exports to the rest of China. In 2009, the national oil production was 189 million tonnes and the consumption was 385 million tonnes; net-import accounted for the balance 196 million tonnes. The major consumers were the industry (41%) and transportation (35%) sectors. As China is still in the process of industrialisation, both sectors will continue to maintain high growth and consumption is expected to rise. Domestic oil production is difficult to increase; even though oil production has increased from 105 million to 189 million tonnes from 1980 to 2009 [13], an increase of 78.8%, annual growth rate has slowed by 2009. While domestic oil demand will increase for next 20 years, the dependence on foreign import will be higher and the demand of liquid biofuels will increase.

C-2.5 Selection of biomass liquid fuel feedstock

(A) Option of biomass liquid fuel feedstock from existing crops

Table C-7 Crop residues in Xinjiang in the year 2009

Crop varieties	Grain to straw ratio	Actual quantity *1,000 tonnes*	Unutilized quantity *1,000 tonnes*	Main purposes
Primary residues				
Wheat straw	0.73	4,604	437	Fertilizer, feed, fuel
Corn stalk	1.25	5,492	458	Fertilizer, feed, fuel
Cotton straw	3.53	8,901	3,118	Fertilizer, feed, fuel
Bean straw	1.71	551	49	Fertilizer, feed, fuel
Sunflower straw	2.02	836	59	Fertilizer, feed, fuel
Secondary residues				
Wheat shell	0.26	1,640	115	Fuel
Corn cob	0.24	1,055	74	Fuel

Note: Source of data of grain to straw ratio: Mao-Song Li, Wang Yafeng, China's major developments and status of crop straw resources for nearly 20 years, Collected papers of symposium on national pollution and integrated control of agricultural source, P152, and Bi Yuyun, Study on straw resource assessment and utilization, 2010, PhD papers, p.66.

As a result of the analysis of the total amount of crop residues and residues per unit area, crops in Xinjiang which are suitable for the development of liquid biofuels are mainly cotton stalk, corn stalk and wheat straw. Of these, only cotton stalks can be used in large quantities, suitable as biofuel feedstock, since the stalks of other crops are mostly used as feed and are generally not available for energetic use in a larger scale.

(B) Option of biomass liquid fuel feedstock from existing forestry

The forests in Xinjiang are divided into forest land and shrub land according to forest density; see **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Table C-8 Total forest volume and forest volume per unit area

	Area (1,000 ha）	Volume (1,000 m^3)	Volume per unit area (m^3/ha)
Forest land	2,016	301,005	149
Shrub land and others	4,600	38,140	8.3

Note: Source of data: Fifth review of continuous census of forest inventory in Xinjiang in 2007, internal information

Shrub vegetation mainly grows in the Gobi desert and wilderness land, according to the fifth census in 2006. In Xinjiang there are 4.6 million hectares of shrub land, which account for 69.5% of total forest area. The bushes however are mainly natural with a small accumulated volume, less than 12% of total volume, and a per unit area of 8.3 m^3/ha, about

5.6% of the value of 149 m^3/ha for forests. Thus, the bio-mass volume per unit area that could be utilized is too small. The priority biofuel feedstock would be forest land.

Special forests in frost land are mainly used for national defense, environmental protection and other special purposes and are subject to special protection along with the firewood forests which are used as fuel by rural residents. Neither can be used as bio-fuel feedstock. Shelter forests are located mainly in the natural protection forest areas in the mountains, an area of about 1.1 million ha, with a role of water conservation, logging is strictly banned and trimming is not allowed, so they have almost no utilised potential. The woods used as bio-liquid fuel is obtained mainly from the artificial shelter forest, timber forest and economic forest. According to the fifth census result and above analysis, see available resources in forest land in Table C-9.

Table C-9 Various forest lands and residuals according to different purposes

Type	**Forest land** *(1,000 ha)*	**Wood production** *(kg/ha)*	**Residuals** *(1,000 t)*	**Obtainable residuals** *(1,000 t)*	**Unutilized residuals** *(1,000 t)*
Shelter forest	1,531	375	574	224	11
Firewood forest	12	600	7.2	7.2	0.36
Economic forest	324	750	243	243	12
Total	**1,867**		**824**	**474**	**24**

Note: forest area data from Fifth Review of Continuous Census on Forest Resource in Xinjiang in 2007, Wood production rate from Biomass Power Generation Technology, Beijing State Power Huadian Engineering Co., Ltd., 2006.12,16, non-utilization coefficient from Zhao Yongqiang, Biomass Resources of China and Key Provinces, 2007.11,17

The data indicates that the available resources and unused resources from forestry are small, the resources per unit area are very limited and are therefore not suitable as feedstock for biofuels.

(C) Option of feedstock for liquid biofuels in the existing grass industry

Cultivated grass in Xinjiang is primarily used as livestock feed. With severe degradation and the increasing number of livestock on the grasslands of Xinjiang, there is no space to grow energy grass in the future.

(D) Energy plant growing on marginal lands

In addition to the selection of biofuel feedstock from existing agricultural crops and forestry, energy plants could be grown in marginal lands in Xinjiang where a sufficient water supply exists. This includes crops such as sweet sorghum, energy trees such as fast-growing poplar, *Populus, Tamarix, Elaeagnus, Haloxylon*, apricot, willow and elm. Energy grass such as *Splendens*, sand reed and *Bouton* barley can be used as biomass energy feedstock in Xinjiang [14]. Taking the size of available biomass, resistance to drought, anti-saline-alkali and economic aspects into account, sweet sorghum and tamarisk are the prime candidates for energy plants for the production of the next-generation liquid biofuels. Sweet sorghum has been in the experiment demonstration phase in Xinjiang in recent years. The demonstration area is more than 1,333 ha [15], the potential volume of sweet sorghum production is large, the yield per hectare is up to 31.5 t, it has anti-salinity and resistance to drought features and it is also suitable for planting in Xinjiang. Tamarisk has a high tolerance to salinity, is resistant to drought and is already widely distributed in Xinjiang. The economic value of being the plant for *herba cistanches,* a medicinal value, is much higher and increases the enthusiasm of the farmers. By the end of 2008, 16,700 ha were planted with tamarisk in Hotan region, Xinjiang for growing *herba cistanches*.

In summary, cotton stalks, sweet sorghum and tamarisk were selected as the most promising feedstocks for next-generation liquid biofuel in 2030 in Xinjiang.

C-2.6 Estimate of biomass liquid fuel amount

The amount of cotton plantations is predicted in accordance with the existing farmland planting structure and increasing amount of arable land, the extension of sweet sorghum and tamarisk planting is predicted in accordance with land use potential and use proportion.

(A) Amount of available cotton stalks in 2030

With a population of 21.6 million in 2009, a cultivated area of 4.1 million ha, and an expected population of 30.7 million in 2030 [16], an increase in grain production per unit area using the advances in technology (a 10% increase in yield per unit area) is expected. According to the "Overall Land Use Planning of Xinjiang Uygur Autonomous Region (2006-2020)[10]" the cultivated area demand will be 5.3 million ha in 2030, an additional area of 1.2 million ha. While reserve land resources in Xinjiang can meet this demand under economic conditions, considering the ecological balance, the expected increase of cultivated land will be limited only to meet the needs of population growth. There is no spare land to develop for grain production, so it is predicted that 1.2136 million hm^2 arable land can be added. The straw yield of cotton in 2030 is calculated in accordance with the existing planting structure. See straw yield of cotton by 2030 in Table C-10**Fehler! Verweisquelle konnte nicht gefunden werden.**.

(B) Available tamarisk and sweet sorghum in 2030

Under the circumstance of meeting the growing needs of arable land in Xinjiang, 2.1 million ha of land is available. The remaining land resources are basically the land suitable for forest or grassland as the development and utilisation of the remaining land resources are more difficult, due to higher requirement of sweet sorghum for natural conditions than tamarisk. It is predicted that 10% of the land can be used to grow sweet sorghum and 35% of it can be used to plant energy forest. See the prediction of available acreage, yield and volume by 2030 in Table C-10.

Table C-10 Volume prediction of biomass liquid fuel

	Cotton	Sweet sorghum	Tamarisk	Total
Planting area (1,000 ha)	2,006	211	737	2,954
Yield (1,000 t)	12,684	6,647	6,632	25,963
Available volume (1,000 t)	4,439	6,647	6,632	17,720

C-2.7 Demonstration project summary of second-generation liquid biofuel in China

C-2.8 Demonstration project of second-generation liquid biofuel in China

China's second-generation biofuel production is still in an experimental stage, so there are no plans for large-scale production and the technology should still be improved. Only a few companies such as the Henan Tian Guan Group have participated in the development of second-generation biofuel technology, but the operational scale has been very small.

At present, there are nine cellulosic ethanol plants (including pilot plants) completed and under construction in China (see Table C-11**Fehler! Verweisquelle konnte nicht gefunden werden.**). The current combined production capacity is 367,200 t/a. It is expected that one additional plant can be put into operation in 2011 with a production capacity of 10,000 t/a.

Table C-11 Biofuel enterprises utilising cellulosic feedstocks

Enterprise	Fuel type and output (t/a)	Feedstock	Investment [100 million Yuan]	Location	Remarks
Anhui Feng-Yuan Group	ethanol 600	Corn stalks	n/a	Bengbu, Anhui	Completed in 2009
Henan Tianguan Group	ethanol 5,000	Corn stalks	0.62	Industrial park, development zone, Zhenping county, Nanyang city, Henan	Operated in 2007
Shangdong Zeshen Biotech CO., Ltd.	ethanol 3,000	Stalks	n/a	Zeshen industrial park, west of Jiaopu village, Laohu town, Dongping county, Shangdong	Acceptance by Chinese Academy of Sciences on Apr.8, 2011
Joint venture by COFCO and Sinopec	ethanol 10,000	Corn stalks	n/a	Zhaodong, Helongjiang	begun at third quarter of 2011
East China University of Science and Technology	ethanol 600	Agricultural and forestry waste	0.17	Fengxian, Shanghai	863 Program *(China's high-tech development plan)*

Enterprise	**Fuel type and output (t/a)**	**Feedstock**	**Investment [100 million Yuan]**	**Location**	**Remarks**
Subsidiary of Guangcai Energy Co., Ltd, Binzhou Guanghua Bioenergy Group Co., Ltd.	ethanol ethanol 3,000	Sweet sorghum stalks	0.25	Yanxin region, Binzhou, Shangdong	Completed and operated in 2005
Santai Wine (Group) Company in Jimsar County,Xinjiang	ethanol 100,000	Sweet sorghum stalks	2.0	Santai town, Jimsar county, Xinjiang	Operated since 2007, discontinued in 2009
COFCO	ethanol 100,000	Sweet sorghum stalks	n/a	WuYuan county, Inner Mongolia	Technology by Qinghua University, feedstock and site by WuYuan county
Planning and Design Institute under Ministry of Agriculture	ethanol 5,000	Sweet sorghum stalks	n/a	Huachuan county, Heilongjiang	863 Program, Technology of ethanol preparation from sweet sorghum stalks, Acceptance by the end of 2005
Inner Mongolia Jinjiao Special New Materials Co., Ltd	biodiesel 150,000t	Non-food oil plants or aquatic material, such as plum, sunflower, food residues and other aquatic products as feedstock	n/a	Binhe new zone, Xitu Hi-tech district, Baotou	Operation since 2008

(A) Fuel ethanol production using crop stalks as feedstock

Fuel ethanol production using crop straw or stalks as feedstock involves straw and stalk collection, production technology development, equipment manufacturing and production facility construction. The cellulosic biomass ethanol production technology is more complicated than the starch or sugar-based one. Even though the pilot production has been successful on a small or medium scale, it is difficult to ensure that industrial production can be successful without demonstration tests of the scaled up units. The cost of second-generation biofuel ethanol production is far higher than the ethanol sales price (whether the cost of cellulase can drop is the key factor to achieving the industrial production of cellulosic ethanol). There are no government subsidies to cover potential business losses. Consequently, there is no formation of large-scale industrial production capacity during the Eleventh Five-Year period.

Currently, the main demonstration projects or pilot plants of fuel ethanol production from straw and stalks are:

(1) 600 t/a corn stalk fuel ethanol production pilot plant in FengYuan, Anhui

Anhui FengYuan Biochemical is the only manufacturer of ethanol fuel designated by the State, and supplies fuel ethanol to Anhui, Shandong, Jiangsu, Hebei and other provinces. The annual design capacity is 320,000 t of fuel alcohol. The Anhui FengYuan Biochemical Co., Ltd. and China Petroleum and Chemical Industry Group Anhui Petroleum Corporation under PetroChina established one joint venture, and the new company is registered with capital of 1 billion RMB, located in Bengbu.

Anhui FengYuan Group and FengYuan National Engineering Research Center on Fermentation Technology creatively proposed the process of first separation and then fermentation in ethanol production from straws and stalks, and partnered with domestic universities and research institutes to carry out systems engineering research. Through collabourative research, FengYuan Group National Engineering Center on Fermentation Technology has successfully broken through two major technological bottlenecks in the development of cellulose hydrolysis enzyme preparation technology based on straw use and strain development for pentose fermentation.

One medium scale pilot project with an annual production capacity of 300 t of fuel ethanol from straws was completed in 2006, and then the company invested 90 million Yuan in 2009 to build a 5,000 t/a corn cob and corn stalk combined ethanol preparation demonstration device, which adopts alkaline cooking pretreatment process and has the supporting production unit for cellulase solid fermentation with a C5/C6 sugar fermentation process. According to data from the medium scale pilot by Anhui FengYuan, about 6 t dry straw can produce 1 t of fuel ethanol by per unit, at cost between 4,000 and 4,300 Yuan/t which is 300 to 500 Yuan/t less than that from the corn. This figure may also drop as the technology matures.

(2) 50,000 t/a corn stalks fuel ethanol preparation production demonstration line by Tian Guan Group

A 50,000 t/a stalk fuel ethanol preparation production demonstration line by Tian Guan Group is located in the Industrial Park, Development Zone, Zhenping county, Nanyang city, Henan Province. Its total investment is 61.5 million Yuan, which includes cellulase preparation device with an annual output of 10,000 t and a straw ethanol preparation device with the capacity of 5,000 t/a. The consumption of cellulosic feedstock like corn stalks is about 2 million tonnes. The industrial production demonstration line has been put into operation and it can smoothly produce ethanol out of cellulosic straws. One tonne of ethanol requires 6.5 to 7.0 tonnes of the straw and the product quality is qualified at 100%. The cost of ethanol production is 15% more compared to that from grain as feedstock at current prices. The pretreatment process of the feedstock production line adopts the intermitted steam blast method, increasing the conversion ratio of straw to sugar to 43%. The company cultivated cellulase strains with high activity to produce cellulose which reduces the cellulase cost of ethanol production to 1,000 Yuan/t (the cost was about 3,000 Yuan/t in the past). The company has developed new alcoholic fermentation equipment to solve the low concentration alcohol problem of cellulase ethanol fermentation, so that ethanol content reaches more than 7%; sugar alcohol conversion rate reaches 91% and the overall level of technology in the project is in a leading position in China [17]. It ranked No.

1 in evaluation during a national demonstration cellulosic ethanol demonstration projects sponsored by the National Development and Reform Commission, and Ministry of Finance in October 2007.

The line project is attached to key research projects--straw ethanol industry key technology research and industrialisation demonstration projects of National Sci-Tech Support Program implemented by the Ministry of Science. This project is sponsored by Tianguan Group and Zhejiang University, Shanghai Tianzhiguan Renewable Energy Company, Zhengzhou University, among others, and is designed to reduce the cost of straw ethanol production through cellulosic ethanol feedstock pretreatment, integrated enzyme production, creation of multi- fermentation strains, fermentation fluid treatment, feedstock acquisition, storage and transportation and other key technology breakthrough research, to achieve the non-grain alternative for biomass energy and to further promote the development of China's biomass energy industry. It was accepted by expert group of the Ministry of Science on March 16, 2011, that a solid-state enzyme continuous culture device was developed in the project to resolve basically the problem of difficult temperature and humidity control, inconsistent quality and other issues in solid culture, to achieve the continuous production; optimise the enzymatic process, to achieve glycosylated cellulase with no more than 100 IU per gram of straw; select the engineered strain with stable performance, ensure sugar conversion rate of 45% and liquor content of more than 7% (by volume) after fermentation; this project has applied for patents, and 6 enterprise standards were developed [18].

(3) 3,000 t/a straw enzymolysis fermentation fuel ethanol preparation industrial demonstration project by Shangdong Zeshen Biotech Co., Ltd.

A 3,000 t/a straw enzymolysis fermentation fuel ethanol preparation industrial demonstration project by Shangdong Zeshen Biotech Co., Ltd. is located in Zeshen industrial park, west of Jiaopu village, Laohu town, Dongping county, Shangdong, this project was constructed by Shangdong Zeshen Biotech Co., Ltd. and the Institute of Process Engineering, China Academy of Science. It was accepted by an expert group from the Chinese Academy of Sciences in 2006 to be put into operation. Every 7 tons of straw can produce 1 ton of ethanol product. The project uses proprietary technology of new solid-state fermentation, clean straw steam blast technology without adding acid-bases and no pollution, gas phase dual-dynamic solid fermentation technology and straw solid-phase enzyme fermentation- new separate coupling technology. In cellulase production technology, water-saving dual-energy gas dynamic solid fermentation reactor was invented, a 100 m^3 pure solid fermentation bioreactor was constructed which was the largest at home and abroad, and a 5 m^3 large-scale clean straw steam blast processing system, 110 m^3 straw solid-phase enzyme reactor which was triple coupling simultaneous absorption, separation and fermentation was successfully developed. These technologies had China's independent intellectual property rights, obtained a complete technical process parameters, accumulated valuable experience for 10,000 ton-class ethanol industrialization production of straw enzymolysis fermentation, greatly reducing the cost of ethanol distillation. It is only one unit which can be implemented at home and abroad for pure solid-state fermentation industrialisation and full use of large-scale straw steam-blast biomass volume [19], straw cellulose conversion rate is more than 70%, ethanol yield out of dry straw is more than 0.15 g/g, ethanol concentration with activated carbon adsorption and desorption is 69.8% and ethanol production cost is 4,200 to 5,000 Yuan/t. China's average retail gasoline price was 6,460 Yuan/t by the end of 2007, so bioethanol has had a good economic competitiveness instead of gasoline [20].

The technology of this demonstration project was developed by the CAS Knowledge Innovation Project Cellulosic Ethanol Industry Key Technology Research and Demonstration. The researcher CHEN Hongzhang from the Institute of Process Engineering, China Academy of Science, was responsible for this project and it was accepted by the Chinese Academy of Sciences on Apr. 8, 2011. In the project, the research was carried out on key technology of straw component separation, cellulose solid-state fermentation and straw cellulose high concentration fermentation alcohol coupling separation process. Key technologies of straw enzymolysis fermentation fuel ethanol made significant breakthroughs, laying a solid foundation in solid-state fermentation technology industrialization and straw separation and full utilisation of biomass volume, eventually realising continuous and stable operation of 3.000 t/year straw enzymolysis fuel ethanol fermentation production line, and the overall cost of straw ethanol reached 5,200 Yuan/t.

(4) COFCO 10,000 t/a corn stalk cellulose ethanol preparation project in Zhaodong, Heilongjiang

COFCO is one of China's key assigned fuel ethanol enterprises and owner of the biomass COFCO Biochemical Energy (Zhaodong) Co., Ltd. together with Jilin Fuel Ethanol Company. The COFCO Group, Sinopec Group, and the Danish Novozymes Co. signed a cooperation agreement in 2010 to build a 10,000 t/a corn stalk cellulose ethanol preparation demonstration project in Zhaodong city, Heilongjiang in the third quarter of 2011. In this demonstration plant, COFCO as the main investor is responsible for 200 million Yuan in investments, Sinopec Group acts as co-investor and Novozymes will provide enzyme preparation for the plant. The pilot plant will be built in Zhaodong because the area is rich in corn stalk resources. Zhaodong is the main corn ethanol preparation base of COFCO Group. To verify the suitability of corn stalk ethanol preparation technology of COFCO Group, the COFCO Biochemical Energy (Zhaodong) Co., Ltd. in Zhaodong, Heilongjiang, COFCO invested in a 500 t/a medium cellulosic ethanol preparation pilot plant in 2006. The feedstock is corn stalk with an annual consumption of 3,500 tonnes using cellulose enzyme preparation of Novozymes (Novozymes) Company. COFCO and Novozymes carried out joint research and development, successfully producing cellulosic ethanol. The ethanol fermentation volume fraction is up to 7% and the recycling rate of solid material pretreatment is more than 90%. The cellulose conversion rate is more than 80%, conversion rate of glucose fermentation is more than 90% of theoretical conversion rate and it can be run continuously. This technology has been applied for a number of domestic and foreign patent applications [21].

COFCO shareholding enterprise Jilin Fuel Ethanol Company is the largest fuel ethanol plant in Asia. With the support of its main shareholder, China National Petroleum Co., COFCO invested to carry out straw cellulosic ethanol preparation research and development with major achievements: in 2008-2009, COFCO completed a feasibility study of 3,000 t/a corn stalk ethanol preparation industrialization demonstration project and passed an environmental review by the Ministry of Environmental Protection. The project was scheduled to start construction in 2010. It’s located in the production plant of Jilin Fuel Ethanol Co., Ltd, in the Jilin Economic Development Zone, Jilin City. The cellulase of the production line is supplied by Danish Genencor International Co., and continuous steam blast fiber pretreatment equipment with enzymatic hydrolysis process was adopted from the Canadian Sanpuda Biological Processes. Auxiliary materials include cellulose, sodium hydroxide, urea, phosphoric acid, and yeast. It can produce fuel ethanol after feedstock rough cutting, crushing, soaking, hydrolysis, steam blast blow, hydrolysis, fermentation, distillation, separation and other processes. It is designed to use corn stalks as feedstock, but does not exclude other fiber materials. The total investment of this demonstration project is 139 million Yuan, of which, the construction investment is 136 million Yuan, and the environmental protection investment is 450,000 Yuan. If completed, the annual production capacity is 3,000 tonnes of fuel ethanol, with by-products including 2,565 t/a of DDGS feed, 12,810 t/a of lignin residues and 1,720 t/a of CO2. As of the writing of this report, information about the precise completion date was not available.

(B) Fuel ethanol preparation with agricultural and forestry waste as feedstock

A 600 t/a agricultural and forestry waste fuel ethanol preparation demonstration plant of Shanghai East China University

The Shanghai East China University of Science and Technology has undertaken the State 8th Five Year Plan, 9th Year Plan, 10th Year Plan Sci-Tech Brainstorm Stress Projects and the projects of the so-called “863 Program”, have been studying the forestry wastes fuel ethanol technology. The State allocated for the projects of the 863 Program, dedicated for industrial pilot of waste biomass fuel ethanol preparation technology, 600 t/a medium-scale acid hydrolysis cellulosic ethanol pilot plant was built in Fengxian, Shanghai. Sawdust and rice husk are used as raw material in the project, the cost of fuel ethanol production is 6,000 Yuan/t in accordance with the present technology and it will not have much market competition if the state does not subsidize. The East China University of Science and Technology has also applied for the patent in the development of biomass cellulosic ethanol production technology; there is no report on the industrial applications of patented technology at present.

As straw resources are fewer in Shanghai, it will be the R&D center and equipment production base to help the regions with rich straw resources for future factory construction. It will focus on cost reduction and study of large-scale production, increasing the economic competitiveness of the product.

(C) Fuel ethanol preparation with sweet sorghum stalks as feedstock

China has developed a self-owned fuel ethanol preparation technology with sweet sorghum stalks as feedstock (known as sweet sorghum ethanol), and has carried out the cultivation of sweet sorghum and small-scale sweet sorghum stalks fuel ethanol production pilot in Heilongjiang, Inner Mongolia, Xinjiang, Shandong, Jilin and other places.

(1) 3,000 t/a medium-scale sweet sorghum ethanol pilot plant of Guancai Energy Co., Ltd. in Binzhou, Shandong

In 2005, the subsidiary of Guancai Energy - Binzhou Guanghua Bio-energy Group Co., Ltd. invested 25 million Yuan to construct a 3,000 t/a medium-scale sweet sorghum ethanol pilot plant in Xinyang District, Binzhou City, Shandong Province. The device will rely on domestic technology with independent development and is an innovative project with combination of sweet sorghum planting pilot and medium-scale ethanol preparation pilot. Through the actual production, the data shows that cost can be controlled within a reasonable limit, a full set of production process has withstood the test of production practices, and the medium-scale pilot has succeeded. The technical report has passed the identification of the Science and Technology Department of Shandong Province.

Self-developed one-step biomass hydrolysis fermentation distillation technology has helped achieve sweet sorghum ethanol preparation industrialization and has solved the conflict between feedstock seasonal production and year-round industrial processing. It is expected to overcome the issues of large feedstock volume, storage difficulties and preservation and heavy transport workload, reducing the costs and expenses of sweet sorghum ethanol preparation and substantially improving economic feasibility of sweet sorghum ethanol preparation. This will create the technical and economic condition for the large scale production of sweet sorghum ethanol preparation. The Guancai Energy Co has the intellectual property rights of new sweet sorghum stalk fermentation fuel ethanol preparation technology, which is characterized by three one-step methods:

- Harvesting, crushing filling, storing and sugar maintaining- to complete feedstock preservation for factory's annual production within a month;
- Biomass hydrolysis fermentation and distillation - extract 45% crude alcohol semi-finished product through sweet sorghum straw fermentation and alco hol preparation;
- Salt adding, extracting and distillation – to produce fuel ethanol through salt adding, extracting and distillation of 45% crude alcohol.

Taking sweet sorghum stalks as fuel ethanol feedstock at a purchase price of 2,000 Yuan/t, the cost of fuel ethanol will be less than 3,500 Yuan/t after adding processing fees. One tonne of fuel ethanol can be produced from 16 tonnes of sweet sorghum stalks; 500 kg of biodiesel can be produced from the waste. The preparation of sweet sorghum ethanol only uses the stalks so the grain can be still used as food. It also has very good adaptability compared to other crops and is more resistent to drought, water-logging and salinity. Over the years, the farmers in the Binzhou have planted sweet sorghum in small parts of their crop area mainly for the production of wine and brooms. In order to meet the needs of agricultural energy development, the Binzhou Municipal Government has attached great importance to the cultivation of sweet sorghum. Farmers have been organised for three consecutive years to achieve a large-scale cultivation, increasing experience and obtaining positive results. According to the production demands, the city's large-scale cultivation of sweet sorghum was near 4,000 ha in 2006, the subsidiary of Guancai Energy - Binzhou Guanghua Bio-energy Group Co., Ltd. organized the farmers to plant nearly 2,000 ha of sweet sorghum and it was expected to produce 10,000 tonnes of fuel ethanol per year.

(2) 100,000 t/a sweet sorghum straw fuel ethanol preparation project of by Santai Wine (Group) Company in Jimsar County, Xinjiang

The demonstration project includes one industrial alcohol pilot base and 45,000 hectares of sweet sorghum planting demonstration base, is located in the Santai Wine (Group) Company in Jimsar County, Xinjiang, and is supported by the Development and Reform Commission of Xinjiang Uygur Autonomous Region. The Xinjiang Uygur Autonomous Region and other parties invested a total of 197 million Yuan. The plant was put into operation in 2007, but only 8,000 t of ethanol was produced due to the shortage of sales channels and funds. The operation discontinued in 2009. The technology was developed by a scientific research team composed of the Xinjiang Academy of Agricultural Sciences, Institute of Botany under Chinese Academy of Sciences, the Agricultural Engineering and Design Institute under the Ministry of Agriculture, Biomass Engineering Center of China Agricultural University and the Qinghua University. The sorghum variety Keller from the Selection of Institute of Botany, Chinese Academy of Sciences was selected as feedstock with a sugar content in straw of up to 17-20%. The strain was introduced from the United States with a growth period of about 130 days and a yield of more than 90 t/ha (at a dry weight of 31.5 t /ha). The process adopted a more mature technology of the solid-state fermentation process and there was no pre-hydrolysis process. A flow-chart of the process is shown in Figure 3-1. Through 500 t/a medium scale straw fermentation ethanol (63%) preparation pilot, the cost of production is less than 3000 Yuan/t (as of 2007). The liquor rate is 10-18%, the average rate is 13% (with leaves) and 15% (without leaves). Cellulose conversion rate is 25 to 30%. The straw storage period is 4 months and total sugar loss rate drops to 10%.

Key process: The sugar in the material for sweet sorghum straw fermentation alcohol preparation can be directly fermented and it belongs to the traditional fermentation process. The material which cannot be directly fermented for liquor preparation consists mainly of three structural components: fiber, wood fiber and gelatinous fiber. Crushing before the pretreatment, the fibers have the hydrolysis with fiber hydrolase to prepare glucose, the liquor is made after solid fermenting to get 95% fuel ethanol through distillation and concentration.

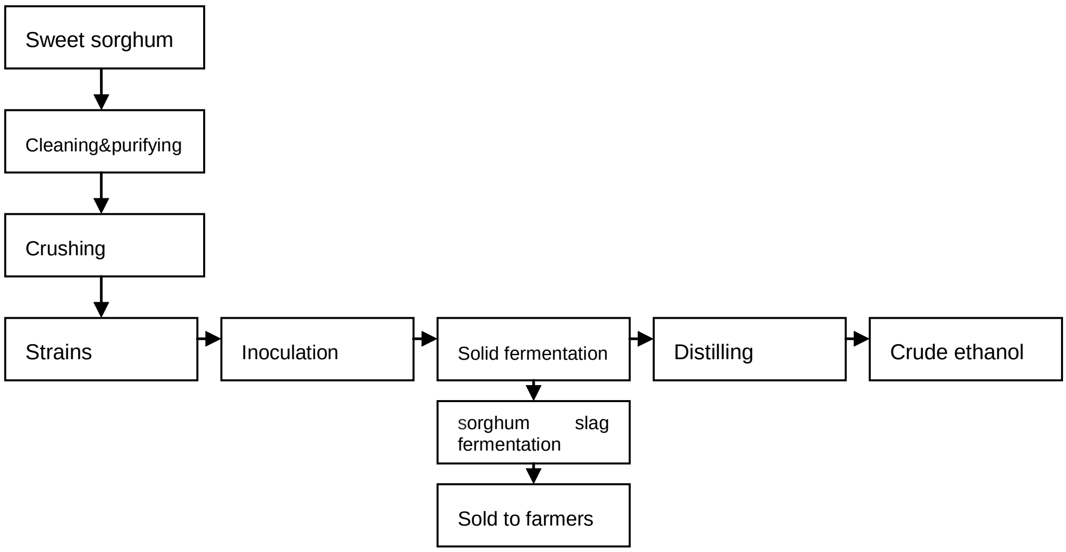

Figure C-5 Sweet sorghum straw fermentation alcohol preparation process

(3) Pilot plant of 100,000 t/a medium scale sweet sorghum stalk fuel ethanol pilot project in Wuyuan County, Inner Mongolia

For this project, the Qinghua University provided the technology, COFCO provided the funds and WuYuan County the feedstock and land. The focus is on sweet sorghum planting with a newly adopted strain (TSH-1) and a drum type solid-state fermentation (ASSF) device. The results showed that the fermentation time is 44 hours, 28 hours less than previous fastest fermentation time in China. The sugar alcohol conversion reaches 94.4%, higher than the target of 90%. The theoretical ethanol yield is 87%, 7 percentage points higher than the target. The equipment used in the fermentation process is feasible, the total energy input is 49.1 MJ/L, the energy content of crop seeds is 5. 9 MJ/L, the energy content of by-products is 95.4 MJ/L, the total energy output is 122.5 MJ/L, the net energy value is 73.5 MJ/L and the energy efficiency is 0.40 [22].

In 2006, the cultivation and transportation cost was 2,571 Yuan/t, feedstock acquisition cost was 3.040 Yuan/t, the total production cost was 4,262 Yuan/t, by-product reduced the cost by 870 Yuan/t, so ethanol fuel unit cost (including feedstock cost) was 3,392 Yuan/t.

(4) 5,000 t/a sweet sorghum stalk solid fermentation industrialization demonstration project in Huachuan, Heilongjiang

This demonstration project included sweet sorghum stalk fermentation fuel ethanol device and a sweet sorghum planting base. The device adopts a £traditional solid state fermentation (SSF) process, the total energy input is 29.43 MJ/L, the energy content of crop seeds is 5.50 MJ/L, the energy by-products contain is 0, the total energy output is 18.22MJ/L, the net energy value is -11.21 MJ/L, and the energy efficiency is 1.6. [22]

In 2005, the cultivation and transportation cost was 2,803 Yuan/t, the feedstock acquisition cost was 3,000 Yuan/t, the total production cost was 4,517 Yuan/t, by-product reduced the cost of 1,000 Yuan/t, so ethanol fuel unit cost (including feedstock cost) was 3,517 Yuan/t.

The project was supported by the Planning and Design Institute under the Ministry of Agriculture and accepted by the planning energy technology field office of the 863 Program at the end of 2005. An annual 400 t/a sweet sorghum stalk liquid-state fermentation ethanol preparation pilot demonstration project was built in Anqiu City, Shandong Province; the development of 400 t/a sweet sorghum stalk fluidised yeast immobilised bed fast fermentation technology and process equipment was completed. This technology is suitable for industrialisation of sugar feedstock liquid-state fermentation fuel ethanol preparation. Based on the study of the 9th Five-Year Plan, progress in the solid fermentation of sweet sorghum stalks was achieved, optimising the feedstock treatment, strain preparation, fermentation process control, distillation and other process parameters. This effectively reduced the process energy consumption and shortened the fermentation time. The main advantage is the easy operation, low sugar residual and high energy conversion efficiency. This project results had been awarded with Blue Sky Award 2005 UNIDO global top ten investment scenarios to apply new technologies for renewable energy utilisation.

(D) Non-food oil plants or aquatic plants and residues for bio-diesel preparation

150,000 t/a of bio-diesel production base of Inner Mongolia Jinjiao Special New Materials Co., Ltd.

In 2008, a 150,000 t/a bio-diesel production line was put into trial production by the Inner Mongolia Jinjiao Special New Materials Co., Ltd. in Binhe New Zone, Xitu Hi-tech District, Baotou, Inner Mongolia. The Jinjiao Group uses non-food oil plants for production of bio-diesel, such as plum, sunflower, food waste and sludge residues. It adopted hydrothermal liquefaction and hydrocracking process technology for bio-based diesel preparation. It's claim is that low cost, good fuel feature, and good compatibility with petroleum fuels, larger matching ratio and other characteristics have been achieved.

C-2.9 Demonstration project summary of second-generation biomass liquid fuel in China

In general, the cellulosic ethanol projects developed in China have passed the labouratory research stage. Most of the projects are in the pilot or demonstration stage, consistent with the stage in foreign countries. Compared to the international situation, China's cellulosic ethanol project technology research is relatively centralized and projects mainly adopt the biotransformation route, i.e. the pre-treatment enzymatic hydrolysis–fermentation process. There is little emphasis on other process technology, such as thermo-chemical conversion, gasification, microbial fermentation or concentrated biological processes (CBP). The key biological conversion processes, such as pre-treatment and enzyme process, lack high level proprietary intellectual property rights and the ability of core equipment localization. The research of hemicellulose (pentose) is still in its infancy.

C-2.10 Summary of next-generation liquid biofuel demonstration projects in China

(1) The key projects in the "Eleventh Five-Year Plan" National Science & Technology Pillar Program: Agriculture and Forestry Biomass Project include:

- Research on dedicated biomass efficient degrading microbial screening and building processes
- Research to ensure resource efficient cultivation of biomass.
- Production and comprehensive utilisation of lignocellulose sugar
- Comprehensive utilisation production technology demonstration for grease resources

(2) In 2007, the Chinese Academy of Sciences launched the key project Cellulosic ethanol high-temperature fermentation and bio-refinery, with a project implementation period from 2008 to 2011. It dealt with the key technology bottleneck of lignocellulose fermentation fuel ethanol preparation and developed key innovation technologies with proprietary intellectual property rights with the goal to ensure market competitiveness. The project was divided into four sub-topics where research was conducted by units of the Chinese Academy of Sciences, at a funding of 25 million Yuan: (a) lignocellulose pretreatment technology research; (b) discovery, transformation and application of new lignocellulose degrading enzymes; (c) high-temperature ethanol system bio-technology transformation; (d) cellulosic ethanol fermentation process optimization and control. The ultimate goals were to design a medium-scale pilot demonstration device which could produce high-temperature cellulosic ethanol, to develop a mathematical model to carry out the economic analysis of cellulosic ethanol technology and to analyse the economic state of high-temperature fermentation of cellulosic ethanol under different design options (operating conditions, production scales) compared to other major technology systems in China and abroad. A strategic analysis and economic feasibility study for a 10,000-ton cellulosic ethanol technical was completed.

(3) On research topic of Microbial Technology State Key labouratory of Shandong University, cellulase, ethanol and other products were in trial production.

(4) The East China University of Science and Technology had built one 600 t/a cellulase ethanol-product demonstration plant in 2005. The plant used cellulase waste double dilute acid hydrolysis fuel ethanol preparation technology with waste wood as raw material, HCl hydrolysis, iron dichloride as catalyst for hydrolysis and fermentation of glucose and xylose; the conversion rate reached 70%.

(5) The Tianjin University researched methods for lignocellulose bioconversion to ethanol. The main focus was on the pretreatment of ammonia blast and microwave steam blast, high-solid enzyme system research, wine and pichia fermentation kinetics research and whole process evaluation design.

(6) The Institute of Bast Fiber Crops (IBFC) under Chinese Academy of Agricultural Sciences (CAAS) and Shaanxi Normal University cooperated to carry out the bast fiber and other fiber pretreatment. Saccharification glycolysis fuel ethanol preparation research got the breakthrough and formed the bast fiber degrading fuel ethanol preparation technology. Total sugar conversion rate of hemp fiber was 67%, while fuel ethanol conversion rate was more than 40%. The technology had been identified by the Ministry of Agriculture.

(7) The National Science & Technology Pillar Program Straw ethanol key technology research and industrialisation demonstration project in the "Eleventh Five-Year Plan"

The project was aimed to reduce straw ethanol production cost, realize non-food alternative options of biomass energy, and further promote the development of China's biomass energy industry through the research breakthrough of some key technologies, such as the cellulosic ethanol feed feedstock pretreatment, combined enzyme production, yeast strains construction, fermented broth governance, feedstock acquisition, storage and transportation, etc. The project included 4 topics of straw ethanol industrialization demonstration key technology development, preparation of straw-degrading microorganism and fermentation process optimization, straw ethanol enzyme fermentation key technology research and development, straw ethanol engineering scale and key equipment development. The research was carried out by the Tianguan Group, Zhejiang University, Shanghai Tianziguan Renewable Energy Co., Ltd. and Zhengzhou University. The project was launched in June 2007 and it was expected to be accepted by the Ministry of Science and Technology in April 2011.

(8) Researchers from Shanghai Jiaotong University announced in late December 2008 that they developed sweet sorghum straw debris ethanol preparation with the active dry enzyme solid state fermentation (SSF) method.

The research result had been published in the magazine *Energy and Fuel of the American Chemical Society* (ACS) issued on December 23, 2008. The study described the effective method of sweet sorghum straw ethanol preparation after storing it for 8 months in dry and crushed form. It determined the different parameters with the active dry enzyme solid state fermentation (SSF) method, including temperature, crushed size, enzyme vaccination rate and the impact of water content to enzyme growth, CO2 and ethanol generation, and sugar use. Solid-state fermentation involves growth of micro-organisms on the solid debris containing water. The researchers from Shanghai Jiaotong University found that temperature and debris size were important to the enzyme growth and ethanol production rate.

Furthermore, enzyme vaccination rate and water content were also greatly related to enzyme growth, even if they had little effect on the ethanol production rate [23].

(9) Lixing (from Agricultural Machinery Research Institute in Jilin province) and Pan Jinxu (from Jilin Chuangjie Automation Co., Ltd.) brought up the development of cellulosic ethanol and hydrogen combined generation device.

C-2.11 Related patents to cellulose ethanol

In early January 2008, Dr. Duan Liping from Chinese Science and Technology Information Institute carried out the patent search in the patent database of China's State Intellectual Property Office (SIPO), where the summary was set as cellulose and ethanol. She found that there were 14 patents related to cellulosic ethanol which the institutes and individuals in China had applied for (see Table C-12).

Table C-12 Patents related to cellulosic ethanol

Patent ownership agency	No. of patents	Description
Institute of Process Engineering, Chinese Academy of Sciences	2	Cellulose solid phase enzyme liquid fermentation coupled ethanol preparation method and device
Institute of Process Engineering, Chinese Academy of Sciences	1	Straw extracting ethanol Method with glucose and/or xylose
Tianjin University	1	Method of rice fermentation high concentration ethanol preparation
East China University of Science and Technology	2	Method of cellulase waste dual acid hydrolysis fuel ethanol preparation and the method of fermented liquor waste dietary fiber preparation in biomass ethanol system
Shaanxi University of Science & Technology	1	Method of biomass pre-treatment
Henan Agricultural University	2	Method of pomace or straw fermentation fuel ethanol preparation
Tianjin University of Science and Technology	1	Method of lignocellulosic hydrolysate fermentation alcohol and nucleic acid preparation

C-2.12 Next-generation biomass liquid fuel policies

At present, the main policies in China with respect to the development of next-generation liquid biofuels are:

1) The long-term development plan for renewable energy

From a long-term point of view, China should actively develop the liquid biofuel technology with cellulosic biomass as raw material. By 2010, the annual use of non-food raw material ethanol fuel increased to 2 million tonnes and the annual use of bio-diesel reached 200,000 tons. By 2020, annual use of bio-ethanol fuel will reach to 10 million tonnes and annual use of bio-diesel will reach 2 million tonnes, with a net-replacement of about 10 million tonnes of petroleum products.

2) Notice on strengthening bio-fuel ethanol project management and promoting healthy development of the industry (Fagaiwei [2006] No. 2842)

The policy to be implemented by the state related to bio-fuel ethanol calls for “designated production, targeted distribution, market liberalization and fair competition”. Ethanol biofuel construction projects must be approved by the state investment authority. A region may not launch a project without national approval, regardless of feedstock.

3) It was proposed in the *Interim Procedures of Renewable Energy Development Special Fund Management* that the state would focus on supporting the development of bio-ethanol fuel and bio-diesel. The financial sector of the State Council established by law specific funds to support the development and utilisation of renewable energy.

4) It was proposed in *Interim Procedures of Straw Energy Utilization Subsidy Fund Management* that the state would support the companies which carried out straw fuel, straw gasification, straw pyrolysis and other straw energy production.

5) The assigned companies approved by the state will be exempted from the consumption tax for the production and sale of denatured fuel ethanol. Their value-added tax will be implemented with a refund after collection.

C-3 Prospect analysis of next-generation biomass energy in Xinjiang

C-3.1 Scenario selection

According to the conclusion above, the following plants are selected for analysis of scenarios forecast:

- Sweet sorghum, because it is adaptable to large-scale planting with sufficient yields and can be grown on marginal lands;
- Cotton stalks, because cotton is planted in many areas of Xinjiang (cotton stalks are agricultural waste, and are available in large amounts);
- Tamarisk, because it can be planted in large-scale on marginal lands, together with *herba cistanches*.

C-3.2 Sweet sorghum

For the scenario analysis, a site in Santai town in Jimsar County of Northern Xinjiang was selected; the location is shown in Figure C-6. Sweet sorghum is generally planted in sandy ground with a soil plough depth of 20 to 25 cm. The soil has an organic matter content of more than 1%, and fertilizer retaining capacity and good drainage capacity. Irrigation water is also available. The solid-state fermentation process is used for the conversion process and the annual processing scale is 100,000 tonnes; the planting area of sweet sorghum is about 2,800 ha with a transportation radius of 5 km.

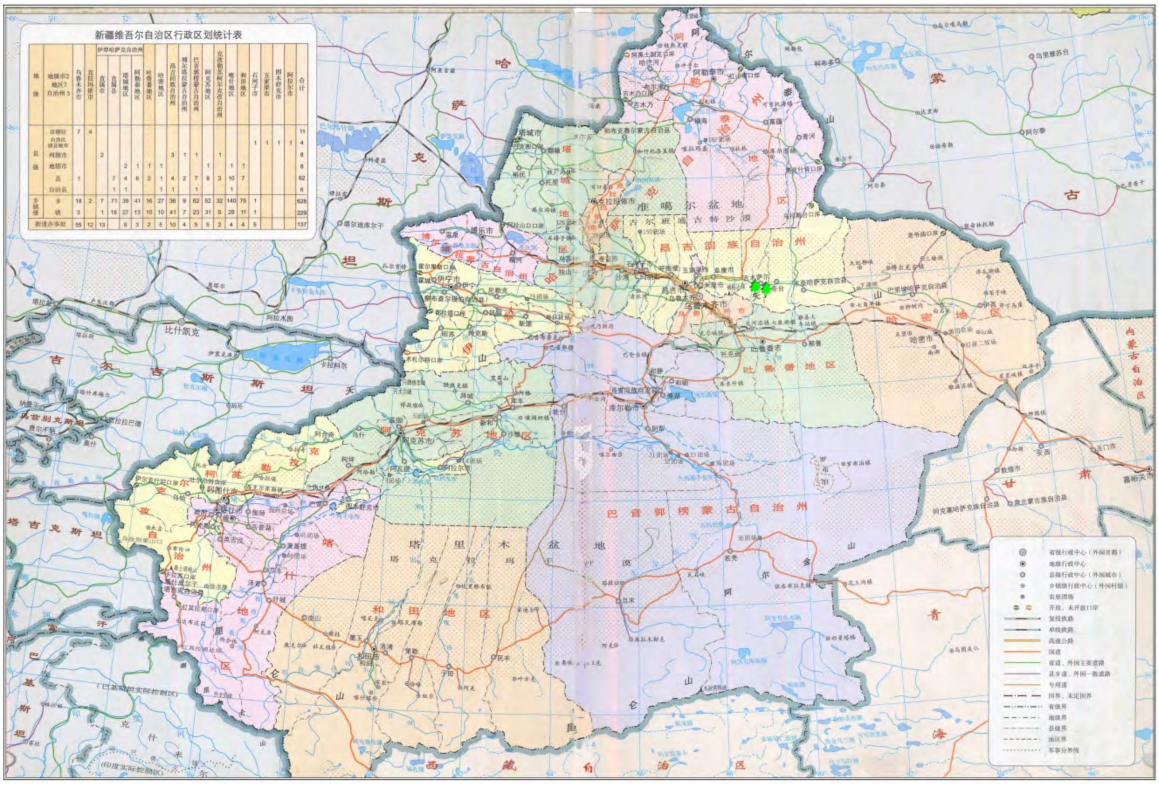

Figure C-6 Scenario for sweet sorghum next-generation ethanol production

C-3.2.1 Process flow description

(1) Planting process

Sowing

Species selection: Species which are suitable for planting locally, high-quality, high yield and of strong stress resistance, are selected according to ecological conditions and processing requirements. The density is 67,500 plants / hm2 in flat and fruitful land, while 75,000 plants / hm2 on the hillside. Sowing quantity is decided according to the seed germination rate, seed quality, soil quality, soil moisture content, damage conditions of soil insects, planting methods and other conditions. Normal sowing quantity is 15 kg/hm2.

Fertilization

While sowing 119 kg/ha phosphate fertilizer (counted in P_2O_5), 206 kg/ha nitrogen fertilizer (counted as N), and 40.5 kg/ha potassium fertilizer (counted in K_2O) are applied.

Field management

The thinning and final singling shall be taken at the period between 4-6 leaves stage of sweet sorghum to avoid late thinning which would lead competition of moisture, nutrients and sunlight in seedlings. The spacing shall be kept consistent between seedlings, and double seedling could be left at the two ends of the place where the seedling is lost to compensate the loss. Tillering at the base should be removed in time for the jointing stage.

Disease and pest control

(A) Agricultural control: Varieties with strong resistance are selected and the varieties should be changed regularly to maintain the resistance and reduce the incidence of pests and diseases. Reasonable farming system, crop rotation and other agronomic measures should be adopted to reduce the incidence of harmful organisms.

(B) Medium and low toxic chemical pesticides, which are less harm to natural enemies, are selected for biological control to avoid sensitive times of natural enemies to pesticides, create a suitable environment for breeding of natural enemies, and protect natural enemies. Natural enemies are used and released to reduce the incidence of harmful organisms.

(2) Conversion process

At present there are two main fermentation processes for sweet sorghum stalks fuel ethanol preparation (1) juice liquid state fermentation after juicing, a more mature technology; (2) stalk solid state fermentation after smashing.

Liquid state fermentation with sweet sorghum stalks

Liquid state fermentation is the fermentation using extracted juice of sweet sorghum stalks. India is one of the countries which have studied sweet sorghum liquid state fermentation ethanol preparation technology early-on, and India has screened out the alcohol yeast achieving high yields.

After the optimisation of the process conditions of sweet sorghum juice fermentation ethanol preparation, the result show that sugar concentration of sweet sorghum stalk juice is 17.8%, inoculation rate is 10%, pH value is 4.5, fermentation time is 48 h, ethanol concentration can reach to 10.2% after fermentation and residual sugar concentration is 1%. Although the liquid fermentation technology is relatively mature, there are still some disadvantages: juicing requires high energy consumption; juice storage is difficult, residual sugar in stalk residue is high, sugar use ratio is low during fermentation and large amount of sewage is created.

Sweet sorghum stalks solid-state fermentation

Solid-state fermentation (SSF) refers to an ethanol preparation process by fermentation with one or more type of microbes and little or no free flowing water. Compared with deep liquid-state fermentation, solid-state fermentation has the advantages of less drainage, less pollution, simple equipment, low energy consumption, high sugar use rate and simple pre- and post-processing technology. Compared to smashing and juicing sweet sorghum stalks, the solid-state fermentation has higher productivity than liquid state fermentation. However, there are still disadvantages of solid-state fermentation technology: microbial growth is restricted by nutrition diffusion; overheating can happen due to metabolic heat accumulation; automatic control to the fermentation process is a little difficult, and there is less experience in technology development.

The solid-state fermentation technology is applied for this scenario analysis; see the process flow in Figure C-7.

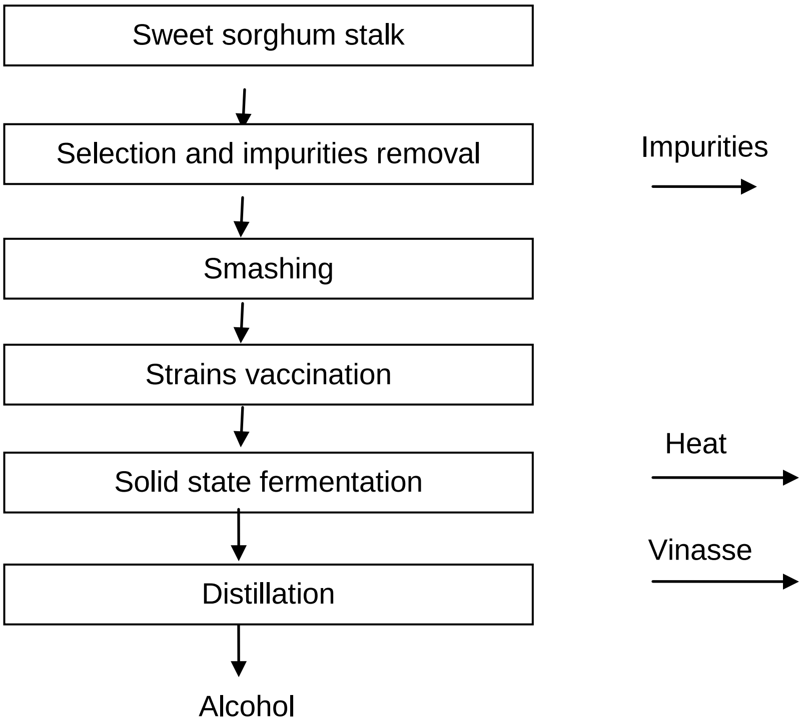

Figure C-7 Solid-state fermentation process flow

C-3.2.2 Input and output data

(1) Input-output for planting sweet sorghum

Sweet sorghum planting data adopts field survey data of sweet sorghum planting in Santai town, Jimsar County of Xinjiang Changji Hui autonomous prefecture. Agricultural fertiliser use data comes from related documentation.

Table C-13 Input and output for sweet sorghum planting

Items	**Quantity**	**Unit**	**Remarks**
Output			
Total biomass	34.5	t dm/ha	Expert Consultation by Cao Yanshan
Sweet sorghum seed production	3	t dm/ha	Expert Consultation by Cao Yanshan
Sweet sorghum stalk production (including residue and sugar)	31.5	t dm/ha	Expert Consultation by Cao Yanshan
Residue contained in stalks	19.8	t dm/ha	Paper data calculation [24]
Sugar contained in stalks	11.7	t dm/ha	Paper data calculation [24]
Input			

Items	Quantity	Unit	Remarks
Input of seeds	15	kg/ha	Paper [25]
Input of nitrogenous fertiliser (counted as N)	206	kg/ha	Paper [25]
Input of phosphate fertiliser (counted as P_2O_5)	119	kg/ha	Paper [25]
Input of potash fertiliser (counted as K_2O)	40.5	kg/ha	Paper [25]
Input of pesticides (0.02% permethrin powder)	30	kg/ha	Expert Consultation
Input of pesticides (40% Dimethoate EC)	600	kg/ha	Expert Consultation
Input of diesel	37.5	kg/ha	Expert Consultation by Cao Yanshan
Input of water	7,200	m^3/ha	Expert Consultation by Cao Yanshan
Input of electric power	45	kWh/ha	Expert Consultation by Cao Yanshan

Note: Expert Consultation to Cao Yanshan, chief engineer from Santai Wine Co., Ltd.

(2) Sweet sorghum transportation input

If 100,000 tons (dry weight) of sweet sorghum are processed annually, the planting area is about 2,900 ha and the transport radius is 5 km; the annual processing of fresh sweet sorghum stalk is about 300,000 tons, the average transport distance is 3.5 km, one 4-t-truck consumes 3 kg of diesel per hundred km, the diesel consumption will be 31.5 t.

(3) Input-output of ethanol conversion from sweet sorghum

Table C-14 Input and output of ethanol conversion from sweet sorghum

Item	Quantity	Unit	Remarks
Input			
Input of sweet sorghum stalk	3.325	t dm	Expert Consultation by Cao Yanshan
Input of water	8	m^3	Expert Consultation by Cao Yanshan
Input of strains	175	kg	Expert Consultation by Cao Yanshan
Input of electric power	100	kWh	Expert Consultation by Cao Yanshan
Input of steam	4.5	t	Expert Consultation by Cao Yanshan
Output			
Ethanol production	1	t	Expert Consultation by Cao Yanshan
Vinasse production	8.5	kg/ha	Calculation

Note: Expert Consultation by Cao Yanshan, chief engineer from Santai Wine Co., Ltd.

C-3.2.3 Conclusions

There is domestic research available on sweet sorghum fuel ethanol preparation, including data from manufacturing enterprises. The entire process from planting to ethanol conversion can be adequately quantified.

C-3.3 Cotton stalks

For the scenario calculations, Baojiadian town, Manas county of Xinjiang Changji Hui autonomous prefecture in Northern Xinjiang was selected for the planting area (Figure C-8). The soil in the 20-25 cm thick plough layer has more than 1% organic matter content, good water and fertiliser retaining capacity, and good drainage. The land is flat with loose soil and low salinity and close to the water resource. The irrigation is carried out in the winter and soil preparation is done after adding moisture in the spring.

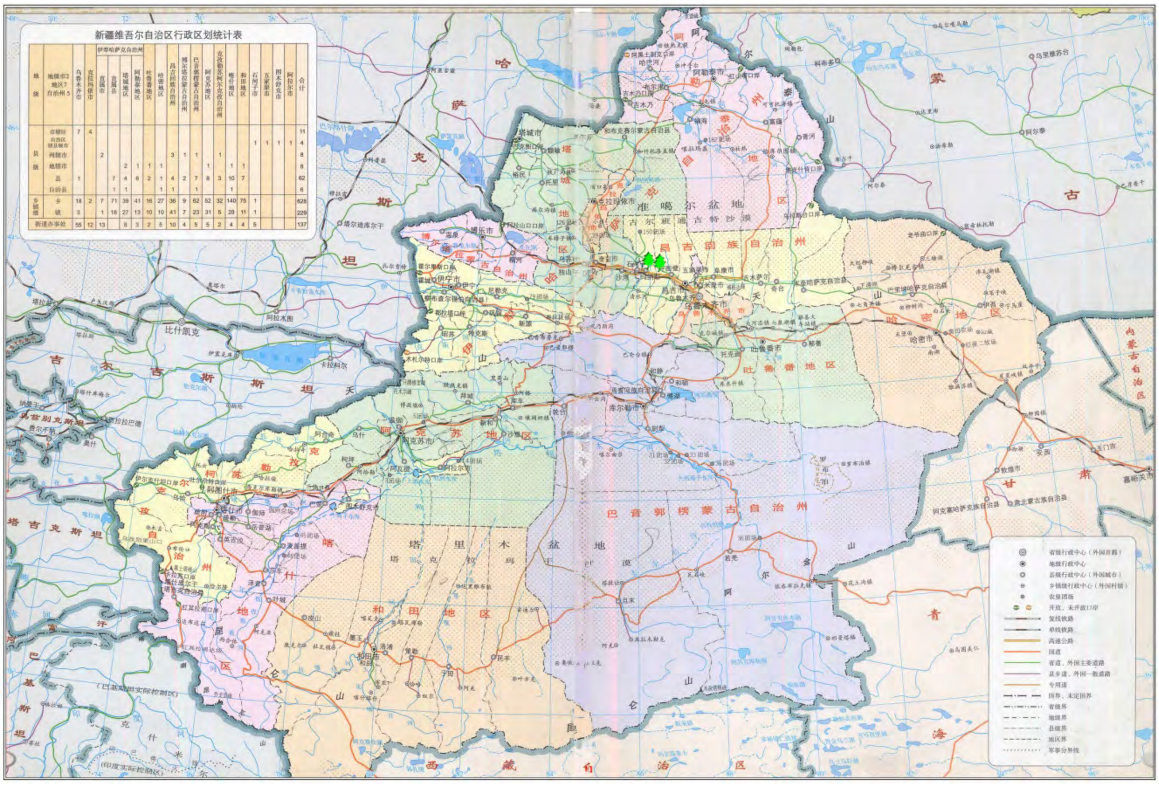

Figure C-8 Scenario geographic location of next-generation ethanol from cotton stalks

C-3.3.1 Process flow description

(1) Planting process

Sowing

The seeds shall be selected by hand before sowing, it is required that seed purity be more than 98%, the clarity shall be 99% and damage rate less than 1%. The seeds shall be treated with a fungicide. The sowing density is assumed to be 225,000 plants/ha, the rate of empty holes should be less than 2%, with no dislocation, the soil has to be covered tightly.

Fertilisation

Before plowing, phosphatic fertilizer 135 kg/ha (counted in P2O5), nitrogenous fertilizer 240 kg/ha (counted in N) and potash fertilizer 30 kg/ha (counted in K2O) shall be applied.

Topping

Cotton topping is an agricultural technique in which the shoot tips of cotton plants are cut off by farmers. Topping should happen when the plant height is between 80 and 95 cm and the number of fruiting branches of single plant is between 10 and 12. Topping should be thorough with no missing, no hurting of cotton plant, and a mass topping shall be taken, if necessary, to prevent cotton remaining green and late-maturing.

Disease and pest control

The monitoring of diseases and pests shall be done regularly; the control should adhere to the principle of prevention first, integrated control. Medium and low toxic chemical pesticides, which are less harmful to natural enemies, are selected for biological control, avoiding sensitive times of natural enemies to pesticides, creating a suitable environment for breeding natural enemies and protecting natural enemies. If possible, natural enemies should be used and released to reduce the incidence of harmful organisms.

(2) Conversion process

There are several ways to biologically convert lignocelluloses feedstock into alcohol: step-by-step hydrolysis and fermentation (SHF), simultaneous saccharification and fermentation (SSF) and direct microbial conversion (DMC).

Step-by-step hydrolysis and fermentation (SHF)

Step-by-step hydrolysis and fermentation is when enzymatic hydrolysis of the cellulose is proceeding at the same time as alcohol fermentation. The biggest advantage of this approach is that each step proceeds separately in the optimum temperatures ranged from 45 to 50 °C for enzymolysis and 30 to 35 °C for alcohol fermentation. The biggest (and sometimes) fatal drawback is that the released sugar during enzymolysis will make feedback inhibition to enzyme activity, making it impossible to increase the concentration of cellulose.

Simultaneous saccharification and fermentation (SSF)

During simultaneous saccharification and fermentation (SSF), the cellulose enzymolysis happens at the same time as the ethanol fermentation of glucose. The glucose that is generated during enzymolysis is rapidly used by microbes, removing the feedback inhibition of the glucose to cellulose enzymolysis. SSF is a typical ethanol preparation method for lignocellulose, and this method is applied in almost all pilots both at home and abroad. On one hand, the big factory tank produces cellulase through fermentation; on the other hand, cellulase and yeast strains are added into pre-treated feedstock for simultaneous saccharification and fermentation. Unhydrolyzed residue of lignin and cellulose are separated out to provide energy when combusted and the ethanol is reclaimed through the traditional distillation technology.

Direct microbial conversion (DMC)

Direct microbial conversion is when cellulose in crop stalks converts directly to alcohol through fermentation of certain microorganisms. These microorganisms can not only produce hydrocellulose of cellulose enzyme, but also generate ethanol through sugar fermentation. The first two methods require independent production of cellulose enzyme, but this method combines all the three steps into one step: cellulase production, cellulose hydrolysis and sugar fermentation to alcohol. Neurospora crassa and Fusarium oxysporum Schlecht are two funguses that have been extensively studied for direct conversion of lignocellulosic feedstock to ethanol. Both funguses have the ability to produce cellulase, hemicellulase, and generate ethanol through fermenting glucose and xylose. They produce hydrolysis substrate of cellulose under aerobic conditions, and produce ethanol through sugar fermentation under the condition of half oxygen introduction.

C-3.3.2 Input and output data

(1) Input and output of cotton planting

Table C-15 Input and output of cotton planting

Item	Quantity	Unit	Remarks
Output			
Cotton	1.8	t dm/ha	Expert Consultation
Cottonseed	2.7	t dm/ha	Expert Consultation
Cotton stalk	12.45	t dm/ha	Expert Consultation
Root	1.35	t dm/ha	Expert Consultation
Input			
Seed	67.5	kg/ha	Expert Consultation
Mulching film	48	kg/ha	Expert Consultation
Nitrogenous fertilizer (counted as N)	240	kg/ha	Expert Consultation
Phosphate fertilizer (counted as P_2O_5)	135	kg/ha	Expert Consultation
Potash fertilizer (counted as K_2O)	30	kg/ha	Expert Consultation
Pesticides: 48% trifluralin herbicide	1.5	kg/ha	Expert Consultation
Pesticides: EC 20% dicofol	4.5	mL/ha	Expert Consultation
Pesticides: abamectin 1.8%	300	mL/ha	Expert Consultation
Pesticides: 2.5% efficient Cyhalothrin EC	300	mL/ha	Expert Consultation
Diesel fuel	37.5	kg/ha	Expert Consultation
Water	2,700	m^3/ha	Expert Consultation
Electricity	675	kWh/ha	Expert Consultation

Note: Source of data: deputy director of Agricultural Station of Baojiadian town, Manas County

(2) Input for transportation of cotton stalks

If annually treated cotton stalks amount to 100,000 t (dry weight) per year, the required cotton acreage is about 8,000 ha, the transportation radius is 10 km, annually treated fresh cotton stalks is 200,000 t, average transport distance is 7.5 km, a 4-t-truck consumes 3 kg of diesel per hundred km per ton and a total of 45 t of diesel is required.

C-3.3.3 Conclusion

Next-generation fuel ethanol generation from cotton stalks has only been done on a labouratory research level. There is no related medium scale pilot and production, and are lacking reliable input and output data from ethanol preparation from cotton stalks. According to relevant papers, 6.5 to 7.0 t of other stalks is required to produce 1 t of ethanol [26]. Related data about ethanol conversion from stalks is not available due to technical confidentiality.

C-3.4 Tamarisk (salt cedar)

The scenario selected for planting assumes the Hotan region, Xinjiang. The district exhibits a flat terrain, low winds and available irrigation facilities. The soil is sandy soil or alkali soil.

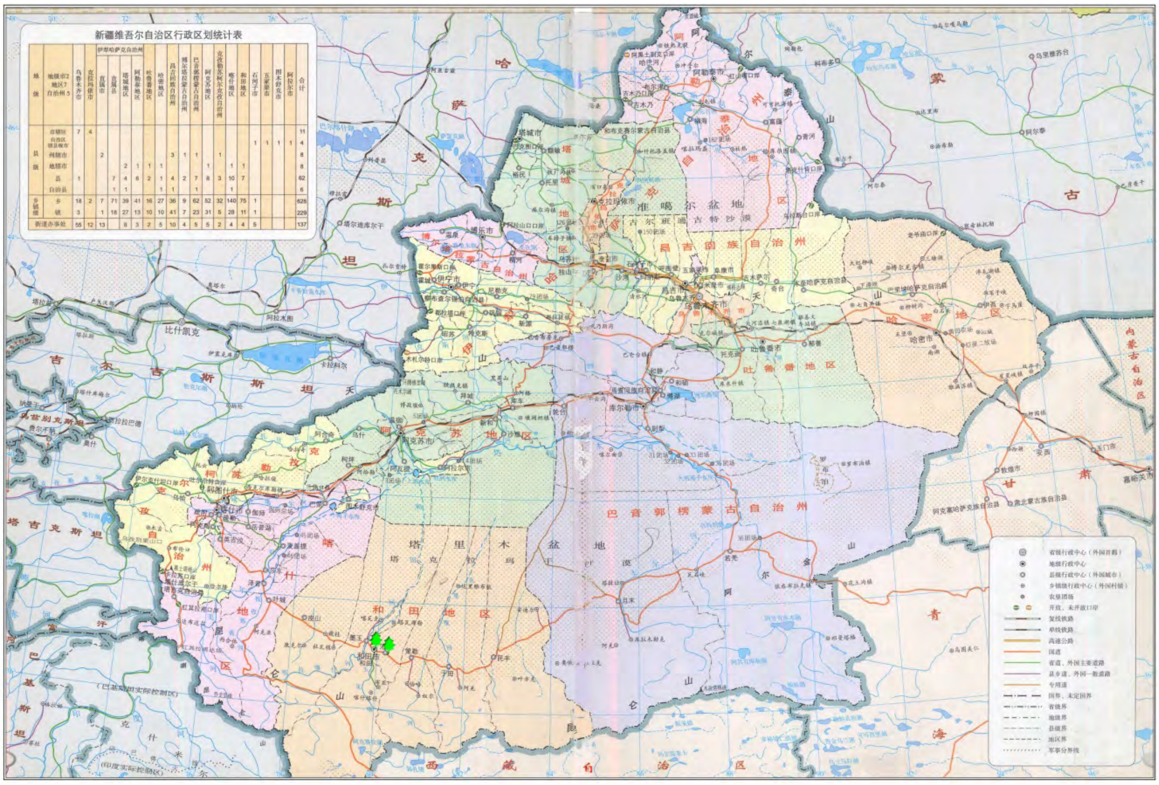

Figure C-9 Scenario for next-generation ethanol preparation from tamarisk

C-3.4.1 Process flow description

(1) Planting process

Cuttingage

Cutting wood of branchy tamarisk is an easy way to create adventitious roots, so a cuttage nursery can be conducted. Branches that are 1 cm thick, 30 to 40 cm long and 1 year old are chosen for cutting wood and the cuttage is done in spring. The line spacing is 40 cm; plant spacing is 10 cm; irrigation should be done every 10 d after cuttage; the survival rate will reach to more than 80% to 90%; the height of seedling is 1 to 1.2 m and the stem diameter is 0.8 cm.

Field planting

Big seeding is better for field planting; seedlings with a height of 1 m and a diameter of 0.7 to 1 cm are required. Field planting can be done in autumn, winter and early spring with 2 m of line spacing and 50 cm of plant spacing, soaked in water for 1 to 2 h before planting and 15 to 20 cm of the root shall be cut and kept if it’s too long. Field planting hole shall be dug with a diameter of 30 to 40 cm and a depth of 30 cm. The seedling should be put into the planting hole; be treaded down while filling and then enough water shall be irrigated immediately with repeat irrigation every 20 d, ensuring a survival rate of up to 90%. The density is 1,600 plants per hectare [27].

Plant cutting

Branchy tamarisk has a strong ability to sprout, and it is suitable for plant cutting. It grows fast and 7.5 to 15 tonnes of coppice shoots can be harvested per hectare of forest land every year [25].

C-3.4.2 Input and output data

(1) Input and output for planting

Table C-16 Input and output of tamarisk planting

Item	Quantity	Unit	Remarks
Output of branchy tamarisk	9	t dm/ha	Reference [28]
Input of cuttage branches	300	kg/ha	One cuttage branch is calculated as 0.2kg
Nitrogenous fertilizer (counted as N)	70	kg/ha	Reference [27]
Input of diesel	37.5	kg/ha	Expert Consultation
Input of water	3,600	m^3/ha	Expert Consultation Irrigate 1,200 m^3/ha before cuttage and 2,400 m^3/ha after cuttage.

Note: Expert Consultation by deputy director of Agricultural Station of Baojiadian town, Manas County

(2) Transportation input for tamarisk branches

If 100,000 t of tamarisk (dry weight) is treated annually, then the tamarisk planting area is about 11,000 ha, transport radius is 10 km, the annual treatment capacity of fresh tamarisk is about 125,000 t, average transport distance is 8 km, a 4 t diesel truck consumes 3 kg of diesel per hundred km and 30 t diesel will be required.

C-3.4.3 Conclusions

Research on fuel ethanol preparation using cellulose exists and medium scale pilot or demonstration plants are being built. There is a lack of reliable input and output data of fuel ethanol preparation with cellulose.

C-4 Conclusion

Analysing from available amount of agricultural residues per unit area, annual net biomass of energy crops and adaptability under the natural conditions in Xinjiang, cotton stalks, sweet sorghum and tamarisk are selected as the final choice of feedstock of biomass liquid fuel for the prediction of the year 2030. The prediction shows that available feedstock volume of biomass for next-generation liquid biofuel production in 2030 is 18 million tonnes, including 4.4 million tonnes of cotton stalks which will produce 680,000 tonnes fuel ethanol, 6.6 million tonnes of sweet sorghum which will produce 2 million tonnes fuel ethanol and 6.6 million tons of tamarisks which will produce 1 million tonnes fuel ethanol, according to the rough conversion rate mentioned above from feedstock volume of biomass to liquid biofuel .

The existing cellulosic ethanol projects in China have mostly completed the labouratory research stage and are now in pilot or demonstration stages, comparable to the situation in other countries. Compared with foreign countries, Chinese process options on technology research of cellulosic ethanol are relatively concentrated, and all projects which have been at medium scale pilot and large scale demonstration state have adopted biotransformation, i.e. pretreatment - enzymatic hydrolysis - fermentation process. For other technologies, such as thermo-chemical conversion, gasification - microbial fermentation, concentrated biological process (CBP) and other processes, the attention is not very high. For the key link of biological conversion processes, such as pretreatment and enzyme preparation technology, the research on the use of hemicelluloses (pentose) is only in its infancy due to lack of the ability of high level proprietary intellectual property rights and the localization of core equipments.

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Appendix D:
Background data for economic analysis
Utrecht University

D-1 Overview Settings for economic analysis

No	Crop	Country	Smallholder/plantation	Management system	End product	Timeframe	Byproducts
1	Soy	Argentina	smallholders	low mechanisation, no tillage	SVO	2010	animal feed
2	Soy	Argentina	smallholders	no mechanisation, no tillage	FAME	2010	animal feed
3	Soy	Argentina	plantation	high rate of mechanisation, tillage	FAME	2010	animal feed
4	Soy	Argentina	plantation	high rate of mechanisation, no tillage	FAME	2010	animal feed
5	Soy	Argentina	plantation	high inputs (irrigation), no tillage	FAME	2020	animal feed
6	Soy	Argentina	plantation	high rate of mechanisation, tillage	FAME	2020	animal feed
7	Soy	Argentina	plantation	high rate of mechanisation, no tillage	FAME	2020	animal feed
8	Sugarcane	Brazil	centralised system (with outgrowers)	mechanisited harvesting, no irrigation (intermediate inputs)	EtOH	2010	surplus bagasse into electricity
9	Sugarcane	Brazil	centralised system (with outgrowers)	manual harvesting, irrigation (high in-puts)	EtOH	2010	surplus bagasse into electricity
10	Sugarcane	Brazil	centralised system (with outgrowers)	mechanised harvesting, irrigation	Next EtOH	2020	surplus bagasse into next EtOH
11	Sugarcane	Mozambique	centralised system (with outgrowers)	no irrigation (intermediate inputs)	EtOH	2010	surplus bagasse into electricity
12	Sugarcane	Mozambique	centralised system (with outgrowers)	irrigation (high inputs)	EtOH	2010	surplus bagasse into electricity
13	Sugarcane	Brazil	centralised system (with outgrowers)	mechanised harvesting, no irrigation (intermediate inputs)	EtOH	2020	surplus bagasse into electricity
14	Sugarcane	Brazil	centralised system (with outgrowers)	mechanised harvesting, irrigation (high inputs, high rate mechanisation)	EtOH	2020	surplus bagasse into electricity

No	Crop	Country	Smallholder/plantation	Management system	End product	Timeframe	Byproducts
15	Sugarcane	Brazil	centralised system (with outgrowers)	mechanised harvesting, irrigation (high inputs, high rate mechanisation)	Next EtOH	2030	surplus bagasse into next EtOH
16	Sugarcane	Mozambique	centralised system (with outgrowers)	no irrigation (intermediate inputs)	EtOH	2020	surplus bagasse into electricity
17	Sugarcane	Mozambique	centralised system (with outgrowers)	irrigation (high inputs)	EtOH	2020	surplus bagasse into electricity
18	Palm	Indonesia	smallholders	intermediate inputs	SVO	2010	no pome use
19	Palm	Indonesia	smallholders	intermediate inputs	FAME	2010	no pome use
20	Palm	Indonesia	plantation	high inputs	FAME	2010	no pome use
21	Palm	Colombia	smallholders	intermediate inputs	FAME	2010	no pome use
22	Palm	Malaysia	plantation	high inputs	FAME	2010	no pome use
23	Palm	Indonesia	plantation	high inputs	FAME	2020	pome use
24	Palm	Malaysia	plantation	high inputs	FAME	2020	pome use
25	Jatropha	Tanzania	smallholders	low inputs, marginal land, no irrigation	SVO	2010	seedcake as fertiliser
26	Jatropha	Tanzania	plantation	high inputs, good land, no irrigation	FAME	2010	seedcake as fertiliser, shells as fuel
27	Jatropha	Tanzania	plantation	intermediate inputs, marginal land, no irrigation	FAME	2010	seedcake as fertiliser, shells as fuel
28	Jatropha	Tanzania	smallholders	low inputs, marginal land, no irrigation	FAME	2010	seedcake as fertiliser, shells on field
29	Jatropha	Tanzania	smallholders	smallholder, intermediate inputs, marginal land	FAME	2010	seedcake as fertiliser, shells on field
30	Jatropha	Mali	smallholders	low inputs	FAME	2010	seedcake as fertiliser, shells on field
31	Jatropha	Mali	smallholders	intermediate inputs	FAME	2010	seedcake as fertiliser, shells on field
32	Jatropha	India	smallholders	low inputs	FAME	2010	seedcake as fertiliser, shells on field

No	Crop	Country	Smallholder/plantation	Management system	End product	Timeframe	Byproducts
33	Jatropha	India	smallholders	intermediate inputs	FAME	2010	seedcake as fertiliser, shells on field
34	Jatropha	Tanzania	plantation	high inputs, good land, no irrigation	FAME	2020	seedcake as fertiliser, shells as fuel
35	Jatropha	Tanzania	plantation	intermediate, marginal land, no irrigation	FAME	2020	seedcake as fertiliser, shells as fuel
36	Jatropha	Tanzania	smallholders	low inputs, marginal land	FAME	2020	seedcake as fertiliser, shells on field
37	Jatropha	Tanzania	smallholders	intermediate inputs, marginal land	FAME	2020	seedcake as fertiliser, shells on field
38	Jatropha	Mali	smallholders	low inputs	FAME	2020	seedcake as fertiliser, shells on field
39	Jatropha	Mali	smallholders	intermediate inputs	FAME	2020	seedcake as fertiliser, shells on field
40	Jatropha	India	smallholders	low inputs	FAME	2020	seedcake as fertiliser, shells on field
41	Jatropha	India	smallholders	intermediate inputs	FAME	2020	seedcake as fertiliser, shells on field
42	Cassava	Mozambique	smallholders	low inputs (see table for definition)	EtOH	2010	(electricity mix difference between countries)
43	Cassava	Mozambique	smallholders	intermediate inputs	EtOH	2010	
44	Cassava	Tanzania	smallholders	low inputs	EtOH	2010	
45	Cassava	Tanzania	smallholders	intermediate inputs	EtOH	2010	
46	Cassava	Thailand	smallholders	low inputs	EtOH	2010	
47	Cassava	Thailand	smallholders	intermediate inputs	EtOH	2010	
48	Cassava	Mozambique	smallholders	low inputs	EtOH	2020	
49	Cassava	Mozambique	smallholders	intermediate inputs	EtOH	2020	
50	Cassava	Mozambique	plantation	high inputs	EtOH	2020	

No	Crop	Country	Smallholder/plantation	Management system	End product	Timeframe	Byproducts
51	Cassava	Tanzania	smallholders	low inputs	EtOH	2020	
52	Cassava	Tanzania	smallholders	intermediate inputs	EtOH	2020	
53	Cassava	Tanzania	plantation	high inputs	EtOH	2020	
54	Cassava	Thailand	smallholders	low inputs	EtOH	2020	
55	Cassava	Thailand	smallholders	intermediate inputs	EtOH	2020	
56	Cassava	Thailand	plantation	high inputs	EtOH	2020	
57	SRC Euca-lyptus	Mozambique	plantation	less suitable land, well managed planta-tion, no irrigation	next EtOH	2020	
	SRC Euca-lyptus	Mozambique	plantation	less suitable land, well managed planta-tion, no irrigation	solid		
58	SRC Euca-lyptus	Brazil	plantation	less suitable land, well managed planta-tion, no irrigation	Next EtOH	2020	
59	SRC Euca-lyptus	Brazil	plantation	suitable land, well managed plantation, no irrigation	Next EtOH	2020	
60	SRC Euca-lyptus	Mozambique	plantation	less suitable land, well managed planta-tion, no irrigation	Next EtOH	2030	
61	SRC Euca-lyptus	Brazil	plantation	less suitable land, well managed planta-tion, no irrigation	Next EtOH	2030	
62	SRC Euca-lyptus	Brazil	plantation	suitable land, well managed plantation, no irrigation	Next EtOH	2030	
63	SRC poplar	Ukraine	plantation	less suitable, well managed plantation, no irrigation	BTL	2020	
64	SRC poplar	Ukraine	plantation	suitable, well managed plantation, no irrigation	BTL	2020	
65	SRC poplar	Ukraine	plantation	less suitable, well managed plantation, no irrigation	BTL	2030	
66	SRC poplar	Ukraine	plantation	suitable, well managed plantation, no irrigation	BTL	2030	
67	Switchgrass	Argentina	plantation	less suitable land, well managed planta-	Next EtOH	2020	

No	Crop	Country	Smallholder/plantation	Management system	End product	Timeframe	Byproducts
				tion, no irrigation			
68	Switchgrass	Argentina	plantation	less suitable land, well managed plantation, no irrigation	BTL	2020	
69	Switchgrass	Argentina	plantation	less suitable land, well managed plantation, no irrigation	Next EtOH	2030	
70	Switchgrass	Argentina	plantation	less suitable land, well managed plantation, no irrigation	BTL	2030	
71	Rice straw	China			Next EtOH	2020	
72	Wheat straw	Ukraine			Next EtOH	2020	
73	Rice straw	China			Next EtOH	2030	
74	Wheat straw	Ukraine			Next EtOH	2030	

D-2 Input data for soy

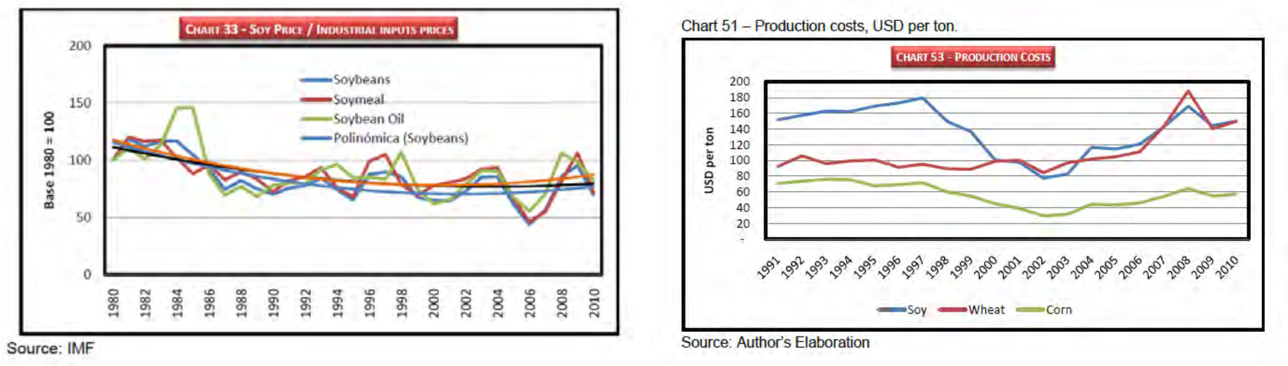


Figure D-1 Soybean prices and production cost fluctuations of soy produced in Argentina (INTA 2011)

Table D-1 Input data for analysis

Country	**Argentina**	**Argentina**	**Argentina**	**Argentina**	**Argentina**	**Argentina**	**Argentina**	**Source**
Setting No.	1	2	3	4	5	6	7	
System	Small-holders	Small-holders	Plantation	Plantation	Plantation	Plantation	Plantation	
Mechanisation	low	low	high	high	high (irrigation)	high	high	
Tillage	no	no	yes	no	no	yes	no	
Endproduct	SVO	FAME	FAME	FAME	FAME	FAME	FAME	
Year	2010	2010	2010	2010	2020	2020	2020	
Yield t/ha	2,8	2,8	3,6	4,5	4	4	5	(INTA 2011)
t dry per ton fresh	0,865	0,865	0,865	0,865	0,865	0,865	0,865	
Yield dry t	2,51	2,42	3,11	3,89	3,46	3,46	4,33	
Transport distance field-processing unit	400	400	140	190	140	140	190	(INTA 2011)
Transport distance SVO to filling station	150	150	150	150	150	150	150	Est. IFEU
Discount factor	8,2	8,2	8,2	8,2	8,2	8,2	8,2	(van Eijck et al. 2011)
Price soy beans /ton	168,82	168,82	168,82	168,82	168,82	168,82	168,82	(INTA 2011)
Transport costs $/ton km	$0,06	$0,06	$0,06	$0,06	$0,06	$0,06	$0,06	
crushing$/ton grain	$12	$12	$12	$12	$5	$5	$5	(van Dam et al. 2009)
Allocation to oil	20%	20%	20%	20%	20%	20%	20%	
Density tons/liter	0,000892	0,000892	0,000892	0,000892	0,000892	0,000892	0,000892	"
Energy content biodiesel (GJ/l)	0,032728							"
Conversion costs biodiesel $/l	$0,00	$0,12	$0,12	$0,12	$0,12	$0,12	$0,12	"
wage rate ($/hour)	$3,18	$3,18	$3,18	$3,18	$8,29	$8,29	$8,29	"
ton grains per ton oil	5,897	5,897	5,897	5,897	5,897	5,897	5,897	"

Table D-2 Input data for analysis (source: van Dam et al. 2009)

Setting			**1**	**2**	**3**	**4**	**5**	**6**	**7**
Cost item		Unit							
Inputs	Seeds	US$/ha	$32,64	$32,64	$45,70	$45,70	$45,70	$45,70	$45,70
	Herbicides	US$/ha	$93,66	$93,66	$113,87	$113,87	$113,87	$113,87	$113,87
	Insecti-cides	US$/ha	$50,10	$50,10	$75,50	$75,50	$75,50	$75,50	$75,50
	Fertilizers	US$/ha	$29.7	$29.7	$102,60	$102,60	$102,60	$102,60	$102,60
Monitoring		US$/ha	$3,00	$3,00	$3,00	$3,00	$3,00	$3,00	$3,00
Labour & Machinery		US$/ha	$0,00	$0,00	$0,00	$0,00	$0,00	$0,00	$0,00
	Labour input	US$/ha	$4,87	$4,87	$2,83	$2,83	$7,24	$7,24	$7,21
	Fuel input	US$/ha	$8,21	$8,21	$13,30	$13,30	$13,30	$13,30	$13,57
	O&M	US$/ha	$9,71	$9,71	$11,74	$11,74	$11,74	$11,74	$11,74
Harvesting costs		US$/ha	$43,20	$41,71	$43,20	$43,74	$43,74	$43,74	$54,68
Marketing costs		US$/ha	$29,97	$29,97	$29,97	$30,34	$30,34	$30,34	$30,72
Land rent	Land rent	US$/ha	$150,00	$150,00	$150,00	$150,00	$150,00	$150,00	$150,00
irrigation							$50,00		
Total costs		US$/ha	$455.1	$455.1	$591,71	$592,62	$647,03	$597,03	$608,59

D-3 Input data for sugarcane

Setting number	8	9	10	11	12	13	14	15	16	17	Source
Country	Brazil	Brazil	Brazil	Mz	Mz	Brazil	Brazil	Brazil	Mz	Mz	
Year	2010	2010	2020	2010	2010	2020	2020	2030	2020	2020	
yield	60	90	90	76	100	63	94,5	94,5	79,8	105	(De Vries et al. 2011; Herreras 2011) (van der Hilst 2011 sub)
sugarcane field to ethanol factory (km)	50	50	50	50	50	50	50	50	50	50	IEFU est.
Ethanol plant to filling station (km)	200	200	200	200	200	200	200	200	200	200	IFEU est.
transport costs ($/ton km)	0,035	0,035	0,035	0,096	0,096	0,035	0,035	0,035	0,096	0,096	(CEPAGRI et al. 2011)
Conversion to ethanol ($/m3)	164,27	164,27	164,27	164,27	164,27	113	113	113	113	113	(van den Wall Bake et al. 2009)

Setting number	11	12	16	17	
Country	Mozambique	Mozambique	Mozambique	Mozambique	
Year	2010	2010	2020	2020	Source
Land rent	22	22	22	22	(van der Hilst)
Land clearing	1350	1350	1350	1350	(van der Hilst)
Planting					Xhinavane mill 2010)
Seeds	357	357	357	357	(Xhinavane mill 2010)
land preparation	398	398	398	398	
cultivation labour	27	27	27	27	
cultivation chemicals	115	115	115	115	
cultivation fertiliser	231	231	231	231	
cultivation mechanized	150	150	150	150	
Ratoon cultivation					(Xhinavane mill 2010)
Labour	248	248	248	248	
Pesticide/Herbicide	115	115	115	115	
Fertiliser	219	219	219	219	
Mechanized (tractors, ripeners)	194	194	194	194	
Irrigation	0	604	604	604	(van der Hilst)
instalment	0	2697	2697	2697	
Labour	0	182	182	182	
Maintenance	0	106	106	106	
Electricity	0	245	245	245	
Bulk Supply	0	72	72	72	
Harvest and delivery					(Xhinavane mill 2010)
harvest $/ton	9	9	9	9	
Market price sugarcane	35 $/ton	35 $/ton	35 $/ton	35 $/ton	(Jelsma et al. 2010)

			Brazil
	Cost item		$/ha
	mechanised operation		$24,47
	labour		$72,47
	inputs		$205,50
Soil preparation and planting			$302,45
	mechanised operation		$56,79
	labour		$85,65
	inputs		$303,70
fertilisers, agrochemical application and others			$446,14
	mechanised operation		$286,45
	labour		$391,87
Harvest			$678,31
transport of sugarcane			$0,00
	own land		$155,30
	land leasing		$50,20
land remuneration			$205,50
	owner/manager remuneration		$77,18
	administration costs		$110,44
Administration			$187,62
	facilities		$24,79
	irrigation/fertiirrigation		$0,00
	machines		$58,98
Depreciation			$83,77
	machines		$65,89
	facilities		$0,00
	working capital		$24,47
	agricultural tillage		$15,37
	irrigation/ ferti		$14,12
Capital remuneration			$119,85
	Irrigation		$163,24

D-4 Input data for Palm

Country	Indonesia	Indonesia	Indonesia	Colombia	Malaysia	Indonesia	Malaysia	Colombia	Source
Setting nr	18	19	20	21	22	23	24	21	
Endproduct	SVO	FAME	FAME	FAME	FAME	FAME	FAME	FAME	
Year	2010	2010	2010	2010	2010	2020	2020	2020	
Yield FFB t/ha	16	16	17	18	19	19	19	19	IFEU/UU
Transport plantation to mill km	7	75	75	75	75	75	75		(Global Biopact 2011)
mill to refinery (km)	200	200	200	200	200	200	200		
refinery to end user (km)	200	200	200	200	200	200	200		
Discount factor				10,00%					(Fedepalma 2010)
kg FFB's per liter SVO (OER)	4,76			4,76					
Price FFB /kg	$0,15	$0,15	$0,15						(Fedepalma 2010)
Price FFB /ton	$152,97	$152,97	$152,97	$152,97	$60,17				(Ismail et al. 2003; Fedepalma 2010)
Transport costs $/ton km FFB	$2,24	$2,24	$2,24	$0,11					(Ministerio de Transporte 2003; Global Biopact 2011)
Transport costs $/ton km oil				$0,06					(Ministerio de Transporte 2003)
Production CPO per ton				35,23					
Refining and esterification ($/l)		0,20	0,20	0,20	0,20	0,02	0,02	0,2	
Wages agricultural sector $/day	$3,00	$3,00	$3,00	$7,07		$3,00			Laboursta
Exchange rates	IDR 8.910			CLP 1.966	MYR 3,13	IDR 8.910			oanda

	Indonesia		Malaysia
	1st year	>1 years	
Seed / Seedlings	11	11	
Fertilizers	543	182	103
Phytosanitary control	0		
Weed control	18	18	
other Supplies	0		

Labour other	79	162	105
Labour harvesting	168*	168	168
Transport	0		119
Total Maintenance	41		39
Total Fixed Capital	0		
Land rent	2	2	7
Administration costs	0		21
TOTAL ($/ha)	$860,73	$542,51	$563,12
	(Global Biopact 2011)	(Global Biopact 2011)	*(Ismail et al. 2003)

D-5 Input data for Jatropha

Setting number	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	
Country	**Tanzania**	**Tanzania**	**Tanzania**	**Tanzania**	**Tanzania**	**Mali**	**Mali**	**India**	**India**	**2020**
Land rent	20	20	20	20	20	0	0	\$19,92	\$19,92	
discount rate	8,20%	8,20%	8,20%	8,20%	8,20%	8,20%	8,20%	(15%)	(15%)	
market price (\$/kg)	\$0,14			\$0,14		\$0,11	\$0,11	\$0,19	\$0,19	
wage rate (\$/day)	\$2,00	\$2,00	\$2,00	\$2,00	\$2,00	\$2,46	\$2,46	\$1,29	\$1,29	
Harvest efficiency kg/person/day	40	40	40	40	40	40	40	40	40	40
conversion costs	\$0,20	\$0,20	\$0,20	\$0,20	\$0,20	\$0,20	\$0,20	\$0,14	\$0,14	\$0,02
transesterification costs		\$0,25	\$0,25	\$0,25	\$0,25	\$0,25	\$0,25	\$0,25	\$0,25	\$0,15
Distribution (\$/l)	\$0,01	\$0,01	\$0,01	\$0,01	\$0,01	\$0,01	\$0,01	\$0,01	\$0,01	\$0,01

Data Tanzania: (van Eijck et al. 2011), (van Eijck 2009) (conversion -0,03\$/l due to glycerine sales)

Data Mali: (Pallière and Fauveaud 2009), land: (Baxter 2011), Wages: (API Mali 2010), market prices seed: personal communication Ard Lengkeek (Mali Biocarburant)

Data India: (Estrin 2009) (Altenburg et al. 2009)

Labour requirements for Jatropha for a low and intermediate input system (days ha^{-1} yr^{-1}).

Plantation year→ Task↓	0	1	2	3	4	5	6	7	8-23
Low input system									
Field preparation[a]	32								
Planting[a]	28								
Weed control[b]	31	31	31	16					
Harvesting[c]	0	2	4	6	9	17	21	24	28
Post harvest activities[d]	0	0	0	0	0	2	2	2	3
TOTAL	91	33	35	21	9	19	23	26	30
Intermediate input system									
Field preparation[a]	32								
Planting[a]	28								
Weed control[b]	31	31	31	16					
Pruning[e]	0	11	11	11	11	11	11	11	11
Fertilisation[g]	9	6	7	7	7	7	7	7	7
Pest and disease control[h]	7	12	9	9	9	9	9	9	9
Harvesting[c]	0	2	4	6	9	17	34	41	49
Post harvest activities[d]	0	0	0	0	1	2	3	4	5
TOTAL	107	62	63	51	41	51	71	79	82

[a] Loos (2008).

[b] For year 3 half of the number of days of year 0 to 2 is assumed that is reported by Loos (2008).

[c] 40 kg seeds person^{-1} day^{-1} is assumed (FACT Foundation 2010).

[d] Post harvest activities (dehulling) are assumed to require 10% of the labour demand for harvesting.

[e] Average of days reported by Loos (2008) for year 0 to 3. For year 3 to year 23 it is assumed that the same number of days is needed per year as year 3.

[g] Loos (2008) for year 0 to 3. For year 3 to year 23 it is assumed that the same number of days is needed per year as year 3.

[h] Loos (2008) for year 4 to 8 the amount of days is assumed to be equal to year 3 and for the years after that it is assumed that only 10% of this time is required.

Inputs and costs required for the cultivation of Jatropha (excluding land and labour)

Task	Value	Unit	Number of units over lifetime?	
			Low input system	Intermediate input system
Field preparation (hoes and machetes)[a]	10	$ ha^{-1}	1	1
Planting material (seeds) [b]	1	kg ha^{-1}	1	1
Tools for weed control[c]	6	$ ha^{-1}y^{-1}	4	4
Tools for pruning (machetes)[d]	10	$ piece^{-1}	-	3
Fertiliser (manure)[fe]	11	$ ha^{-1}y^{-1}	-	24
Pesticides [f]	20 2	$ ha^{-1}y^{-1} year 0-8 $ ha^{-1}yr^{-1} year 9-23	- -	9 15
Packaging material (60 kg bags)	0.45	$ piece^{-1}	322	677

[a] Endelevu Energy (2010).

[b] At no costs, Loos (2008).

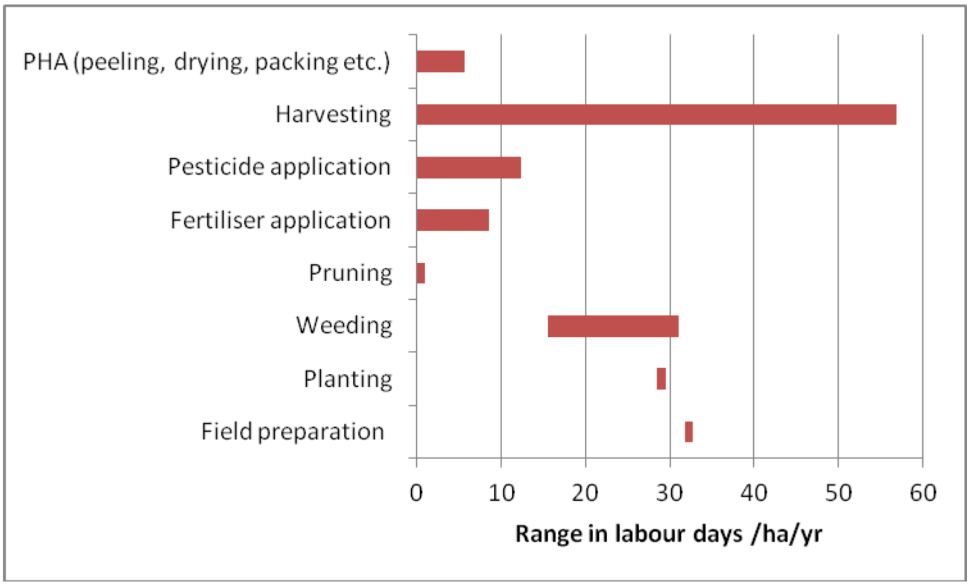
[c] Endelevu Energy (2010)

[d] Endelevu Energy (2010), the lifetime of this tool is assumed to be 10 years.

[e] Average of Loos (2008), 16 $ yr^{-1}, and Endelevu Energy (2010) 6.3 $ yr^{-1}.

[f] Average of Loos (2008), 15 $ yr^{-1}, and Endelevu Energy (2010) 26 $ yr^{-1}. After year 8, only 10% of this amount is assumed.

Land rent is 20 $ per ha per year.
Wages are 2 $ per day



Range in labour days required for jatropha cultivation

	$ l^{-1}	$ GJ^{-1}
Transport seeds to refinery[a]	0.25	7.03
Seedpress conversion to SVO[b]	0.20	5.52
Subtotal	0.45	

D-6 Input data for cassava

Country	**Mozambique**	**Mozambique**	**Tanzania**	**Tanzania**	**Thailand**	**Thailand**	
Setting nr	42	43	44	45	46	47	
System	Smallholders	Smallholders	Smallholders	Smallholders	Smallholders	Smallholders	
Inputs	low	intermediate	low	intermediate	low	intermediate	
Year	2010	2010	2010	2010	2010	2010	2020
Yield t/ha	4	6	6	12	20	22	6
Transport distance field-chips	10	10	10	10	10	10	10
Transport distance chips-ethanol	100	100	100	100	100	100	100
Transport distance ethanol-distribution	200	200	200	200	200	200	200
Discount factor	8,20%	8,20%	8,20%	8,20%	8,20%	8,20%	8,20%
kg roots per liter ethanol	7,5	7,5	7,5	7,5	7,5	7,5	
average wage in agricultural sector($/day)	2	2	2,00	2	3,3-4,3	3,3-4,3	$4,00
Price fresh roots /ton	$58	$58	$91	$91	$45	$45	$58
Transport costs $/ton km	0,096						
Transport costs fresh roots $/kg					$0,004	$0,004	

Country	Mozambique	Mozambique	Tanzania	Tanzania	Thailand	Thailand
Setting nr	42	43	44	45	46	47
Year	2010	2010	2010	2010	2010	2010
COSTS						
Land preparation ($/ha)	$60,00	$60,00	$60,00	$60,00	70,04	$70,04
Plantation ($/ha)	$58,00	$58,00	$58,00	$58,00	31,93	$31,93
Treatment ($/ha)	$62,00	$108,00	$62,00	$108,00	40,685	$81,37
Harvesting $/ha)	$104,00	$104,00	$104,00	$104,00	90,64	$90,64
Labour costs ($/ha)	284	330	284	330	233,295	$233,30
Varieties/stakes	$10,24	$10,24	$10,24	$10,24	$42,23	$42,23
Fertilizers		$52,00		$52,00	$33,48	$66,95
Herbicide&Insecticide		$20,52		$20,52	$15,97	$31,93
Fuels and lubricant					$0,72	$1,44
Agricultural materials and auxil-liaries	$17,76	$17,76	$17,76	$17,76	$0,46	$0,93
Maintenance costs					$0,31	$0,31
Material cost	$28,00	$100,52	$28,00	$100,52	$93,16	$93,16
Interest					$31,93	$31,93
Land rental costs	$20,00	$20,00	$20,00	$20,00	$56,65	$56,65
Depreciation costs for agricultural machines					$1,65	$1,65
Interest for agricultural machinery					$0,21	$0,21
Fixed costs					$58,50	$58,50
TOTAL	$48,00	$120,52	$48,00	$120,52	$183,60	$183,60
TOTAL incl Labour	**$332,00**	**$450,52**	**$332,00**	**$450,52**	**$416,89**	**$416,89**

Annual labour requirements for cassava for a low and intermediate input system (days ha^{-1} yr^{-1})

Plantation year → Task↓	1
Low input system	
Field preparation	30
Planting	29
Weed control	31
Harvesting	52
TOTAL	142
Intermediate input system	
Field preparation	30
Planting	29
Weed control	31
Pruning	7
Fertilisation	7
Pest and disease control	9
Harvesting	52
TOTAL	165

Thailand costs, based on (Nguyen et al. 2008)

Yearly inputs and costs required for the cultivation of cassava (excluding land and labour)

Task	Value	Unit	Number of units	
			Low input system	Intermediate input system
Field preparation (hoes and machetes)[a]	10	$ $ha^{-1}yr^{-1}$	1	1
Planting material (cuttings) [b]	12	$ ha^{-1}	1	1
Tools for weed control [c]	6	$ $ha^{-1}yr^{-1}$	1	1
Tools for pruning (machetes)[d]	10	$ $piece^{-1}$	-	1
Fertilisers (100 kg urea)[e]	52	$ $ha^{-1}yr^{-1}$	-	1
Pesticides [f]	20	$ $ha^{-1}yr^{-1}$	-	1
Packing [g]	0.45	$ $piece^{-1}$	105	234

[a] Endelevu Energy (2010).

[b] Planting material, data from Southwest China 17% of total costs, (Zhang et al. 2003).

Costs of cassava ethanol production, excluding feedstock costs

	$ l^{-1}	$ GJ^{-1}[c]
Transport to refinery[a]	0.06	2.73
Conversion[b]	0.25	11.97
Distribution of ethanol[b]	0.01	0.34
Total	**0.43**	**15.04**

[a] Data from Zambia, (Simwambana 2005)

[b] Data derived from pilot plant in Thailand, capacity unknown, (Nguyen et al. 2008), 2.5 t fresh cassava produces 1 t cassava chips of which 333 l of ethanol can be obtained, this means 7.5 kg fresh cassava per litre ethanol (133 l t^{-1}).

[c] Energy content 26.4 GJ_{LHV} t^{-1}, density 791 kg m^{-3}, (Hamelinck 2004)

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Appendix E:
Background data for next generation biofuels (Utrecht Univ.)

E-1 Energy crop production components

Generally the cost of energy crop production is estimated following the equation below:

$$C = \left(\sum_{i=1}^{i_t} \left(ecc_i \sum_{y=1}^{n} f_i(y) \Big/ (1+dr)^y \right) \right) \Big/ \left(yld\ rot \sum_{y=1}^{n} f_{yld}(y) \Big/ (1+dr)^y \right)$$

where
i_t = the number of cost items with different time pattern, (dimensionless), see Table ??
C = costs of biomass ($\$/t_{dm}$);
yld = yield of the energy crop, based on rainfed production, (t_{dm}/ha/yr);
rot = rotation cycle (years);
n = number of years of plantation lifetime (year);
ecc_i = cost of energy crop cost item ($);
$f_i(y)$ = number of times that cost item occurs per year
i is applied on the plantation in year y (dimensionless);
dr = discount rate (dimensionless) and
$f_{yld}(y)$ = the binary number, harvest (1) or not (0) in year y (dimensionless)

For each cost item in Table E-1, an estimate is made for the share of labour, materials (e.g. planting materials and chemicals) and machinery (includes depreciation, maintenance and fuel) within the total costs. All costs and benefits are spread out equally over the years and expressed in net present value (NPV). Land suitability variation in economic performance is included by means of differences in yields and fertilizer application rate. Also the prices of land, fuel, labour and fertilizer vary between regions.

Table E-1 Generic energy crop production cycle management

Cost category	Cost item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Land rent	Land rent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Establishment - Soil preparation	Clearing and Ploughing	1														
Establishment – Planting / seeding	Planting	1														
Fertilizing	Fertilizing		2	1	2	1	2	1	2	1	2	1	2	1	2	1
Weeding	Chemical	1														
	Mechanical	1	1													
Pesticide application	Chemical	1	1													
Harvesting	Harvest		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Forwarding to roadside	Extraction		1	1	1	1	1	1	1	1	1	1	1	1	1	1

Agricultural machinery: The costs of agricultural machinery (in $h-1) are calculated following standardised methodologies to estimate the costs of agricultural equipment. The costs of machinery are divided into capital, repair and maintenance, fuel, lubrication, labour, storage, insurance and other costs. We assume that the price of diesel (excluding taxes) doubles by 2030, following the doubling of the price of crude oil.

Land rent: Data on the (country average) price of land classified as suitable for crop production (in $ ha-1 y-1).

Establishment: The establishment of energy crops starts with soil preparation (ploughing and harrowing). Energy crops are established using live seedlings or cuttings and a seed drill and roller. The price of seedlings and cuttings is assumed constant to 2030.

Fertilizing: The amount of nitrogen (N), phosphorus (P) and potassium (K) removed from the field in the harvested matter as a proxy for the application rate. The rationale is that all nutrients removed from the field need to be replaced to avoid soil mining. Further, the amount of N removed from the field is increased by 43% to account N lost in runoff water, percolation water and N lost through soil erosion and volatisation. In the case of P and K an uptake efficiency of 100% (on the long term) is assumed.

Weeding: Herbicide application is only required during the establishment phase.

Disease and insect control: Disease and insect control is dependent on the species and region, but is generally not required.

Harvesting: Two harvest systems are considered; manual and mechanised harvesting. For grasses, only mechanised harvesting is efficient and includes a self-propelled forage harvester and a pull-type harvester-baler.

E-2 Value of cost item for eucalyptus production in Brazil

Cost description	**Value**	**Unit**	**Source**
General data			
Wages: Field worker	2.05 to 5.53	e/h	calculated
Tractor	9.38	e/h	CHDSS
Soil preparation			
tractor, ploughing	0.72	h/ha	Van den Broek
tractor, deep ploughing	1.8	h/ha	Van den Broek
labour, ploughing	0.72	h/ha	same as tractor hours
labour, deep ploughing	1.8	h/ha	same as tractor hours
Fencing			
labour	20.00	h/ha	Faundez
material and machinery	313.69	e/ha	Faundez
Planting			
Planting density	2100	plants/ha	Faundez
plant costs	0.05	e/plant	estimated based on literature
labour	28	h/ha	Van den Broek
transport of plants	1.7	h/ha	Van den Broek
transport of personnel	1.4	h/ha	Van den Broek
Weed control			
Weeding, manual -labour	23	h/ha	Van den Broek
Mechanical weeding	2.4	h/ha	Van den Broek
Chemical weeding	1.2	h/ha	Faundez
chemical	90	e/ha	Faundez
Fertilisation			
labour	12	h/ha	Faundez
fertilizers	49-148	e/ha	various, own calculations
Pest and disease control			
Pesticides: labour	8	h/ha	Faundez
Chemicals, pomp	6	e/ha	Faundez, assumption
Fungicides: labour	8	h/ha	Faundez
Chemicals, pump	3	e/ha	Faundez, assumption
Land rent			
land rent, VS areas	104	e/ha	World Bank, own calculations
land rent, mS areas	35	e/ha	World Bank, own calculations
Harvesting			
Claas harvester	230	ke/machine	Gillard
tractor & trailer	97	ke/machine	Gillard
harvesting speed	0.5-1.9	h/ha	Gilland, own calculations
labour	2.0-7.7	h/ha	Gilland, own calculations
Stump removal			
tractor and other machinery	210	e/ha	Hartsough, own calculations
labour	5.9	h/ha	Hartsough, own calculations
labour, very suitable areas	24-58	e/ha	calculated
machinery, very suitable areas	221-540	e/ha	calculated
lifetime	21	years	

E-3 Overview of state-of-the-art second generation biofuels technologies

Next ethanol

Estimated production costs for various fuel processing routes range from 13-30 US$/GJ. Of the many possible process chains to produce lignocellulosic ethanol technologies, the following have been defined as promising short, medium and longer term approaches: simultaneous saccharification and fermentation (SSF), simultaneous saccharification and co-fermentation (SSCF) and consolidated bioprocessing (CBP), which combines all of the hydrolysis, fermentation, and enzyme production steps into one.

For CBP, efficiencies and yields are expected to increase and costs to decrease by 35% and 66% relative to SSF, respectively (Hamelinck et al., 2005). Pretreatment is one of the key technical barriers causing high costs, and a multitude of possible options exist. So far, no “best” technology has been identified (Sims et al., 2010; da Costa Sousa et al., 2009). Alternatively, multiple steps (including pretreatment) can be combined with other downstream conversion steps and material can be bioprocessed with multiple organisms simultaneously. Apart from pretreatment, enzymes are another key variable cost and are the focus of major global efforts in RD&D and cost reduction (e.g., Sims et al., 2010; Himmel et al., 2010). Finally, all of the key individual conversion steps (e.g., pretreatment, enzymatic hydrolysis and fermentation) are highly interdependent. Therefore, process integration is another very important focus area, as many steps are either not yet optimized or have not been optimized in a fully integrated process.

Table E-2: Second generation ethanol production costs projected to 2030 and current development status

Process	**Feed-stock**	**Efficiency and process economics**	**Potential technical advances and challenges**	**Production cost by 2030 (US$/GJ)**
Consolidated bioprocessing (CBP)	Ligno-cellulosic	Eff. ~ 49% for wood and 42% for straw(ethanol) + 5% power. [19]	Lignin dissolution and a cellulose-rich residue.[7] Develop CBP organisms [44]	13.5 to 16[8] 15.5[19] future
Separate hydrolysis/ co-fermentation		Eff.~39% (ethanol) + 10% power[1]	Efficient C5 conversion.[2, 3, 4] R&D investment.[5] Advanced enzyme [6]	25[1]-27[19] 28-35[48]
Separate hydrolysis and fermentation	Barley straw	Steam explosion, enzyme hydrolysis, ethanol fermentation.[9] High solids 15%.	System integration, high solids, decrease toxicity for fermentation	30 9 (Finland) from pilot data
Simultaneous saccharification & fermentation	Corn stover	Dilute acid hydrolysis, 260 million L/yr; FC: 6.6, CC*: 10.1, CR: 1.1 for ethanol [24]		15.5 (US) nth plant, future [24]
	Ligno-cellulosic Various [1]Eff. 35% ethanol + 4%	Generic; 90 million L/yr; FC:14; CC*:14. At 360 Mi L/yr; FC:14; CC*:10; CR:0.5	Meta-analysis conditions[43] with other commercial biofuels	28 (2015) 23.5 (2022)
		Eff. kg/L ethanol (poplar, miscanthus, switchgrass, corn stover, wheat: 3.7, 3.2,	Process integration - capital costs per installed liter	18-22[10] (2020) break

	power	2.6, 2.6, 2.4). Plant sizes 1500 to 1000 tonnes/day. FC 50% of total. Project by 2025 25% operating cost reduction10	of product $0.9 to $1.3 for plants of 150 to 380 million litres/ annum (2020 estimates). Project by 2035 a 40% operating cost reduction[10]	even $100/barrel; + CCS $95/barrel $50/$CO_2$ tonne
	Bagasse	Standalone plant[35] 370 L/t dry (ethanol) + 0.56 kWh/L ethanol (elec.)	Mechanical harvest improvements sugarcane residues (occurring).	6[35]-15[35] w/ and w/o FC

Abb: *Conversion costs include capex-capital expenses; opex-operating expenses; CR - Coproduct Revenue; FC - feedstock cost; CC- conversion cost; Mi-million.

System Boundaries: [24]10% IRR, 39% tax rate, 20 yr plant life, Double-declining-balance depreciation method (DDB dep), 100% equity, Nth plant, For the biochemical pathway costs are FC: 6, CC*: 10.6, CR: 1.1 and for thermochemical pathway costs are FC: 6.7, CC*: 10, CR: 2.5;

Refs: [1]Hamelinck et al., 2005; [2]Jeffries, 2006; [3]Jeffries et al., 2007; [4]Balat et al., 2008; [5]Sims et al., 2008; [7]Sannigrahi, 2010; [8]Kumar et al., 2007; [9]von Weyman, 2007; [10]NRC, 2009; [19]Hamelinck and Faaij, 2006; [24]Foust et al., 2009; [35]Seabra et al., 2010; [43]Hamelinck et al., 2004; [44]van Zyl et al., 2007; [48]Dutta et al., 2010.

The US National Academies analysed liquid transport fuels from biomass (NRC, 2009), and their cost analysis found the breakeven point for cellulosic ethanol with crude oil to be 100 US$/barrel (0.64 US$/litre) in 2020, which translates to 18-22 US$/GJ. This projection is similar to the 23.5 $US/GJ projected by Bauen et al. (2009) for 2022. NRC (2009) projects that by 2035, process improvements could reduce the plant-related costs by up to 40%, or to within 12-15 US$/GJ, in line with estimates for nth plant costs of 15.5 US$/GJ (Foust et al., 2009). Further cost reductions in some of the processing pathways may come from converting bagasse to ethanol, as the feedstock is already at the conversion facility, and has the potential to produce an additional 30% yield of ethanol per unit land area in Brazil (Seabra et al., 2010).

Several strains of microorganisms have been selected or genetically modified to increase the enzyme production efficiency (FAO, 2008) for SSF (Himmel et al., 2010), for SSCF (e.g., Dutta et al., 2010) and for CPB (van Zyl et al., 2007; Himmel et al., 2010). Many of the current commercially available enzymes are produced in closed fermenters from genetically modified (GM) microorganisms. The final enzyme product does not contain GM microorganisms (The Royal Society, 2008), which facilitates acceptance of the routes.

Synfuels (BtL)

Gasification of biomass to syngas followed by catalytic upgrading has comparable estimated production costs (12-20 US$/GJ) to the biochemical chains. Even though the cost bases are not entirely comparable, the recent estimates for FT syndiesel from Bauen et al. (2009), van Vliet et al. (2009), and NRC (2009) are (in US$/GJ), respectively: 20-29.5, 16-22, and 25-30. The breakeven point would occur around 80-120 US$/barrel (0.51-0.74 US$/litre). High efficiency gains are expected, especially in the case of polygeneration with FT fuels (Williams et al., 2009; Laser et al., 2009; Hamelinck and Faaij, 2006).

Process integration

Process intensification reduces capital costs and enables plants to operate more cost effectively at smaller scale. Therefore chemical/thermal processing that previously could only be conducted at very large scale could now be downsized to match the supply of biomass cost effectively. Efficient heat and mass transfer in micro-channel reactors has been explored to compact reactors by 1-2 orders of magnitude in water-gas-shift, steam reforming and FT processes for conventional natural gas or coal gasification streams (Nehlsen et al., 2003) and significantly reduce capital costs (Schouten et al., 2002; Sharma, 2002; Tonkovich et al., 2004). Such intensification could lead to distributed biomass to liquids (BTL) production, as capital requirements would be significantly reduced (Shah, 2007).

Table E-3: Status of Lignocellulosic based BtL technologies and production costs projected to 2030

Process	Plants	Efficiency and process economics	Potential technical advances and challenges	Production cost by 2030 (US$/GJ)
Gasification to syngas followed by FT synthesis. With and without biomass carbon capture and storage (BCCS).	1	Eff.= 0.42 fuel only; 0.45 fuel + power.[19]	BCCS for CO2 from processing.	14 to 20 (fuel only) 8-11; (fuel/power)[19] 15.2-18.6[43]
	2	80 Mi L/yr; FC:12, CC*17 (2015); 280 Mi L/yr FC:12, CC*8(2022)	Meta-analysis conditions[45] with other commercial biofuels	20-29.5[45]
	3	Eff.= 0.52 w/o CCS and 0.5 w/CCS + 35 and 24 MWe. 4000 tons/day switchgrass. Plant cost ~$650 Mi	Gas clean-up costs and scale/volume. Breakeven with barrel of crude oil of $122 ($113 was with CCS and $50/CO2tonne)	25[10] (w/o BCCS US) 30[10] (w/ BCCS US)
	4	Eff. =0.52 +22 MWe. Capital $500 Mi;	Breakeven with barrel of crude oil of $75.	16-22.5[39]

Abb: *Conversion costs include capex-capital expenses; opex-operating expenses; CR - Coproduct Revenue; FC - feedstock cost; CC- conversion cost; Mi-million.

System Boundaries: [38]7% discount rate, 39% tax rate, 20 yr plant life, MACRS depreciation, 45/55 equity/debt, 4.4% debt interest, Nth plant, FC w/ CCS: 16, FC w/o CCS: 8.8, CC* w/ CCS: 14.7, CC* w/o CSS: 15.7, CR w/ CCS: 2, CR w/o CCS: 2.1; [39]10% discount rate, 10 yr plant life

Refs: [10]NRC, 2009; [19]Hamelinck and Faaij, 2006; [38]Larson et al., 2009; [39]van Vliet et al., 2009; [43]Hamelinck et al., 2004; [45]Bauen et al., 2009.

Appendix F:
Water footprints of biofuel cropping systems in Mexico

Prepared by: Red Mexicana de Bioenergía A.C. (REMBIO)
Antigua Carretera a Pátzcuaro, Nr. 8701
Col. Ex Hacienda San José de la Huerta
Morelia. Mich. CP 58190 – MEXICO
www.rembio.org.mx

With the collaboration of:
Enrique Riegelhaupt
Carlos Garcia Bustamante
Fabio Coralli
Alfredo Fuentes
Gabriela Guerrero
Anna Hennecke

CONTENTS

Morelia, Mexico, September 14, 2011

F-1 Scope of the study

This study focuses on the water footprint of biofuel crops in Mexico. Field data were collected in representative cases of two crops (maize and sugarcane) and several cultivation systems, where actual and theoretical water demands were measured and calculated. Additional considerations are made on other crops that are not presently developed as biofuel feedstock in Mexico but may have significant potential.

F-2 Crops and Systems

Four crops were considered, for three main reasons:
a) the appropriateness as feedstock for biofuels;
b) the wide present cultivation and/or ample potential for cultivation;
c) the diversity of cropping systems.

Maize is the most important crop in Mexico, being a staple food and forage. Total planted area is 8.5 million ha; a wide variety of cropping systems is found, ranging from **very low technology** -based in manual labor with no tillage, no fertilizers, little crop protection and no irrigation- to **very high technology** -using hybrid seeds, chemical fertilizers, full crop protection, aspersion irrigation, full mechanization-. Along with grain sorghum, maize could be an important source of fuel ethanol, even if Mexican domestic output does not matches national consumption and imports cover one third of present demand.

Sugar cane is planted in some 0.7 million hectares, being the feedstock for sugar industry, the biggest agroindustrial complex in Mexico, with over 50 active plants. The two main systems for sugarcane cultivation are rainfed (“temporal”) and irrigated. Most of the harvest (95%) is manual. Ethanol (for beverages, pharmaceuticals, cosmetics) is obtained from molasses, of which only 3.6 % is used for this purpose. Sugar cane could be a main source of ethanol, both by processing molasses (some 1.5 M t/yr are available, or 400 million liters ethanol per year), and also by expanding cropped areas (about 2.9 million ha of grasslands are potentially suitable for cultivation).

Jatropha curcas is a very new perennial oil crop. Little information is available about yields in commercial plantations. By 2010, less than 5 thousand hectares were established in México. Since jatropha takes 4 to 5 years to attain full production, no certain data on productivity are available. The potentially suitable area has been estimated between 2.4 and 4.6 M ha.

Oil palm is a perennial oil crop, relatively new to México. Planted area is about 50 thousand ha. Since many of the plantations are below 5 years old, it is difficult to assess the potential yield. Even if the crop has expanded slowly, there is a sizable potential area for new plantations (up to 1.9 Mha, or 3.4 M liters biodiesel/year).

All potential areas are shown in Figure G-1.

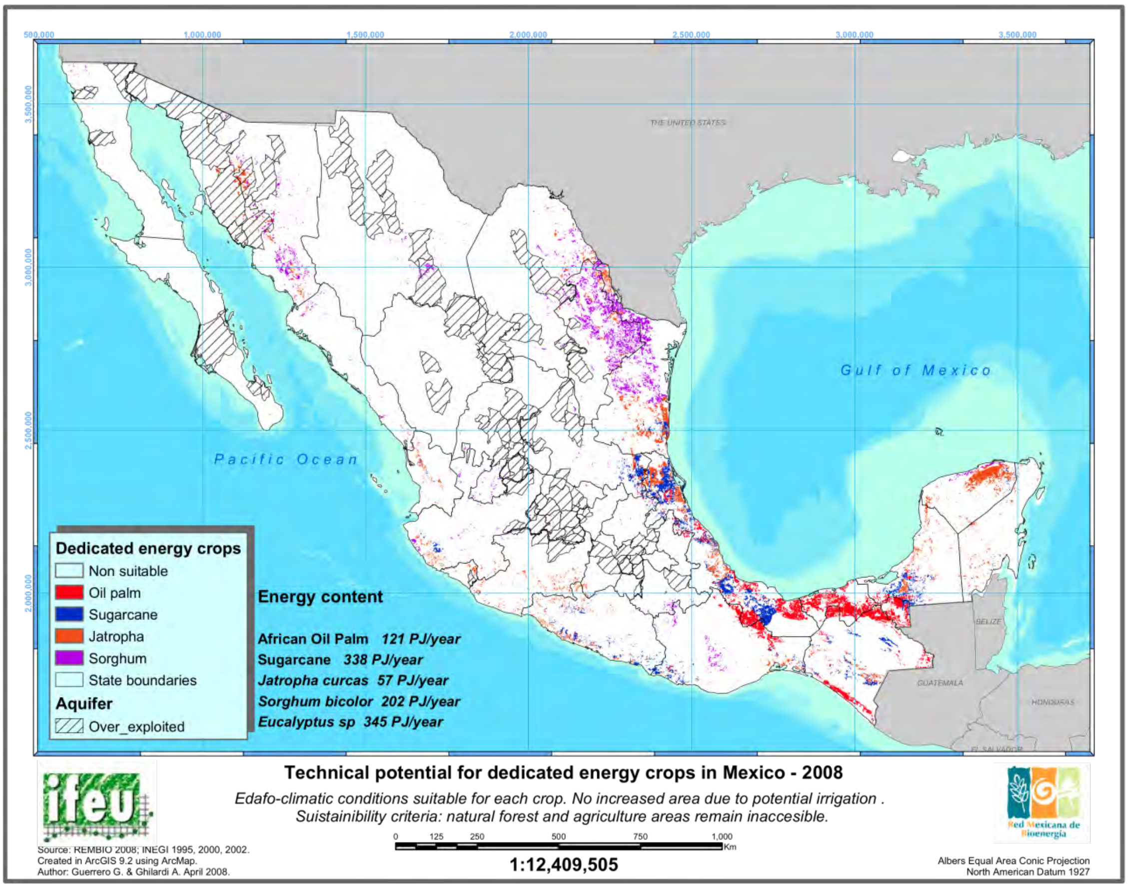

Figure G-1 Potential cropping areas for biofuel crops, rainfed. These areas are presently not cropped, located outside of natural protection areas, and have good to medium aptitude with no irrigation

We selected the most usual cropping systems in Mexico, as shown in Table F-1.

Table F-1 Characterization of cropping systems

No.	Crop	Terrain	Mixed cropping / Crop rotation	Erosion control/soil protection	Irrigation
1	MAIZE	Flat	No	YES	Rainfed
2	MAIZE	Flat	No	no	Rainfed
3	MAIZE	flat	No	no	Gravity
3	MAIZE	hilly	YES	YES	Rainfed
4	MAIZE	hilly	No	no	Rainfed
5	MAIZE	hilly	No	YES	Rainfed
6	MAIZE	hilly	No	no	Rainfed
7	CANE	flat	n.a.	no	Rainfed
8	CANE	flat	n.a.	no	Gravity
9	CANE	flat	n.a.	no	Dripping
10	CANE	hilly	n.a.	no	Rainfed

No.	Crop	Terrain	Mixed cropping / Crop rotation	Erosion control/soil protection	Irrigation
11	CANE	hilly	n.a.	no	Gravity
12	CANE	hilly	n.a.	YES	Gravity
13	OIL PALM	flat	n.a.	n.a.	Rainfed
14	OIL PALM	flat	n.a.	n.a.	Gravity
15	JATROPHA	flat	No	n.a.	Rainfed
16	JATROPHA	flat	No	n.a.	Gravity
17	JATROPHA	flat	Yes	n.a.	Rainfed
18	JATROPHA	flat	Yes	n.a.	Gravity

F-3 Potential cropping areas and sample points in Mexico

The selected cropping areas for each biofuel feedstock are presented from Figure G-2 to Figure G-6 Jatropha curcas, areas suitable for cultivation

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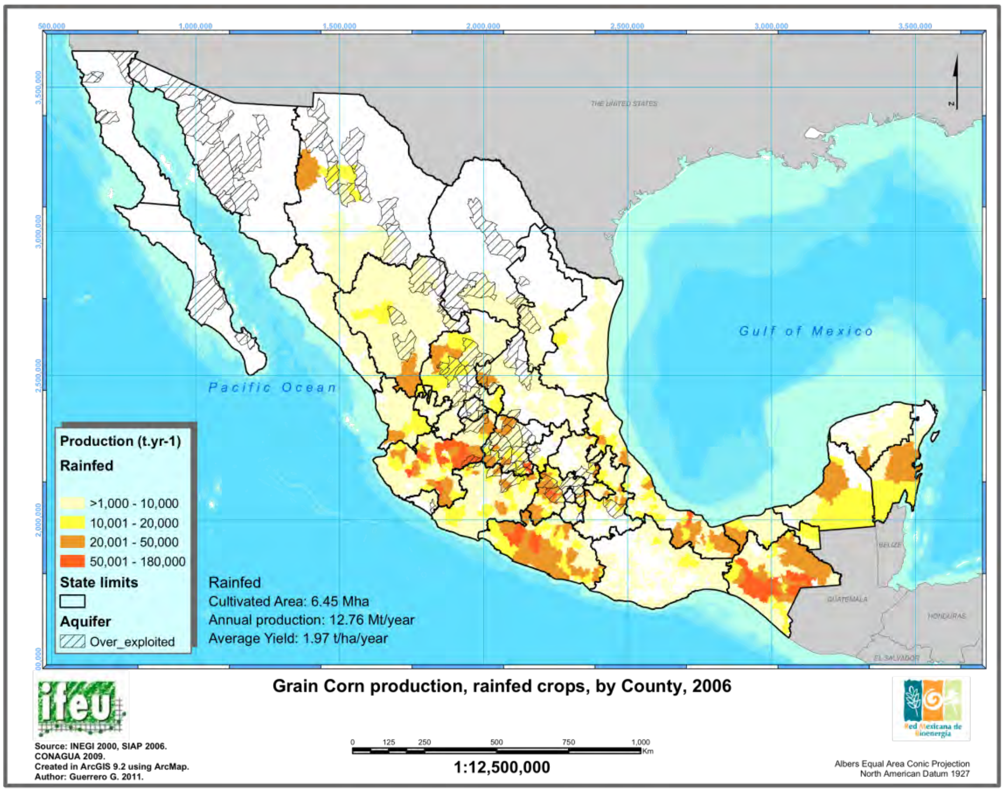


Figure G-2 Maize, rainfed, current areas of cultivation.

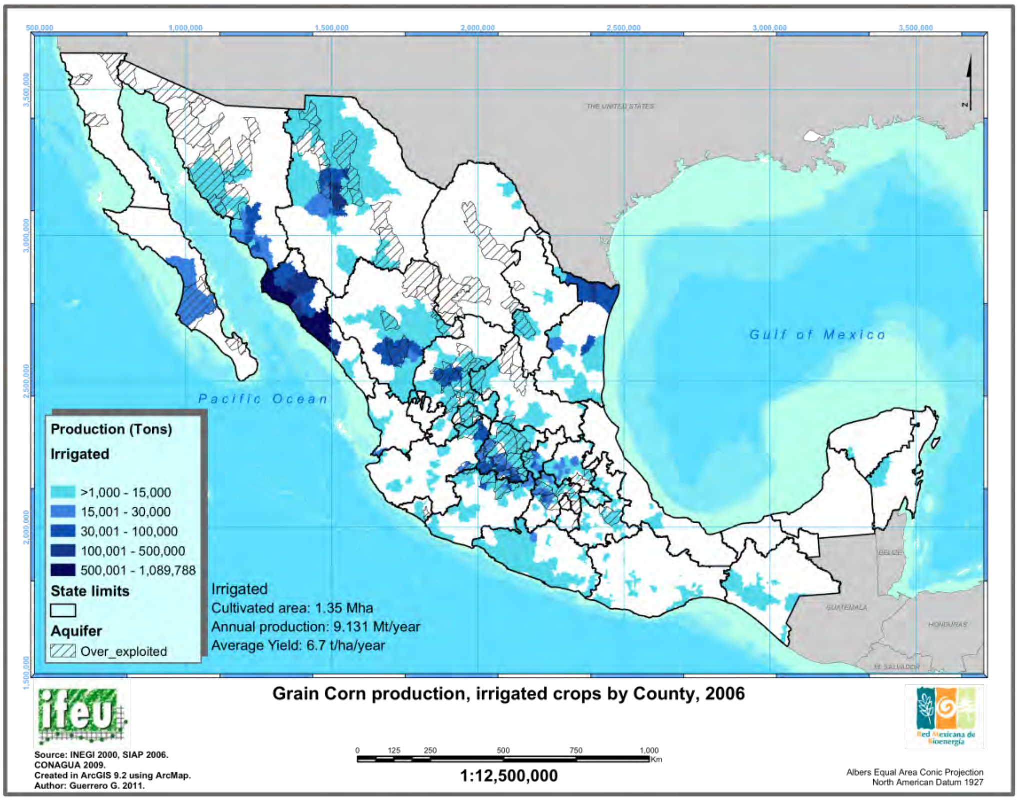


Figure G-3 Maize, irrigated, current areas of cultivation

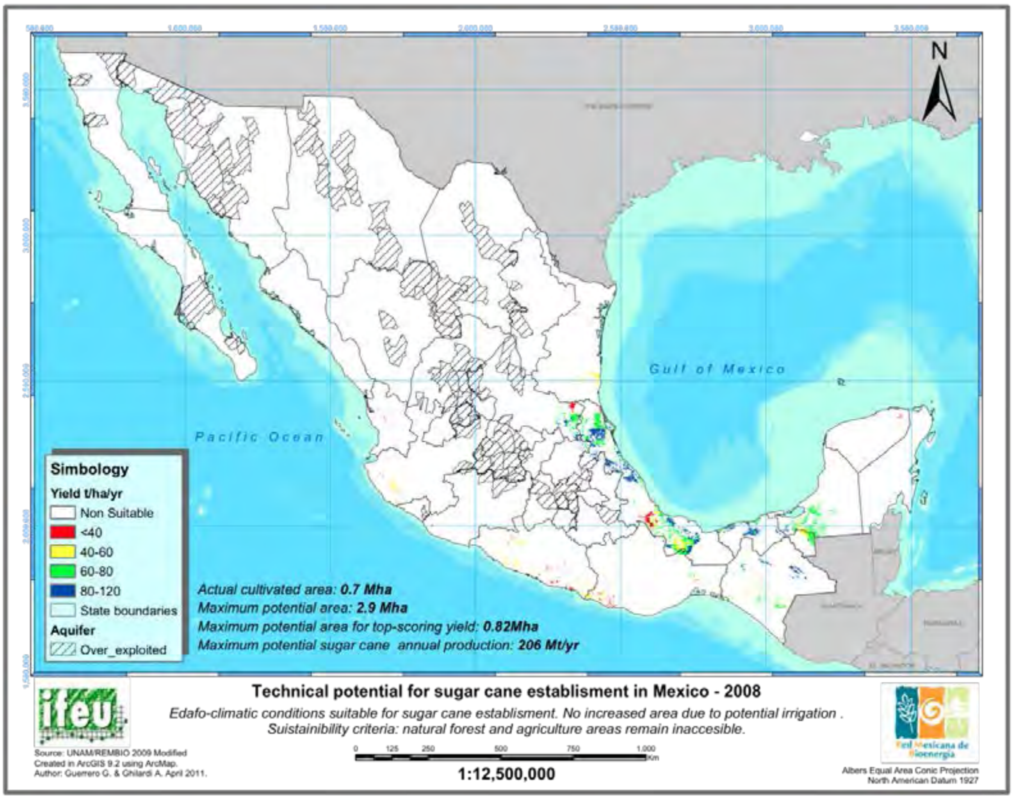


Figure G-4 Sugar cane, areas suitable for cultivation

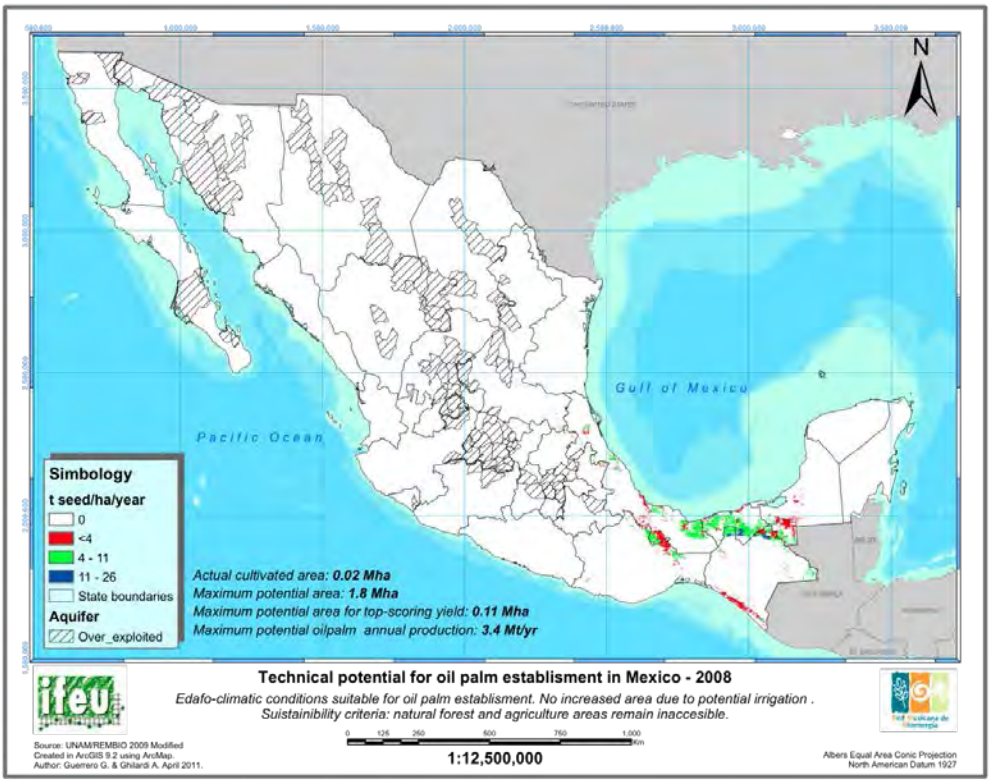


Figure G-5 Oil Palm, areas suitable for cultivation

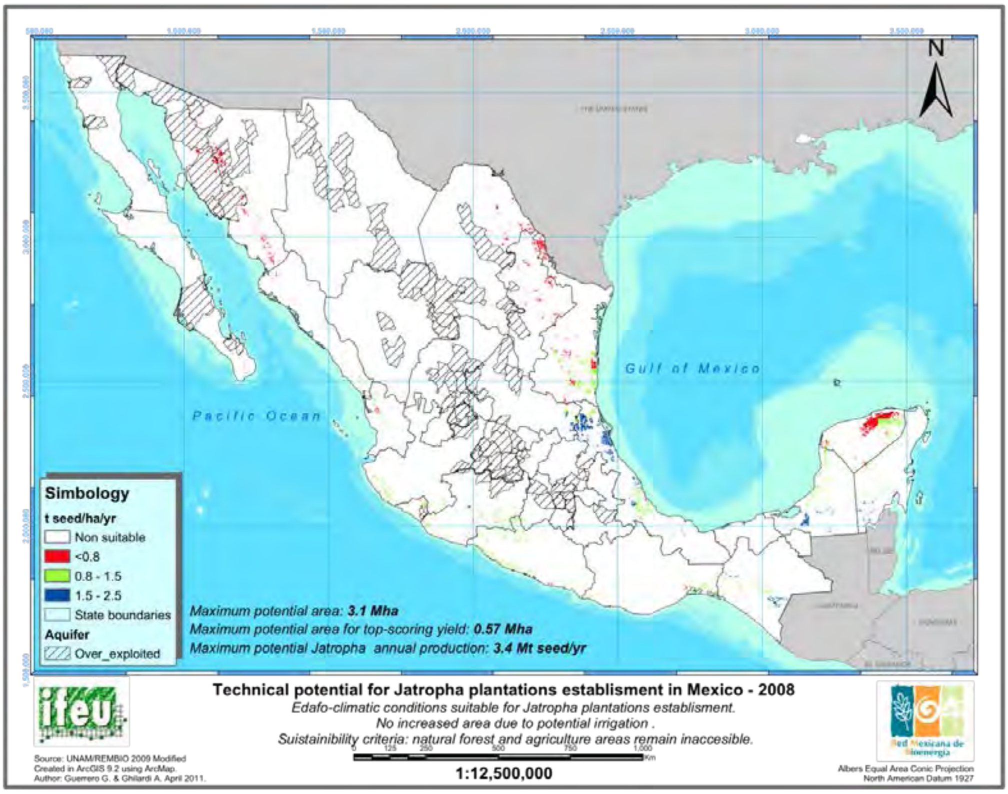


Figure G-6 Jatropha curcas, areas suitable for cultivation

In the first phase of the study we collected complete information from nine points; seven correspond to maize and two to sugarcane, as detailed in Table F-2 and Figure G-7**Fehler! Verweisquelle konnte nicht gefunden werden.**. The questionnaire with details on the data gathered is shown in chapter G-7.

Table F-2 Characterization of cropping systems

ID No.	Crop	Technification Level	Terrain	Mixed cropping/Crop rotation	Erosion control / soil protection	Irrigation	State
1	MAIZE	High	flat	no	no	YES furrow, dam	Guanajuato
2	MAIZE	High	flat	no	no	YES furrow, well	Guanajuato
6	MAIZE	Low	flat	YES maize-lentil/pumpkin	no	no	Michoacán
7	MAIZE	Low	flat	YES maize-“canamargo”	no	no	Michoacán
8	MAIZE	Low	3% slope	YES maize/bean	no	no	Michoacán
11	MAIZE	High	6-7%	YES maize-broccoli	YES contour farming	YES furrow,well	Guanajuato
12	MAIZE	High	flat	no	no	YES furrow, well	Guanajuato
13	SUGARCANE	Medium	undulating	no	no	YES furrow, well	Jalisco
14	SUGARCANE	Medium	undulating	no	no	YES aspersion, well	Jalisco

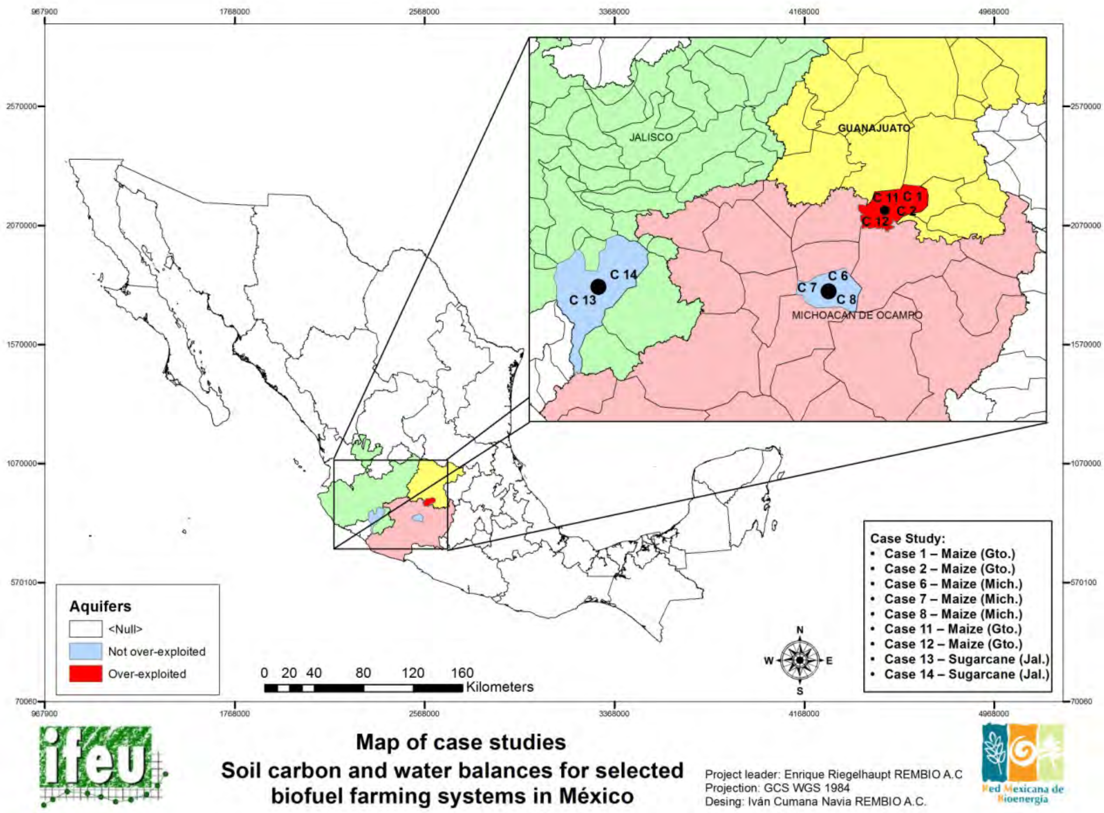


Figure G-7 Sample points for maize and sugar cane

F-4 Water used for the production of biofuels feedstock

A hydric balance was calculated for each one of the cases, using local data for crop, soil type and climatic conditions. The CROPWAT software (FAO) was used for estimation of real evapotranspiration of the crop and irrigation requirement. Effectively applied irrigation volume was obtained from field data (either directly by water source measurements or estimated by applying an efficiency irrigation factor).

The results are presented in two functional units, the first one is water use per hectare, appropriated to assess local water impacts (Figure G-8). The second is water use for GJ of ethanol produced, useful to compare total water use efficiency in biofuels production (Figure G-9).

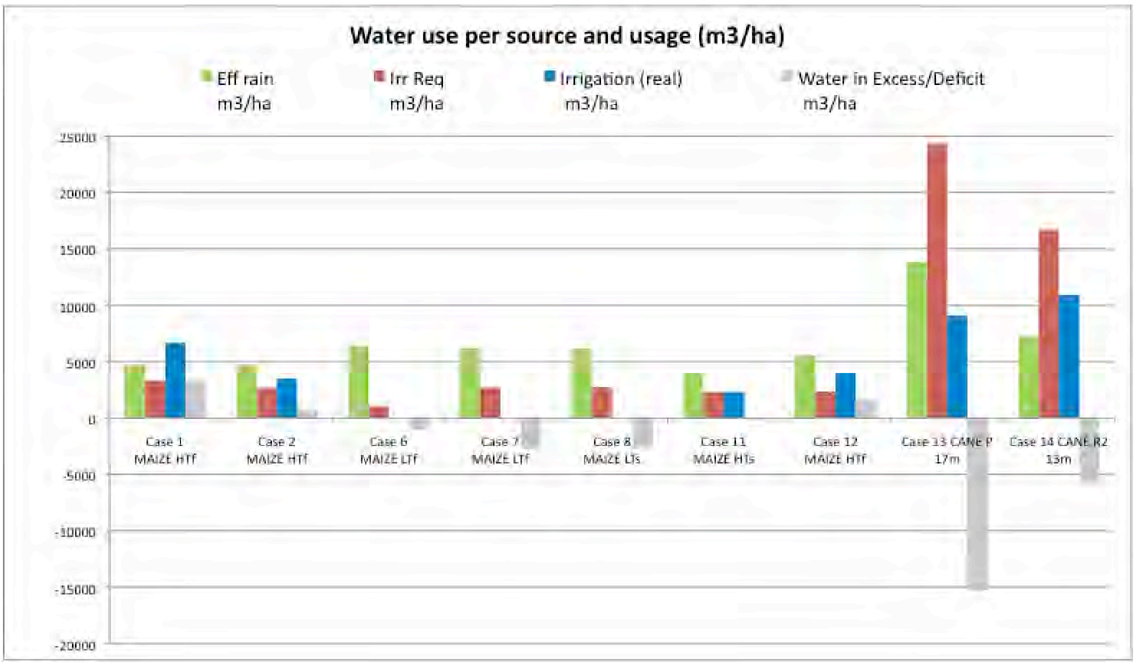


Figure G-8 Water footprint of two biofuel crops in Mexico

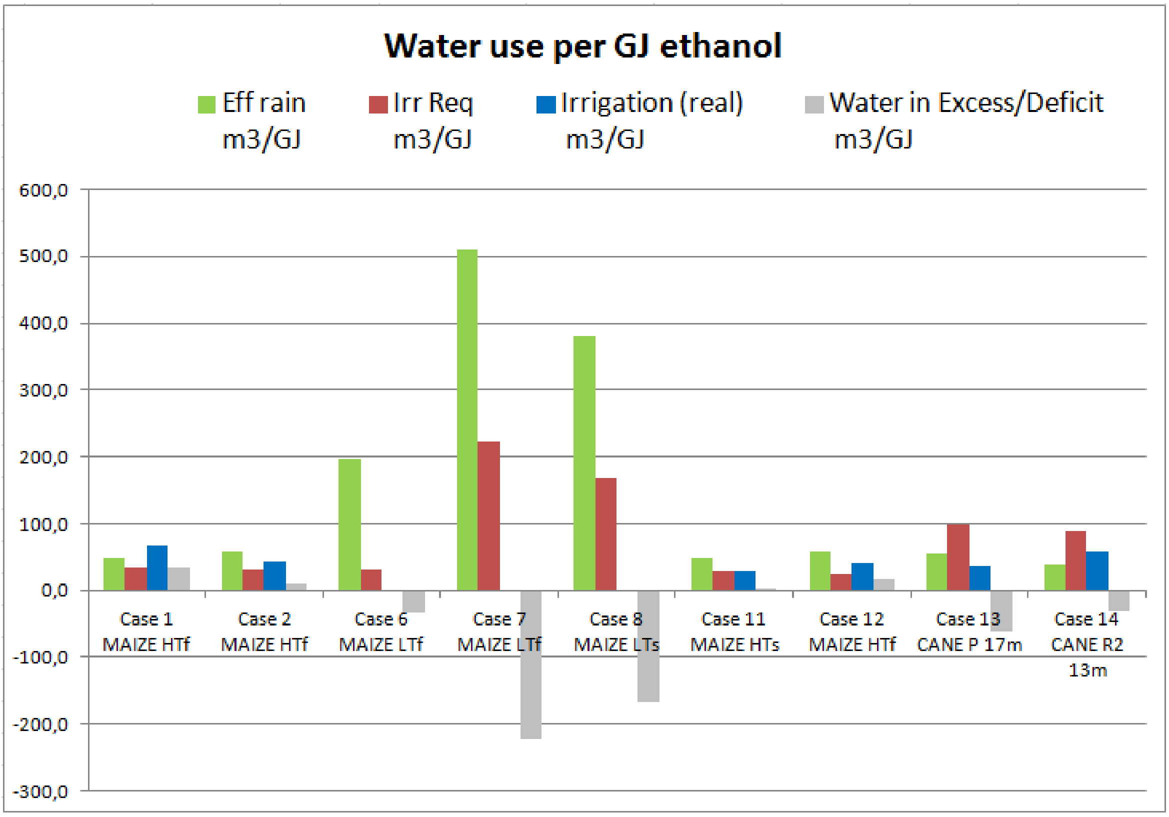


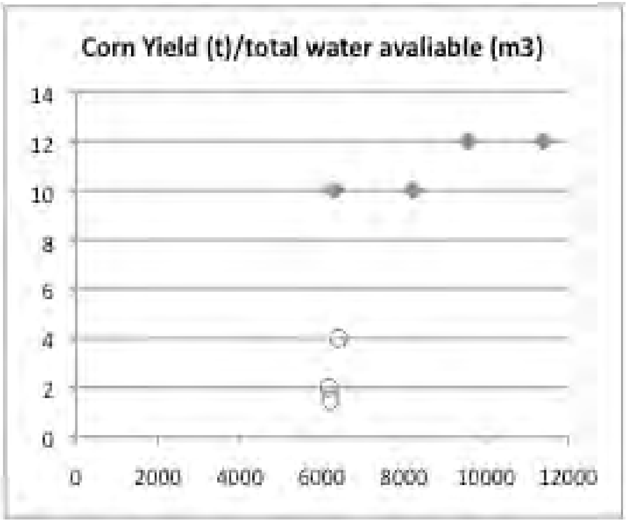
Figure G-9 Intensity of water use of two biofuel crops of Mexico

F-4.1 Water use in maize cropping systems

In the three cases of maize with low technology, not irrigated (6; 7; 8) the crop water demand was not equaled by precipitation; thus water deficits were calculated by CROPWAT. These cases show low grain productivity, because of water stress, and have the higher water specific consumption (between 200 and 510 m3/GJ). In these cases no groundwater is used and environmental impacts are minimal; however the efficiency of green water use is low. Four cases of maize, high technology, with irrigation were also analyzed.

Case 11 stands out: very well timed and proportioned irrigation was made in this plot, with practically neither excess nor deficit. The sum of green and blue water in this case is 6170 m3/ha, very similar to the green water available for the non-irrigated, low technology cases (6398; 6207; 6298 m3/ha), but the yield is 10 t/ha instead of 4; 1.5; 2 t/ha for the low technology plots. This case demonstrates that proper irrigation can optimize the overall efficiency of water use by the crop and achieve high yields.

Cases 1; 2; and 12 also use irrigation, but in excess: the sum of green and blue water add up to 11402; 8221; and 9561 m3/ha, and yields are slightly higher than in the previous case: 12; 10; 11 t/ha. These cases suggest that over-irrigation only allows for moderate yield increase.



Empty circles are non-irrigated cases, losanges are irrigated cases.

Figure G-10 Maize yield vs. total water available

F-4.2 Water usage in sugar cane crop

Figure G-11 shows the relation of sugar cane yield to total water available. The high point corresponds to “plantilla”, i.e. sugar cane harvested after 18 months of growth in a newly planted field. “Resoca 2” is a case of fourth harvest after plantation.[2]

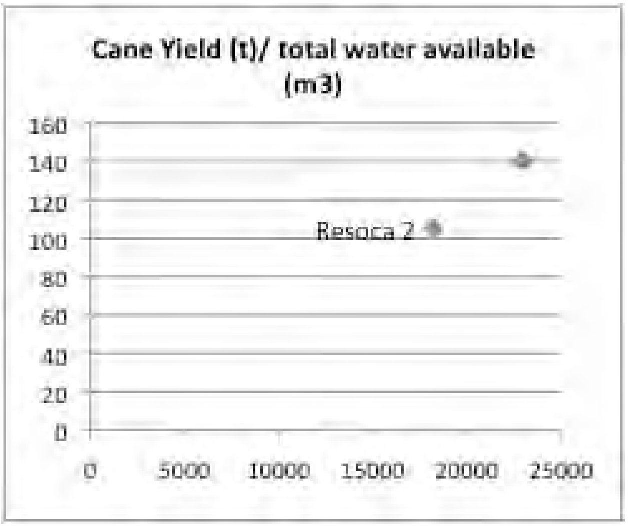


Figure G-11 Relation yield vs. total water available in sugar cane

[2] The cane plantation cycle usually comprises 5 stages: “plantilla” (months 1 to 18); “soca” (months 19 to 31); “Resoca 1” (months 32 to 44); “Resoca 2” (months 45 to 57) “Resoca 3” (months 58 to 70); and “Resoca 4” (months 71 to 83). Thus, there are six harvests over 7 years.

Table F-3 summarizes the results for sugar cane. The water use efficiency decreases slightly along the sugar cane cycle, because yields tend to decrease over time while total water available is more or less constant.

Table F-3 Water available for sugar cane crop

Total water (m3/ha)	Yield (t/ha)	Ratio (m3/t)	Harvest
22922	140	164:1	First
18189	105	173:1	Fourth

F-5 Impact of crops on local water resources

According to CONAGUA (2010), there are 653 main aquifers in México, of which 101 (15.5%) are presently overexploited. CONAGUA defines overexploitation as the condition in which the extraction of water exceeds the natural recharge rate of an aquifer.

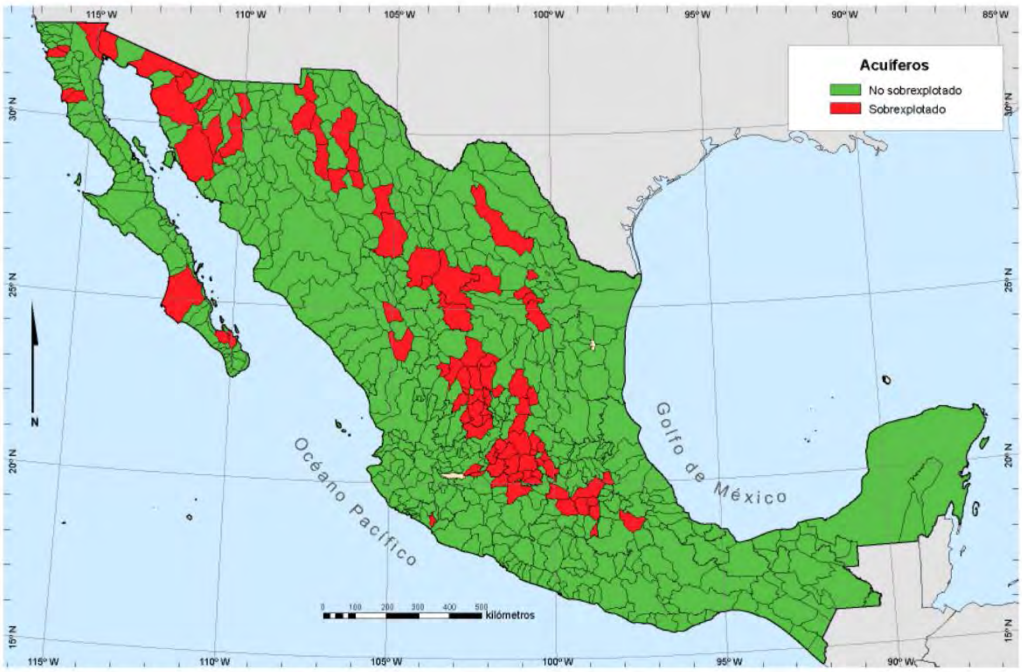


Figure G-12 Aquifers in Mexico. CONAGUA (2011)

In Figure G-2 to Figure G-6 Jatropha curcas, areas suitable for cultivation

The distribution of overexploited aquifers and the areas of potential expansion of four fuel crops is shown. It is clear that most of the potential expansion would occur over aquifers that are not presently overexploited. However, the rate of water extraction needed to irrigate each crop and the areas to be cultivated are not yet well defined. Thus, it is not possible to make any statement on the impacts of this potential expansion before a case-by-case assessment is made.

F-6 Field verification of applicability of sustainability criteria and indicators

GBEP (2011) has proposed two indicators to assess water use sustainability (with no quantitative thresholds):

- Water withdrawn from nationally-determined watershed(s) for the production and processing of bioenergy feedstocks, expressed as the percentage of total actual renewable water resources (TARWR) and as the percentage of total annual water withdrawals (TAWW), disaggregated into renewable and non-renewable water sources.
- Volume of water withdrawn from nationally-determined watershed(s) used for the production and processing of bioenergy feedstocks per unit.

In any case, the verification of these indicators will depend on the availability of trustable field data at cultivation plot and factory levels. In this study, several constraints were identified in this regard, as summarized in Table G-F-4.

Table G-F-4 Constraints in the data for correct verification of indicators regarding water use

Needed data	Constraints	Uncertainty	Probable e rror of estimation
Water pumped from aquifers	Many wells do not have meters Meters out of order Meters not regularly calibrated	HIGH HIGH LOW	+/- 30% +/- 30% +/- 10 %
Water taken from channels	Water allowances based on time Water supply is not regular	MEDIUM HIGH	+/- 20% +/- 30%
Irrigation efficiency	Only rough estimates available	MEDIUM	+/- 20%
Crop yield	Data not accurate (excepted sugarcane)	MEDIUM	+/- 20%

F-7 Questionaire

Form field nr.		CROP	SYSTEM	CODE

date		Owner			
hour		Interviewer			
Geographical coordinates		latitude		longitude	
Heigth					

Parcel	lenght		width	
	slope A		%	
	slope B		%	
	slope C		%	

Description of the system, owner's opinion. *How dou you define his sytem?*

***How many farmers use this system?* (%)**

History of the use of the parcel (What was cropped there? How many years?):

Practice Crop:

Crops

Monoculture	Usual crop rotation	Mixed culture	Others

planting and harvest

Crops	Breed	Plating date	Harvest date	seed kg/ha plants/ha	Yield kg/ha

Handling

	Labor	When? Date (day, month)	How? Manual/ tractor/other	Implement	Depth?
Land preparation					
Planting					

Harvest				

Fertilization

Type					
quantity kg/ha					
How is it applied					

What do you do with stubble?

burning		If burnt, percentage?			
packing		(kg/ha); (packages/ha)			
Grazing		heads/ha		Date start/end	

Plants/ha

Distance between furrows		cm
Number of plants		plants/m

Pesticide/herbicide

Type					
quantity kg/ha					
how?					
when?					

erosion control measures

tillage	cover crop	contour cultivation	terraces	hedgerows	dead barriers

farmer's comments (why and how? Or not?)

Interviewer comments

Contouring data

furrow lenght	distance between furrows	Ridge height	slope%

Type of irrigation

	Flooding	Furrow	sprinklers	gun	pivot

Water source

Well	Dam

Irrigation	**Quantity? (mm)**

Date, first irrigation			
Date, second irrigation			
Date, third irrigation			

drainage? [ ] YES/NO

Well

water flow		l/sec

Soil texture (USDA Classification) as reference

Soil observation / details

is there an impermeable layer in the field?		YES/NO
How deep?		cm

Field capacity, the sample was taken?

	YES/NO		Volume can	cm3
wet weight		g		
dry weight		g		

Stages of crop

Duration from sowing to harvest (Maize) [ ] Months

	Stage 1	Stage 2	Stage 3	Stage 4	Total (months)
Description/ Definition stage	sowing to little plant (10-15 cm)	when is the spike?	when is the cob?	When is "mazorca"? When is the harvest?	
Date					
Root depth (cm)					
With how much dry soil (cm) the crop suffers?					
Severity of water shortages. Scale 0-4					
Scale: 0 (nothing), 1 (unimportant), 2 (something), 3 (much), 4 (very serious), (do not know)					

Soil Sample

Code [ ]

Sample grid

Erosion in parcel	
accumulations	
microfurrows	
little furrows	
furrows	
gullys	
pedestals	

Erosion out of parcel	
accumulations	
microfurrows	
little furrows	
furrows	
gullys	
pedestals	

others			others	

Rock %

Hole 40 cm

Does the texture change? YES/NO

Does the carbon content change? (Color)? YES/NO?

If so, at what depth?

What is the texture of layer 1?

What is the texture of layer 2?

Field Length (m)

Field width (m)

Type of scope (concave, convex, s-shape, uniform)

Scope (%) beginning to end of field. If not regular, take intermediate points in the field.

are there terraces? YES/NO

Distance between terraces

Are there strip cropping? YES/NO

Percentage?

F-8 References

CONAGUA (Comisión Nacional del Agua). 2010. http://www.conagua.gob.mx/atlas/

GBEP (Global Bioenergy Partnership). 2011. http://www.globalbioenergy.org/programmeofwork/sustainability/gbep-24-sustainability-indicators/en/

Appendix G: Background data for local non-GHG environmental impacts of biofuels

Rocio Herrera, Klaus Hennenberg, Öko-Institut Darmstadt

Databases and products for environmental screening

The following collection of databases and products related to the biodiversity (Section 2), soil (Section 3) and water (Section 4) comprises the topics listed below. The focus is set on data that are globally available. In some cases, also regional data sources are given.

1. Protected Areas, areas of high biodiversity and areas of undisturbed wildlife
2. Land Classification Systems and Land-Cover Mapping
3. Forests
4. Wetlands
5. Degraded Land
6. Agricultural Production and Land Use
7. Soil, Slope and Elevation
8. Water, Hydrology and Climate
9. Social and Economic Aspects

The overall structure of the database and product tables is as follows:

Database / Product	**Scope / Content**	**Reference / Availability / Quality**
Name or Acronym	What is the aim, who is the user? What is the content? **→Guidance on using the source**	web link to data or literature Information on spatial cover (global, regional, national), GIS data (in brackets if yes) resolution (site-specific or not, or resolution), link to or inclusion of other products?, data quality (data base, year of acquisition and update)

G-1 Protected Areas, areas of high biodiversity and areas of undisturbed wildlife

Database / Product	**Scope / Content**	**Reference / Availability / Quality**
A to Z Areas of biodiversity importance	Use the A to Z to find out about different areas of biodiversity importance. The A to Z is designed to provide clear, concise and relevant information about each type of area, which can be used by all sectors including business, government and environmental agencies. This web site is developed by UNEP-WCMC in partnership with other institutions. Internationally recognized protected areas such as World Heritage Sites and Ramsar Sites or the many approaches used to prioritize areas for conservation effort and protection including Biodiversity hotspots and Key Biodiversity Areas are listed. **<u>Evaluation:</u> This website is perfect to find out information and sources about areas of biodiversity importance. It offers the perfect overview of biodiversity related important links and sources.**	http://www.biodiversitya-z.org/ Website offers links for further data and information
Integrated Biodiversity Assessment Tool (IBAT)	IBAT provides information on high-priority areas for conservation, whether formally protected or not. The site-scale information including Key Biodiversity Areas (KBAs), Important Bird Areas (IBAs), and Alliance for Zero Extinction (AZE) sites in at least 173 countries, and data from the World Database on Protected Areas (WDPA). IBAT is a response to the need identified by companies to have available fine-scale biodiversity data to incorporate into decision-making processes and management strategies. This information is directly relevant to a number of other stakeholders as well, for example in the creation of national development and conservation strategies. The IBAT for Business	www.ibatforbusiness.org ; https://www.ibat-alliance.org/ibat-conservation/index.php Globally available (GIS), site-specific information. IBAT is a global meta-database for other datasets; its quality depends on quality of the original data. IBAT was published in October 2008 and is up-dated regularly. Required registration and subscription for accessing and downloading the data. Scale of data application: national, provincial and local.

Database / Product	Scope / Content	Reference / Availability / Quality
	tool is available only by partnership or subscription. The individual datasets that are included in the platform are accessible for not-for-profit purposes through a separate version, known as IBAT for Research and Conservation Planning: https://www.ibat-alliance.org/ibat-conservation/index.php. **<u>Evaluation:</u> IBAT provides information including GIS maps on above mentioned areas and brings together different databases of biodiversity relevant areas, legally protected or not, which need to be considered at the beginning of decision making processes. A map viewer at the web site depicts GIS information at country level according to different categories (definition of conditions and uses). IBAT can be used as a starting point to locate sites that are unsuitable for bioenergy feedstock production and those that may be suitable after further ground truth.**	
World Database on Protected Areas (WDPA)	The WDPA plays a critical role in measuring progress toward global goals and targets for biodiversity protection and will function as a key support mechanism in the assessment and monitoring of protected area status and trends. The WDPA is compiled from multiple sources and is the most comprehensive global dataset on marine and terrestrial protected areas available. The WDPA stores key information about protected areas such as name, designation or convention, total area (including marine area), date of establishment, legal status and IUCN Protected Areas Management Category. It also stores the spatial boundary and/or location (where available) for each protected area in a Geographical Information System (GIS). In the site ProtectedPlanet a good help	Strittholt et al. 2007; www.wdpa.org ; http://www.protectedplanet.net/ Integrated in IBAT. Globally available (GIS), site-specific information. GIS data are not available for all protected areas (publishing restriction). Downloaded as csv, kmz or shapefile. More information about methodology: http://www.wdpa.org/PDF/WDPA%20Data%20Standard.pdf IUCN and UNEP. 2010. The World Database on Protected Areas (WDPA). UNEP-WCMC. Cambridge, UK. www.protectedplanet.net Scale of application: national, provincial and local

Database / Product	Scope / Content	Reference / Availability / Quality
	link is included. A new and interactive tool of WDPA is the possible edition of the protected areas by everyone of the "community" (registration necessary). As complement of this global database the database for Natura 2000 sites in the European Union can be used (http://ec.europa.eu/environment/nature/natura2000/db_gis/index_en.htm). Although WDPA should be show information on Natura 2000 sites, not every site is registered. **Evaluation: WDPA gives site specific information including GIS maps on national (catalogued or not by IUCN categories) and international protected areas (World Heritage Sites, Ramsar Sites, etc). Information on protected area categories (IUCN category/ international agreement definition) allows identifying restrictions and opportunities in decision making processes. National protected areas not catalogued should be reviewed according to the guidelines for applying protected areas management categories (IUCN)**	
Key Biodiversity Areas (KBA)	Key Biodiversity Areas (KBAs) are places of international importance for the conservation of biodiversity through protected areas and other governance mechanisms. They are identified nationally using simple, standard criteria, based on their importance in maintaining populations of species (see criteria in Langhammer et al. 2007). KBA mapping includes areas such as BirdLife International´s Important Bird Areas, PlantLife International´s Important Plat Areas, IUCN´s Important Sites for Freshwater Biodiversity and sites identified by the Alliance for Zero Extinction. As the building blocks for designing the ecosystem approach	Center for Applied Biodiversity Science (CBS), Conservation International (CI); Langhammer et al. 2007 http://data.iucn.org/dbtw-wpd/edocs/PAG-015.pdf ; Integrated in IBAT (www.ibatforbusiness.org; https://www.ibat-alliance.org/ibat-conservation/index.php) or data available on request (www.conservation.org). Mapping was carried out, completely or partially, in 183 countries. Process still on going internationally. In some countries KBA do only refer to IBA or AZE. Globally available (GIS), site-specific information; national availability depends on progress in further mapping.

Database / Product	Scope / Content	Reference / Availability / Quality
	and maintaining effective ecological networks, key biodiversity areas are the starting point for landscape-level conservation planning. Governments, intergovernmental organizations, NGOs, the private sector, and other stakeholders can use key biodiversity areas as a tool to identify national networks of internationally important sites for conservation. The Mapping of High Nature Value Farmland (EEA 2004; http://reports.eea.europa.eu/report_2004_1/en) is of relevance for the detection of KBA in the cultural landscape of Europe. **Evaluation: KBA give site-specific information including GIS maps on areas covering high biodiversity values. KBA need t be considered in decision making processes. Where KBA assessment is not yet completed, decision makers should make use of the KBA-tool to identify further biodiversity relevant areas**	Scale of data application: national and provincial.
Alliance for Zero Extinction (AZE)	Prevent extinctions of species by identifying and safeguarding key sites, each one of which is the last remaining refuge of one or more Endangered or Critically Endangered species. Location of 595 areas that worldwide harbour remaining populations of nearly 800 highly endangered species. See detailed mapping criteria under http://www.zeroextinction.org/overview.htm **Evaluation: AZE sites are included in the KBA database. Decision makers should use the AZE approach to identify local and provincial threatened species, and therefore key sites for them (example: Red Natura 2000).**	Alliance for Zero Extinction (2010). *2010 AZE Update.* www.zeroextinction.org . List of sites and species and also a map as pdf. can be download Integrated in IBAT (data available on request, but with strong restrictions) Globally available (GIS), site-specific information. Scale of data application: national, provincial and local
Important Bird Areas (IBAs)	The IBA Program seeks to identify, document, and promote the conservation and sustainable management of a network of sites that are important for the long-term viability of natural-	Stattersfield et al. 1998; Fishpool 2004; http://www.birdlife.org/datazone/sitel; Integrated in IBAT (data available on request)

Database / Product	Scope / Content	Reference / Availability / Quality
	ly occurring bird populations across the geographic range of bird species for which a site-based approach is appropriate (see details on criteria for IBA in Fishpool 2004). The basis for this work is the World Bird Database (WBDB) containing 250,000 records. Endemic Bird Areas (EBA, http://www.birdlife.org/datazone/eba) are the basis for the identification of IBA, but EBA are less site-specific. **<u>Evaluation:</u> IBA are included in the KBA database. They significantly contribute to identifying priority areas for global biodiversity conservation using birds as indicators, and their protection should be incorporated in decision-making processes. Additional local and regional identification of relevant areas for bird protection should be also taken into account by decision makers.**	Globally available (GIS), site-specific information. Data are already available for 176 countries on: http://www.birdlife.org/datazone/geomap.php?r=i&bbox=-150%20-50%20150%2080 A data assessment is still ongoing. Scale of data application: national, provincial and local
Important Plant Areas (IPAs)	Knowledge on the location of IPAs shall contribute to "The Global Strategy for Plant Conservation" sets the overall target of protecting 50% of the world's most important areas for plant diversity by 2010, and should be used during decision making. Mapping of IPAs that are natural or seminatural sites exhibiting exceptional botanical richness and/or supporting an outstanding assemblage of rare, threatened and/or endemic plant species and/or vegetation of high botanic value. Additional information is provided by the Centres of Plant Diversity (North, Middle and South America, see http://botany.si.edu/projects/cpd/table_of_contents.htm) **<u>Evaluation:</u> IPA should be used during decision making processes to identify important areas of plan diversity. Where IPA assessment is not yet completed, decision**	http://www.plantlife.org.uk/international/wild_plants/IPA/ ; http://www.plantlife-ipa.org/reports.asp Globally available, site-specific information (google maps). Data collection had a strong focus on Europe, but is now expanded world wide. GIS information is not available. Scale of data application: national, provincial and local

Database / Product	**Scope / Content**	**Reference / Availability / Quality**
	makers should make use of the IPA-tool to identify further high botanic value areas	
Biodiversity Hotspots	Mapping of Biodiversity Hotspots that contain at least 1,500 species of vascular plants (> 0.5 percent of the world's total) as endemics, and the area has to have lost at least 70 percent of its original habitat. Available are the location of Biodiversity Hotspots (maps and GIS-data) and a species database (http://www.biodiversityhotspots.org/xp/Hotspots/search/Pages/search.aspx). In some region, Biodiversity Hotspots are site specific; in other regions they cover rather large areas with fuzzy boundaries. As a global prioritization system, hotspots are extremely important in informing the flow of conservation resources, and also as an informative basis for public and private decision makers. Related to the Biodiversity Hotspots is the concept of High-Biodiversity Wilderness Areas (Mittermeier et al. 2003, http://www.pnas.org/content/100/18/10309.full.pdf+html), that represent areas of low human impact harbour a high amount of biodiversity. These sites, however, are characterized by a large-area extension. **Evaluation:** **Biodiversity Hotspots provide basic information for decision makers on global pattern of biodiversity. A provincial or local selection of suitable areas is not possible on basis of these data, but information can be used to select priority areas when starting more detailed biodiversity assessments.**	Mittermeier et al. 2005; http://www.biodiversityhotspots.org/xp/Hotspots/resources/pages/maps.aspx Globally available data (GIS), in some cases site specific, in most cases not, depends on country/ region Scale of data application: national.
BioFresh: Biodiver-	**BioFresh** is an EU-funded international project that aims to build a global information platform for scientists and ecosys-	http://www.freshwaterbiodiversity.eu/index.php/index.html Database (GIS) still metadatabase. On going:

Database / Product	Scope / Content	Reference / Availability / Quality
sity of Freshwater Ecosystems	tem managers with access to all available databases describing the distribution, status and trends of global freshwater biodiversity. **BioFresh** integrates the freshwater biodiversity competencies and expertise of 19 research institutions. **Evaluation: As database for the collection of important freshwater ecosystem should be considered by stakeholders. Principally if their activity is being carried out in freshwater areas or close to them. A better use of this database will be possible once the database is completed.**	http://data.freshwaterbiodiversity.eu/ Scale of data application: (still) international
Global 200 – priority ecoregions for global conservation	Global 200 is an attempt to identify a set of ecoregions (Olson et al. 2001; http://www.worldwildlife.org/science/ecoregions/biomes.cfm) whose conservation would achieve the goal of saving a broad diversity of the Earth's ecosystems. These ecoregions include those with exceptional levels of biodiversity, such as high species richness or endemism, or those with unusual ecological or evolutionary phenomena. Data resolution of Global 200 has a global character and is not site-specific. Associated are detailed descriptions of ecoregions including biodiversity features and threads of species (see also WWF Wildfinder http://www.wwfus.org/wildfinder/searchByPlace.cfm#). The data set forms a fundamental background for decision making. **Evaluation: Global 200 ecoregions provide basis information for decision makers about exceptional global biodiversity regions. A provincial or local selection of suitable areas is not possible on basis of these data, but information can be used to select priority areas when start-**	Olson & Dinerstein 2002; http://www.worldwildlife.org/science/ecoregions/global200.html Globally available data (GIS), not site-specific. Scale of data application: national

Database / Product	Scope / Content	Reference / Availability / Quality
	ing more detailed biodiversity assessments.	
Invasives and Threat-ened Species Data-bases	The 2010 IUCN Red List of Threatened Species contains assessments for almost 56,000 species, of which about 28,000 have spatial data. This spatial data collection provided is for most of the comprehensively assessed taxonomic groups such as amphibians, mammals, threatened birds, reef-building corals, groupers, wrasses, angelfish, butterfly-fish, seasnakes, seagrasses and mangroves. Invasives species are registered in the Global Invasive Species Database (GISD). The Global Invasive Species Data-base focuses on invasive alien species that threaten native biodiversity and covers all taxonomic groups from micro-organisms to animals and plants in all ecosystems. Species information is either supplied or reviewed by expert contribu-tors from around the world. As platform for sharing invasive species information at a global level GISD was formed the Global Invasive Species Information Network (GISIN) There are also regional databases: the Inter American Biodi-versity Information Network (http://i3n.iabin.net/index.html), the Delivering Alien Invasive Species Inventories for Europe (http://www.europe-aliens.org/) and the European Network on Invasive Alien Species (http://www.nobanis.org/default.asp). **Evaluation: Land based biodiversity data can be completed with information about invasive and threatened species. Stakeholders should decide if specific analyses are necessary for their concrete area. The state of threat-ened and invasive areas offers a vision of the state of conservation / human influence on the area..**	IUCN Red List of Threatened Species – GIS Data: http://www.iucnredlist.org/technical-documents/spatial-data Global Invasive Species Database (GISD): http://www.issg.org/database/welcome/ (no GIS available) Both databases are continuously updated. Global Invasive Species Information Network (GISIN): http://www.gisinetwork.org/index.html
Ecological Gap	A gap analysis is an assessment of the extent to which a pro-tected area system meets protection goals set by a nation or	http://www.protectedareas.info/ No GIS available. Muster cases available.

Database / Product	Scope / Content	Reference / Availability / Quality
Analysis – Conven-tion on Biological Diversity	region to represent its biological diversity. Gap analyses can vary from simple exercises based on a spatial comparison of biodiversity with existing protected areas to complex studies that need detailed data gathering and analysis, mapping and use of software decision packages. The guide has been produced to help governments and others to implement a gap analysis for a nation's system of protected areas, within the framework of the Programme of Work on Protected Areas agreed by the Convention of Biological Diversity (CBD). The CBD is suggesting that signatory states carry out a gap analysis to identify needs for additional protected areas, to complete ecologically-representative networks of protected area systems. Information about other national and sub-global ecosystem assessment processes can be found under http://eureca.ew.eea.europa.eu Evaluation: This guide provide document and background information to carry out a gap analysis. There are not specific data available, only examples and methodology for those stakeholders which decide to apply this approach.	Scale of data application: international and national
Millenni-um Eco-system Assess-ment (MA); World Data Cen-ter for	The objective of the MA – called for by the United Nations Secretary-General Kofi Annan in 2000 – was to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the con-servation and sustainable use of those systems and their contribution to human well-being. The MA has involved the work of more than 1,360 experts worldwide. Their findings provide a state-of-the-art scientific appraisal of the condition and trends in the world's ecosystems and the services they	MA reports: http://www.maweb.org WDCBE: http://wdc.nbii.gov/ma/ (meta-database) Globally available data (GIS only partially). Different dates of publication and resolution, depends on data and provider. Scale of data application: national, provincial and local

Database / Product	**Scope / Content**	**Reference / Availability / Quality**
Biodiver-sity and Ecology (WDCBE)	provide (such as clean water, food, forest products, flood con-trol, and natural resources) and the options to restore, con-serve or enhance the sustainable use of ecosystems. The WDCBE is the collabourative web site project with the MA. WVCBE is developed as an interactive system that will allow easy access to reports, maps and the data collected during the MA global evaluation of ecosystems. Ultimately, the MA information stored in WDCBE will form the baseline for future assessments of the earth's ecosystems by scien-tists, managers, policy-makers, educators, and the public. **Evaluation: MA publications and data provide ground information for decision makers to guide and guaranty a multivariable ecological approach in the decision making processes. The WDCBE constitutes a tool for this pur-pose. Specific local questions such as selection or as-sessment of areas on basis of given biological or social data should be assisted by site specific data.**	

G-2 Land Cover Classification Systems and Land-Cover Mapping

Database / Product	**Scope / Content**	**Reference / Availability / Quality**
Land Cov-er Classifi-cation Sys-	LCCS is a harmonized land cover classification system devel-oped by FAO and UNEP. LCCS enables comparison of land cover classes regardless of mapping scale, land cover type,	FAO (2005) Version 2.0 (published in 2005) http://www.fao.org/docrep/008/y7220e/y7220e05.htm#Top

Database / Product	Scope / Content	Reference / Availability / Quality
tem (LCCS) – Global Land Cover Network	data collection method or geographic location. It is applicable in all climatic zones and under different environmental conditions. LCCS enables an assessment of land cover and the ability a monitoring of changes. Software has been developed to guide the user to select the appropriate class facilitating the complex classification process and ensure standardization. GLC2000 project and the recently published GlobCover are examples of LCCS application. **<u>Evaluation:</u> LCCS represents a standard legend and guide of classification without geographical limitations, which allows comparing different land cover classification data outputs and methods. This land cover classification system should be considered in the decision making processes to guaranty consistent within and comparability among assessments.**	OfPage Software version 2.0 can be ordered The 3rd version of LCCS is currently in development. Introduction: http://www.gofc-gold.uni-jena.de/documents/jena08/1710_LCCS/Gregorio_LCCS4.pdf Globally applicable classification system. Scale of data application: national, provincial and local
Glob Cover Land Cover Map (GlobCover)	The GlobCover project has developed a service capable of delivering global composite and land cover maps. With a resolution of 300 m, GlobCover represent the newest globally available dataset on land cover with highest resolution. The Global Land Cover Map is compatible with the UN Land Cover Classification System (LCCS) and its land cover categories were in accordance established. The Global Land Cover Map together with a set of MERIS Full Resolution composites provides the results of GlobCover project, an ESA initiative in partnership with JRC, EEA, FAO, UNEP, GOFC-GOLD and IGBP. As input were used observations from the 300m MERIS sensor on board the ENVISAT satellite mission over a period some months (December 2004 – June 2006 and January – December 2009).	Data download: http://ionia1.esrin.esa.int/index.asp Globally available (GIS), site specific (300 m) GlobCover LC version 3 was published in December 2010. Scale of data application: national, provincial and local

Database / Product	Scope / Content	Reference / Availability / Quality
	<u>Evaluation:</u> Land Cover Map GlobCover based on the UN Land Cover Classification System is an essential tool in decision making processes. GlobCover provides high resolution information to identify land cover patterns, which will help private and public decision makers to minimize subsequent disputes between land-use planning and existing uses. Further more, a broad vision of current human activities and therefore possible located ecological pressures can be detected.	
The Global Land Cover 2000 (GLC2000)	GLC2000 presents a consistent picture of the land-cover situation in 2000. Similar to GlobCover, GLC2000 was produced in compliance with the UN Land Cover Classification System (LCCS). The main data set used for this project was the "VEGA 2000" data set, composed of 14 months of daily 1-km resolution satellite data acquired over the whole globe by the VEGETATION instrument on-board the SPOT 4 satellite for the period Nov. 1999 – Dec. 2000. The project was coordinated by the Joint Research Centre (JRC), Institute for Environment and Sustainability. GLC2000 predicts cropland much better than MODIS land cover product, but the reverse is true for pastures (Ramankutty 2008). Ramankutty merges the two satellite-derived land cover classification data sets to present a 5 arc minute dataset (http://www.geog.mcgill.ca/~nramankutty/Datasets/Datasets.html). **<u>Evaluation:</u> GLC2000 allows private and public decision makers to recognize land cover patterns in 1999/2000. Tough GlobCover resolution is more suitable on a local scale; data from GLC2000 are still useful for e.g. trend**	http://bioval.jrc.ec.europa.eu/products/glc2000/glc2000.php Bartholomé / Belward 2005. Reports under http://bioval.jrc.ec.europa.eu/products/glc2000/publications.php Globally available (GIS), site specific (1km). Published in November 2002. Scale of data application: national, provincial and local

Database / Product	**Scope / Content**	**Reference / Availability / Quality**
	analysis.	
MODIS/Terra Land Cover Type Yearly	Also Terra Land Cover Maps comprises layers on different land-cover categories. The data are obtained yearly from MODIS with a resolution of 1 km. Instead of LCCS as classification system (GLC2000, GlobCover), the land classification system of this mapping approach follows the global vegetation classification scheme of the University of Maryland and the International Geosphere-Biosphere Programme (IGBP). There is free direct on-line access to most of the data, and it will be complete in the near future. A new combined Land Cover product has been produced at higher spatial resolution (500m), using Aqua and Terra inputs, that is still under evaluation. **<u>Evaluation:</u> The MODIS/Terra land cover products provide the same as GlobCover and GLC2000 land cover patterns information. Results comparison is limited because of use of different classification systems, in this case IGBP. Failing previous local field checking, source and type of collected data should be considered by decision makers to select land cover data.**	Land Cover Yearly L3 Global 1km https://lpdaac.usgs.gov/lpdaac/products/modis_products_table/land_cover/yearly_l3_global_1km2/mod12q1 Land Cover Yearly L3 Global 500m https://lpdaac.usgs.gov/lpdaac/products/modis_products_table/land_cover/dynamics_yearly_l3_global_500m/mcd12q2 Data Download https://lpdaac.usgs.gov/lpdaac/get_data/data_pool Globally available (GIS), site specific (1 km and 500 m) Data are available since 2001 to present. Scale of data application: national, provincial and local
Global Land Cover Characteristics (GLCC)	The land-cover data set is derived form 1 km Advanced Very High Resolution Radiometer (AVHRR) data spanning a 12 month period (April 1992 – March 1993) and is based on a flexible data base structure and seasonal land cover regions concepts. It was developed on a continent-by-continent basis with the same map projection (Interrupted Goode Homolosine). As classification scheme the International Geosphere-Biosphere Programme (IGBP) land cover legend was used. Funding for the project was provided by the USGS, NASA, U.S. Environmental Protection Agency, National Oceanic and	Olson (1994a, 1994b, cited in Kniivila 2004); http://edc2.usgs.gov/glcc/ Globally available (GIS), site specific (1km) Version 1.2 was published in 1997, and the revised Version 2.0 in 1999 Scale of data application: national provincial and local

Database / Product	Scope / Content	Reference / Availability / Quality
	Atmospheric Administration, U.S. Forest Service, and the UNEP. Others important initiatives in relation with land cover and land use change and interrelated data are the Land Cover /Land Use Change (LCLUC, http://lcluc.umd.edu/index.php) Program (NASA) and the Global Earth Observation System of Systems (GEOSS, http://www.epa.gov/geoss/). **Evaluation: GLCC is based on IGBP classifications. Comparisons of results and analysis of time series with the MODIS /Terra land cover products are possible on basis of the same land cover classification system. Especially decision makers in areas affected by population and production activities booms should consider these analyses in decision making process.**	
Satellite Imagery	Different satellites have been launched, among others: ASTER, IKONOS, Landsat, MODIS or CBERS. The application potential of a given satellite, respectively a given sensor is established as a function of its spatial resolution, temporal resolution, and spectral and radiometric characteristics. According to project objectives, study area and experiences of users, different images will be used. Regarding land cover, medium resolution imagery such as TM and ETM+ 30 m resolution Landsat imagery or CDD 20 m resolution CBERS imagery are suitable for global analysis. Interesting to be mentioned is the TerraLook project, which provides access to satellite images for users that lack prior experience with remote sensing or GIS technology. **Evaluation: Satellite imagery requires experience and knowledge of spatial analysis to extract information for decision makers. Once determine precise parameters and**	Global Land Cover Facility: http://glcf.umiacs.umd.edu/data/ Terralook (USGS): http://terralook.cr.usgs.gov/ and http://terralook.sourceforge.net/ CBERS Program: http://www.cbers.inpe.br/?hl=en Landsat data: http://landsat.usgs.gov Constant production and publication of satellite imagery. Scale of data application: national, provincial and local

Database / Product	Scope / Content	Reference / Availability / Quality
	goals not covered by elabourated tools or data, respective analysis of satellite data can be helpful in decision making processes.	

G-3 Forests[3]

Database / Product	Scope / Content	Reference / Availability / Quality
Forest and woodlands from land-cover mapping	Global land cover maps like GlobCover, GLC2000 and MODIS/Terra Land Cover consider forest and woodland categories that can be used to identify the location of forests on a site scale (see more details under Point 2). **<u>Evaluation:</u> The identification of areas covered by forests and woodlands (important environmental services sites) through the extraction of forest layers must take into account the used land cover classification system and related considerations. Its application on local scale should be checked in decision making processes.**	See details under Point 2. Scale of data application: national, provincial and local.
MODIS Vegetation Continuous Fields (MOD44B)	MOD44B represents a global dataset on the proportion of tree cover based on MODIS data with a resolution of 500 m. The inputs date from October 31, 2000 to December 9, 2001. The training data are derived by aggregating high-resolution Landsat images to the MODIS data. This map contains proportional estimates for vegetative cover: woody vegetation, herbaceous vegetation and bare ground. This technical method will be used for the generation of a new validated global three cover map. The project Global Remote Sensing Survey is managed by	http://glcf.umiacs.umd.edu/data/vcf/ Globally available (GIS), site specific (500 m) Published in 2003 Scale of data application: national, provincial and local

3 Especially for forest assessments, additional regional data are available (see overview in Strand et al. 2007).

Database / Product	Scope / Content	Reference / Availability / Quality
	Global Forest Resources Assessment Program (http://www.fao.org/forestry/fra/remotesensingsurvey/en/ and http://www.fao.org/forestry/fra/48035/en/). **<u>Evaluation:</u> Before using discrete classification schemes, this continuous classification scheme regarding tree cover may represent an advantage for classification in areas of heterogeneous land cover. Decision makers should evaluate their needs to decide on their preferences (e.g. data on land cover classes from GlobCover or proportion of tree cover).**	
Global Forest Resources Assessment. Forestry Databases (FRA 2000 / FRA 2005 / FRA 2010)	Forestry Department of FAO maintains an array of global databases where information covering various aspects of forestry is stored for analysis and further dissemination. FRA 2005 is a global assessment of forest and forestry. It examines the current status and recent trends for about 40 variables covering the extent, condition, uses and values of forest and other wooded land, with the aim of assessing all benefits from forest resources. The report FRA 2010 has been published and will include in its second part (expected 2012) innovative geo-referenced forest information based on a developed MODIS Vegetation Continuous Field. In relation to FRA The Worlds´s Mangroves 1980-2005 can be mentioned. It has no GIS associated data but, as FRA, shows global statistic data. **<u>Evaluation:</u> The evaluated variables in FRA report provide on national scale important background information for planning processes. The database**	http://www.fao.org/forestry/databases/en/ http://www.fao.org/forestry/site/fra/en/ Globally available (no GIS), national level information. No site specific Ongoing purpose: FRA 2010 Remote Sensing Survey. Final report in 2011 (See: http://www.fao.org/forestry/48035/en/) The World´s Mangroves: http://www.fao.org/docrep/010/a1427e/a1427e00.htm Scale of data application: national

Database / Product	Scope / Content	Reference / Availability / Quality
	inform about extent of forest and other wooded land and its changes, composition of growing stock and ownership of forest, among others. Related GIS data are not till now available. Stakeholders should consider this information in the decision making processes.	
Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD)	The GOFC-GOLD is an international platform to provide ongoing space-based and in-situ observations of forest and vegetation cover, to facilitate the sharing of results and observations and to promote cooperative activities. Its aim is to develop and demonstrate operational forest monitoring at regional and global scales through projects and prototype products within three primary themes: Forest Cover Characteristics and Change, Forest Fire Monitoring and Mapping and Forest Biophysical Processes. The GOFC-GOLD is a panel of the Global Terrestrial Observing System (GTOS), which is in turn integrated in the Global Observing Systems Information Center (GOSIC). GOSIC provides access to data, meta-data and additional information, and overviews of the structure and programs, for GTOS, the Global Ocean Observing System (GCOS) and the Global Ocean Observing System (GOOS). These platforms make available also a list of institutions and organizations which process or supply related data. **<u>Evaluation:</u> The portal is designed to promote cooperative activities and it is recommended for specialist and experts. Decision makers could look up this database in a second stage of deci-**	http://www.fao.org/gtos/gofc-gold/catalogs.html and www.gosic.org Globally available (GIS and no GIS), different levels information (regional and global). Data Portal. Publication and update depend on every data and organizations. Scale of data application: national

Database / Product	Scope / Content	Reference / Availability / Quality
	sions making processes to get in depth answers to specific or problematic questions.	
Tropical Rain Forest Information Center	The Tropical Rain Forest Information Center of the Michigan State University is a NASA Earth Science Information Partner. It provides Landsat high resolution remote sensing data as well as digital deforestation maps and databases to a range of users through web-based Geographic Information Systems. The current state of the world's tropical forests is also supplied through maps. To access of data registration is mandatory. Most of satellite imagery has to be paid.. **Evaluation: Products available without charge focus principally in tropical forest region (Brazilian Amazon and Southeast Asia). Forest cover date should be used to compare previous status/ progressive to assess positive or negative developments. Satellite imaginary should be requested by GIS specialists.**	http://www.trfic.msu.edu/products.html http://www.trfic.msu.edu/data_portal.html Globally available (GIS). Site specific (Landsat Data, 30 m) Map Products of Brazilian Amazon and Southeast Asia show forest cover for the years 1973, 1985, 1992 and 1996 Scale of data application: national, provincial and local.
Global Forest Watch and World Intact Forests	The Global Forest Watch is an initiative of the World Resources Institute (www.wri.org) with the goal to map intact forests and forest of high biodiversity. Through a data explorer spatial datasets (GIS) can be downloaded or interactive maps can be queried. This web portal provides specific country GIS data of Alaska, Brazilian Amazon, Cameroon, Canada, Central Africa, Congo, Indonesia, Russia and Venezuela. Several regional and global data are also available. As a follow-up of this assessment the World Intact Forest Landscape map was published in 2007. The	http://www.globalforestwatch.org/english/index.htm Interactive Maps: http://www.globalforestwatch.org/english/interactive.maps/index.htm Data explorer: http://ims.missouri.edu/gfwmetadataexplorer/ Bryant et al.(1997) The Last Frontier Forest Globally available (GIS). Site specific for specific countries/ areas World Intact Forest: http://www.intactforests.org/data.ifl.html Scale of data application: national and provincial.

Database / Product	Scope / Content	Reference / Availability / Quality
	forest zone was identified using existing data based on medium resolution data. Only unfragmented areas larger 500 sq km were analyzed using GLCF images of Landsat 7 (1999-2002). **Evaluation: Products focus on forests with wide extensions in the countries mentioned above. The supplied maps include different themes, not only forest related maps. The intact forest maps should be considered by decision makers to identify unsuitable areas for biomass production or any other productive activity. Countries not included in this project should integrate this approach to avoid "invasion" into intact forest.**	
Global Forest Fragmentation Data	Global Forest Fragmentation Data was provided by the United States Department of Agriculture (Forest Service). The Global Land Cover Characteristics database (GLCC; Loveland et al. 1999) derived from satellite (AVHRR) imagery taken form April 1992 to March 1993 was used to characterize the fragmentation around each forest pixel. Six categories of fragmentation were determined: interior, perforated, edge, transitional, patch, und undetermined). **Evaluation: The forest fragmentation depicted in this map refers 1992-1993 situations. The data can be analyzed together with new data on forest patterns to identify changes and evolutions in forest areas, and especially positive or negative developments of the fragmentation status. Conclusions should be applied by decision makers to define action lines.**	Documentation and data download: http://www.ecologyandsociety.org/vol4/iss2/art3/ Riitters et al. 2000 Globally available (GIS). Site specific (1 km) Published in 2000, based on 1992 – 1993 data. Scale of data application: national, provincial and local

G-4 Wetlands

Database / Product	Scope / Content	Reference / Availability / Quality
Global Lakes and Wetlands Database (GLWD)	GLWD was generated through the combination of best available sources for lakes and wetlands on a global scale (resolution 1:1 to 1:3 million). GLWD presents three levels: large lakes and reservoir (1), smaller water bodies (2) and wetlands (3). Also products from land-cover assessments (GlobCover, GLC2000, MODIS Land Cover) cover information on wetlands and can be used for data verification (see links under Land Cover Classification). **Evaluation: Presence of and proximity to water bodies should be considered in decision processes. GLWD identify where they are and classify them in categories. Subsequent analyses to evaluate quantity and quality for lakes and wetlands should be carried out to assess their current and future suitability for human activities. Such suitability status is essential to guaranty the protection of environmental services related to the lakes and wetlands.**	Lehner/Döll (2004), http://www.geo.uni-frank-furt.de/ipg/ag/dl/f_publikationen/2004/lehner_doell_JHydrol2004_GLWD.pdf Data download: http://www.worldwildlife.org/science/data/item1872.html Globally available (GIS). Site specific (30 Second resolution – 1 km x 1km at the equator) Published in 2004 Scale of data application: national, provincial and local
Wetlands of International Importance (Ramsar Sites Database)	This database provides the list of Wetlands of International Importance selected by the Ramsar Convention Contracting Parties according to established criteria. Together with a Ramsar information sheet, GIS data will be supplied once the user is registered. Georeferenced Ramsar Sites can be found also under WDPA and IBAT. Currently there are 1822 designated Ramsar sites selected by their significance in terms of ecology, botany, zoology, limnology or hydrology. They are important sites for the conservation of global biological diversity and for sustaining human life through ecological and hydrological functions (Ramsar Strategic Framework). **Evaluation: The importance of Ramsar is internationally recognized and their protection must be considered in any decision**	Description: http://ramsar.wetlands.org/Database/AbouttheRamsarSitesDatabase/tabid/812/Default.aspx Datadownload : http://ramsar.wetlands.org/Database/Searchforsites/tabid/765/Default.aspx Globally available (GIS). Site specific. Last Update of the Ramsar Sites List was in October 2008 Scale of data application: national, provincial and local

Data-base / Product	**Scope / Content**	**Reference / Availability / Quality**
	making process also including surrounding areas, where imple-mentation of projects or activities could affect them indirectly.	
BioFresh – Biodi-versity of Freshwa-ter eco-systems	See information under section 1 – Protected Areas, areas of high bio-diversity and areas of undisturbed wildlife	http://www.freshwaterbiodiversity.eu/index.php/index.html
Freshwa-ter Ecore-gions of the World (FEOW)	FEOW provides a global biogeographic regionalization of the Earth's freshwater biodiversity. It is a useful tool for global and regional con-servation planning projects, especially to identify threatened freshwater systems. A description of the freshwater ecoregion and references are enclosed. FEOW is a project of WWF and The Nature Conservancy. A related database is HydroSHEDS (see Point 8: water, hydrology and climate). **Evaluation: Particularly national spatial planning could benefit from this information to initiate appropriate-located low impact projects. A provincial or local selection of suitable areas is not possible on the basis of this dataset and its related information.**	Abell et al. 2008 article and data download under : http://www.feow.org/downloads.php Search and description ecoregions: http://www.feow.org/search/index.php Globally available (GIS). Not site specific. Published in 2008 Scale of data application: national

G-5 Degraded Land

Database / Product	Scope / Content	Reference / Availability / Quality
Global Assessment of Land Degradation and Improvement (GLADA)	Within the GEF-UNEP-FAO program Land Degradation Assessment in Drylands (LADA), the Global Assessment of Land Degradation and Improvement (GLADA) identifies status and trends of land degradation and hotspots suffering extreme constraints or areas at severe risk and, also, areas where degradation has been arrested or reversed. The identification of land degradation hotspots is carried out using remotely sensed data and existing datasets. NDVI indicators and the trend of biomass production are applied to identify land cover and its changes. The classification will be carried out manually, through 30 m resolution Landsat data, to recognize the probable kinds of land degradation. Following-up, field examination will be done by national teams, also within the LADA program. **Evaluation: The results of GLADA provide internationally essential information, especially as the assessment of degraded lands still poses problems from the definition of degraded land to its mapping with a suitable resolution. In case when degraded lands are not interesting for food production, they should be considered by decision makers as priority in biomass production planning reducing possible land and resources competition.**	Reports and case of study: http://www.isric.org/projects/land-degradation-assessment-drylands-glada Globally available (GIS). Site specific (on going) LADA: http://www.fao.org/nr/lada/ GLADIS: Global Land Assessment Degradation Information System is under revision. Data will be available in November 2011. Contact: Riccardo.Biancalani@fao.org Scale of data application: national, provincial and local.
Global Assessment of Soil Degra-	The GLASOD project produced a world map of human induced soil degradation. Soil scientists throughout the world collected the data using uniform guidelines and international	Oldeman et al. 1991, http://www.isric.org/isric/webdocs/Docs/ExplanNote.pdf Oldeman and Van Lynden 2001

Database / Product	Scope / Content	Reference / Availability / Quality
dation (GLASOD)	correlation. The type, extent, degree, rate and main causes of degradation were identified and listed within a database. GLASOD shows some limitations. These are, among others, its low resolution not being appropriate for national breakdowns and its complex legend. Despite a missing updated GLADOD is the most comprehensive database covering land degradation that occurred before 1990. Due to the fact that land degradation is cumulative, results from GLADA will only partly be able to replace information from GLASOD. **<u>Evaluation:</u> Data were collected subjectively by scientists. Until the GLADA project provides better information, the GLASOD database the only one containing global information on degraded lands. Though Its national or regional application is limited, decision makers should consult it together with national or sub national database especially regarding degradation that occurred before 1990.**	Data Download: http://www.isric.org/projects/global-assessment-human-induced-soil-degradation-glasod http://www.grid.unep.ch/data/data.php Viewer Maps: http://www.fao.org/landandwater/agll/glasod/glasodmaps.jsp CD available: http://www.fao.org/ag/agl/lwdms.stm Data: http://www.isric.org/projects/global-assessment-human-induced-soil-degradation-glasod, http://www.fao.org/ag/agl/agll/terrastat/index.asp, www.fao.org/geonetwork Globally available (GIS), not site specific (1:10 Million) Published in 1990. Second revised edition in October 1991. Scale of data application: transnational
South and Southeast Asian Soil Degradation Status Assessment (ASSOD)	This project provided revised sub-regional Guidelines for General Assessment of Status of Human Induced Soil Degradation. As outputs, a South and Southeast Asia Sub-regional Map on the Status of Human-Induced Soil Degradation at a scale of 1:5 Million was generated and a digitized version of the map as well as a digital geographical database is available. Whereas in GLASOD the number of degradation (sub-)types per map unit was restricted to two, ASSOD allows for a potentially unlimited number of degradation types per unit. In ASSOD the degradation is defined in the context of “impacts on agricultural productivity”, others than soil functions have not been considered. This im-	Van Lynden and Oldeman, 1997 Final report and data download: http://www.isric.org/projects/soil-degradation-south-and-southeast-asia-assod Regionally available (GIS), not site specific (1:5 Million) Published in 1997 Scale of data application: national

Database / Product	Scope / Content	Reference / Availability / Quality
	pact on productivity is taken as a standard for the intensity of degradation rather than the intensity of the process (“degree” in GLASOD). Evaluation: **Regional application of GLASOD project. Data were also collected subjectively by scientists. The intensity of degradation only refers to the impact on agricultural productivity, whereas others soil functions are not considered. Decision makers should consult this database as reference to locate degraded lands in the absence of more precise information.**	
Soil Degradation Assessment in Central and Eastern Europe (SOVEUR)	The SOVEUR project for Central and Eastern Europe developed a harmonized soil and terrain database at 1:2.5 million scales. Using regional soil information and auxiliary information on climate, land use and the type of soil pollution, the status of human induced soil degradation and the areas considered vulnerable to defined pollution scenarios were identified and mapped. For the SOVEUR project, the status of degradation was evaluated both in terms of the type and intensity of the process (degree) as well as the impact of degradation on various soil functions (not only impact on productivity like in ASSOD).This FAO project is also available as CD Rom. Evaluation: **The SOVEUR project broadens the degradation concept by considering and evaluating various soil functions. Decision makers within the project area should consult this database as reference to identify degraded lands.**	Van Lynden, 2000 Explanatory note and data download: http://www.isric.org/projects/mapping-soil-and-terrain-vulnerability-central-and-eastern-europe-soveur Regionally available (GIS), not site specific (1:2.5 Million) Published in 2000 Scale of data application: transnational and national

G-6 Agricultural Production and Land Use

Database / Product	Scope / Content	Reference / Availability / Quality
Food Insecurity, Poverty and Environment Global GIS Database (FGGD)	As a part of the Poverty Mapping Project, FAO prepared this database for global analysis of food insecurity and poverty in relation to environment. FGGD provides a GIS database regarding monitoring, assessing and analyzing environmental and other geospatial dimensions of drivers of poverty and food insecurity, particularly in relation to agro-ecological zones, accessibility, farming system zones and crop and livestock production systems. Besides information on, e.g., topography, human population and socioeconomic indicators (Huddleston et. al. 2006, Salvatore et. al. 2005), land productivity potential for different cropping systems are depicted (van Velthuizen et al. 2007). Suitability maps for rainfed production of each case have been elabourated according to three levels of inputs (low, intermediate or high. This database and methods rely on the FAO/IIASA global agro-ecological zoning (GAEZ) method for evaluating productivity potential of the world's land area for rainfed agriculture, updated and published in 2002 (Fischer et al. 2002) **Evaluation: Comprehensive international cropping system database according to GAEZ methodology. Decision makers should consider these suitability maps to locate production areas, especially in case of the absent of national assessments.**	http://geonetwork3.fao.org/fggd/ Suitability maps for crops: http://www.fao.org/docrep/010/a1075e/a1075e00.htm Globally available (GIS). Site specific (30 arc seconds) or not (5 arc minutes) Published in 2007 Global Agro-ecological zoning (GAEZ): http://www.fao.org/nr/land/databasesinformation-systems/aez-agro-ecological-zoning-system/en/, http://www.iiasa.ac.at/Research/LUC/GAEZ/index.html Scale of data application: national
Agro-MAPS: Global	This database contains data on crop production; area harvested and crop yields, for one or more years, for each country. It has been separately prepared by FAO (for Africa and the Middle	Concept and document http://www.ifpri.org/data/gs_agromaps.htm Database

Database / Product	Scope / Content	Reference / Availability / Quality
Spatial Database of Agricultural Land Use Statistics	East), the International Food Policy Research Institute (IFPRI, Latin America, Asia, Australia and New Zealand) and the Center for Sustainability and the Global Environment (SAGE, (the rest of the world). This information is provided regionally according to administrative division and subdivision of the countries. Export and download all available data is possible. A combination of Agro-MAPS and national agricultural statistics with the new gridded map of global croplands for the year 2000 (Ramankutty et al. 2008 – see Section Land Cover) has been developed to present a database of global land use practices describing the areas and yields of 175 individual crops around the year 2000 at a 5 min by 5 min spatial resolution (Monfreda et al. 2008) **Evaluation: Agro-MAPS provide provincial statistic information for every crop. Decision makers could use this database to evaluate agricultural importance of specific crop in a region.**	http://kids.fao.org/agromaps/, http://www.fao.org/landandwater/agll/agromaps/interactive/page.jspx Globally available. Not site specific. Map viewer available. Available data from 1975 Scale of data application: national
Land Use Systems of the World (LUS)	LUS aims to provide worldwide land-use data and to give guidance for its creation. The available LUS beta version has been developed in the framework of the LADA project by the Land Tenure and Management Unit of FAO. The produced maps provided as raster format provide information on land use systems, ecosystems, crops, crop groups, irrigated areas, thermal climate, length of growing period (LGP), soils, slope, population density and infant mortality rate. The overall quality of the map, however, depends heavily on the individual quality of the data for the different countries that varies significantly between mapping regions.	Documents: http://www.fao.org/nr/lada/index.php?option=com_docman&task=cat_view&gid=37&Itemid=157 Data download: http://www.fao.org/nr/lada/index.php?option=com_content&view=article&id=134&Itemid=184&lang=en Globally available. Not site specific (5 arc minutes – 0,0833 decimal degrees) Beta version published, on going. Scale of data application: national

Data-base / Product	Scope / Content	Reference / Availability / Quality
	<u>Evaluation:</u> see more details under GLADA – Point 5.	
Problem Soil Database (ProSoil)	ProSoil provides a literature database on agricultural problem soils. Within the ProSoil database different types of agricultural problem soils have been selected for their consideration: acid soils, calcareous soils, histosols, salt affected soils, sandy soils, steeplands and vertisols. Database queries considering soil types, location, crop types and agricultural technologies relevant literature sources can be identified. Furthermore, according to the World Reference Base for Soil Resources (WRB) a glossary of diagnostic horizons for agricultural problem soils is given. **<u>Evaluation:</u> Decision makers could use this literature database as information source for specific problems. In-depth knowledge is necessary to carry out suitable planning processes and to anticipate later indirect impact.**	http://www.fao.org/AG/AGL/agll/prosoil/default.htm Database: http://www.fao.org/AG/AGL/agll/prosoil/prosoil.asp Literature sources available.

G-7 Soil, Slope and Elevation

Database / Product	Scope / Content	Reference / Availability / Quality
Harmonized World Soil Database (HWSD)	HWSD combines existing regional and national updates of soil information worldwide (SOTER, ESD, Soil Map of China, WISE) including the information from the FAO-UNESCO Soil Map of the World. Based on raster data with a resolution of about 1 km (30 arc seconds by 30 arc seconds) over 15,000 different soil mapping units are recognized in the HWSD. For these mapping units occurring soil types and their properties are listed. The use of a standardized structure allows database queries to identify the location of soils units regarding selected soil parameters (organic Carbon, pH, water storage capacity, soil depth, cation exchange capacity of the soil and the clay fraction, total exchangeable nutrients, lime and gypsum contents, sodium exchange percentage, salinity, textural class and granulometry). Previous Databases such as the World Soil and Terrain Database (SOTER), the Digital Soil Map of the World, the World Inventory of Soil Emission Potentials (WISE) and the European Soil Database (ESD) can be consulted separately. The Soil Map of China integrates in HSWD is not available independently. A global consortium has been formed to prepare a new digital soil map of the world using state-of-the-art and emerging technologies. This new global soil map will predict soil properties at fine spatial resolution (~100 m). The Global Soil Map project will generate thematic digital layers globally using satellite multispectral analyses and legacy soil data (ground truthing data) including soil carbon. This is an initiative of the Digital Soil Mapping Working Group of the International Union of Soil Sciences IUSS (www.globalsoilmap.net) **<u>Evaluation:</u> Most comprehensive soil database. Suitable at**	FAO/IIASA/ISRIC/ISS-CAS/JRC (2008) http://www.iiasa.ac.at/Research/LUC/luc07/External-World-soil-database/HTML/index.html ; Globally available (GIS – own software), site specific (30 arc second). Ground Data Information: - SOTER: http://www.fao.org/nr/land/databasesinformation-systems/soter/en/ - Digital Soil Map of the World: http://www.fao.org/geonetwork/srv/en/metadata.show?id=14116 - WISE: http://www.isric.org/projects/world-inventory-soil-emission-potentials-wise - ESD: http://eusoils.jrc.it/ESDB_Archive/ESDB/index.htm - The Soil Map of China: http://www.issas.ac.cn/english/index.htm Scale of data application: national, provincial and local New Initiative: www.globalsoilmap.net

Database / Product	Scope / Content	Reference / Availability / Quality
	every scale. Decision makers should consider in principle this database, where others have been integrated, to get information on soil distribution and properties.	
World Reference Base for Soil Resources (WRB)	WRB is an initiative of FAO and UNESCO supported by UNEP and ISRIC-World Soil Information which dates back to 1980. The intention of the project was to establish a worldwide soil classification. The WRB is a comprehensive classification system that enables people to accommodate their national classification system, supplying a set of prefix and suffix qualifiers for specials categories. ISRIC (www.isric.org) as an international institute aims to inform and educate through public information, teaching and advocacy; to serve the scientific community as a custodian of soil information and applied research. **<u>Evaluation:</u> International standard for soil classification. Tool for soil specialist and scientists. Decision makers should consider the database as reference to ensure comparability of assessed data with other projects.**	http://www.fao.org/ag/Agl/agll/wrb/doc/wrb2006final.pdf http://www.fao.org/ag/agl/agll/wrb/doc/wrb2007_corr.pdf Global Soil classification system. Published in 1998, second edition in 2006
Soil Datasets – Institute for Environment and Sustainability – Joint Research Centre	The European Soil Portal contains currently many soil data and information; most of the offered data are at European scale, while, when possible, links to national or global datasets are provided. With the term "Soil Dataset", we refer to all digital resources grouped in data, maps and application/services. Data for soil erosion, soil organic carbon content, soil compaction, soil contamination, soil acidification and soil salinization are available directly or contacting the responsible person. The geo-referenced soil organic carbon content data can be directly consulted with a map viewer (http://eusoils.jrc.ec.europa.eu/Website/octop/viewer.htm), the same as the soil erosion (http://eusoils.jrc.ec.europa.eu/website/Pesera/viewer.htm). **Evaluation: The access of the data is well established. Stake-**	Soil Datasets: http://eusoils.jrc.ec.europa.eu/library/esdac/index.html National available (GIS), site specific Scale of data application: national, provincial and local Other data portals: http://ies.jrc.ec.europa.eu/index.php?page=data-portals

Database / Product	Scope / Content	Reference / Availability / Quality
	holders with limited GIS knowledge and experience can consult this data through a map viewer. The resolution of the data is good in comparison with global data but not precise enough to be used in a site-specific level. **with global data but not enough precise to be used in a site-specific level.**	
U.S. General Soil Map (STATSGO2)	STATSGO2 was developed by the U.S. National Cooperative Soil Survey. It consists of a broad based inventory of soils and non-soils areas that occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped. The data are available for the conterminous United States, Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands. Individual state extents are also available. The dataset was created by generalizing more detailed soil survey maps. Where more detailed soil survey maps were not available, data on geology, topography, vegetation, and climate were assembled, together with Land Remote Sensing Satellite (Landsat) images. Map unit composition was determined by transecting or sampling areas on the more detailed maps and expanding the data statistically to characterize the whole map unit. **Evaluation: Once HWSD was published, it is advisable to make use of it preferably. STATSGO2 is not updated.**	http://www.soils.usda.gov/survey/geography/statsgo/ National available (GIS), site specific Published in 1994 by Natural Resources Conservation Service, United States Department of Agriculture. Scale of data application: national, provincial and local
The National Soil Database (NSDB), Canada	The NSDB is the set of computer readable files which contain soil, landscape, and climatic data for all of Canada. It serves as the national archive for land resources information that was collected by federal and provincial field surveys, or created by land data analysis projects. Included data: National Ecological Framework (scale of 1:30 M to 1:1 M), Soil Map of Canada (1:5 M), Agroecological Resource Areas (1:2 M), Soil Landscapes of Canada (1:1 M), Canada Land In-	http://sis.agr.gc.ca/cansis/nsdb/ National available (GIS), site specific or not (depending on data) Scale of data application: national, provincial and local

Database / Product	Scope / Content	Reference / Availability / Quality
	ventory (1:250.000) and Detailed Soil Surveys (1:20.000 to 1:250.000) **Evaluation: Decision makers in Canada should consider these databases as reference to get information on soil distribution and properties. A comparison with global database (HWSD) is advisable.**	
Australian Soil Resource Information System (ASRIS)	ASRIS provides online access to the best publicly available information on soil and land resources in a consistent format across Australia. It covers information at seven different scales. The upper three levels provide broad descriptions across the complete continent. Lower levels provide more detailed information for regions where mapping is complete. This information relates to soil depth, water storage, permeability, fertility, carbon, salinity and erodibility. ASRIS includes a soil profile database with fully characterized and representative sites. Information is displayed using maps, satellite images, tables, photographs and graphics. **Evaluation: Decision makers in Australia should consider this database as reference to get information on soil distribution and properties. A comparison with global database (HWSD) is advisable.**	http://www.asris.csiro.au/index_other.html Data view and download: http://www.asris.csiro.au/mapping/viewer.htm National available (GIS - online) Site specific or not depending on data. Scale of data application: national, provincial and local
NASA's Shuttle Radar Topography Mission (SRTM)	The Shuttle Radar Topography Mission (SRTM) is a joint project between NASA and NGA (National Geospatial-Intelligence Agency) to map the world in three dimensions. Flown aboard the NASA Space Shuttle Endeavour February 11-22, 2000, SRTM successfully collected data over 80% of the Earth's land surface, for all area between 60 degrees North and 56 degrees South. SRTM data is being used to generate a digital topographic map of the Earth's land surface with data points spaced every 1 arc second for the United States of latitude and longitude (approximately 30 meters). SRTM achieved horizontal and vertical accuracies of 20 meters and 16 meters, respectively.	http://www2.jpl.nasa.gov/srtm/index.html Data download: - Seamless SRTM 3 Arc Second (90 m): http://seamless.usgs.gov/products/srtm3arc.php - Seamless SRTM 1 Arc Second (30 m): http://seamless.usgs.gov/products/srtm1arc.php Globally available (GIS), site specific Global Terrain Slope and Aspect Data Documentation - References http://www.iiasa.ac.at/Research/LUC/luc07/External-World-soil-database/HTML/global-terrain-

Database / Product	Scope / Content	Reference / Availability / Quality
	Data view and download through interactive maps is also possible. Further it is notable that based on SRTM GTOPO 30 and the Consortium for Spatial Information of the Consultative Group on International Agricultural Research (CGIAR-CSI) data sets provide datasets on slope and aspect. Both databases are included as supplementary data in the Harmonized World Soil Database. **Evaluate: Most recent projects requiring information on topography refer to this source. Decision makers which need information on slope and aspect should take into account this global database.**	doc.html GTOPO 30: http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/gtopo30_infol CGIAR-CSI: http://srtm.csi.cgiar.org/ Scale of data application: national, provincial and local

G-8 Water, Hydrology and Climate

Database / Product	Scope / Content	Reference / Availability / Quality
AQUASTAT	A FAO's global information system on water and agriculture developed by the Land and Water Division. It contains general and country specific data and information about water resources, water consumption (per Sector) und agricultural water management, with emphasis on countries in Africa, Asia, Latin America and the Caribbean. There are different kinds of data: concrete data (number), country profile (text) and maps (downloadable, geo-referenced or not). For example: main country database (http://www.fao.org/nr/water/aquastat/dbase/index.stm), climate information tool (http://www.fao.org/nr/water/aquastat/gis/index3.stm) or global or spatial maps (http://www.fao.org/nr/water/aquastat/maps/index.stm) The Digital Global Map of Irrigation Areas is a good example of spatial map, which shows the percentage of each 5 arc minutes by 5 arc minutes cell that was equipped for irrigation around the year 2000 (Siebert et al. 2007,	http://www.fao.org/nr/water/aquastat/main/index.stm Globally and regional available (GIS), partially site specific. Data related to main country profile are updated every 5 years. Others, unknown updated. Others graphics and maps: http://www.fao.org/nr/water/infores_maps.html Scale of data application: national and provincial

Database / Product	Scope / Content	Reference / Availability / Quality
	http://www.geo.uni-frankfurt.de/ipg/ag/dl/datensaetze/1_irrigation_map/index.html, http://www.fao.org/nr/water/aquastat/irrigationmap/index10.stm The internet side http://www.fao.org/nr/water/aquastat/infosystems/index.stm links to other information systems, databases and spatial datasets related to the field of water resources and agriculture are presented. Most of them are mentioned within this section **Evaluation: Decision makers should consider this database, which compiles good structured and useful data formats, as starting point. Depending on the planning or decision processes complementary database will be needed. Most of them are mentioned below.**	
International Groundwater Resource Assessment Centre (IGRAC)	The objective of IGRAC is to include groundwater fully in the assessment of freshwater resources of the world to enhance the sustainable utilization of both groundwater and surface water. IGRAC develop a Global Groundwater Information System (GGIS) for various categories of stakeholders, that is accessible through the Internet. IGRAC develop and promote guidelines and protocols for the assessment of groundwater resources. The GGIS offers information related to physiography, demography, agriculture and economics, aquifer characteristics, groundwater quantity, quality, development and problems. This information is available at the national level (map viewer). **Evaluation: IGRAC offers the most complete groundwater information system. An analysis of water availability and quality should not be carried out without the consideration of groundwater data. This dataset allow only a rough analysis, since the data are only national available.**	http://www.igrac.net/ GGIS: http://www.igrac.net/publications/104 Map viewer: http://igrac.nitg.tno.nl/ggis_map/start.html Scale of application: international and national
The World Hydrological Cycle Observing Sys-	WHYCOS is a World Meteorological Organization program aiming at improving the basic observation activities, strengthening the international cooperation and promotion free exchange of data in the field of hydrology. The program is implemented through various components (HYCOSs) at the re-	http://www.whycos.org/cms/home Data and products: http://www.whycos.org/cms/content/data-and-products

Database / Product	Scope / Content	Reference / Availability / Quality
tem (WHYCOS)	gional and/or basin scale.). In the Mediterranean Basin, MED-HYCOS contributes to water resources assessment and management by helping the National Hydrological Services to strengthen their capacities and by promoting the exchange of information and skills among the countries participating in the Project. Three software tools are offered: MedDat (tabular database), MedMap (GIS/visual database) and MedClima (graphic and spatial visualization of climatic data) **Evaluation: WHYCOS allows a quick access to relevant hydrometeorological information without consulting national institution principally in Mediterranean countries. The commercial use of the data is strictly forbidden. Unfortunately the links for data download on the website are not always available.**	MED-HYCOS: http://medhycos.mpl.ird.fr/index.html GIS-hydrometeorological data: http://medhycos.mpl.ird.fr/en/t1.&gn=medmap.inc&menu=softims.inc.html Scale of application: international, national and basin area.
The United Nations GEMS/Water Program	The GEMS/Water Program provides scientifically-sound data and information on the state and trends of global inland water quality required as a basis for the sustainable management of the world´s freshwater to support global environmental assessments and decision making processes. Some publications as such Global Water Quality Index Report, the Digital Atlas – Water Quality for Ecosystem and Human Health or the Development and use of Global Water Quality Indicators and Indices are available but there is not an access for concrete data about countries or specific water parameters. **Evaluation: The available information can help stakeholders with the implementation of programs to build capacity of developing countries for the acquisition and management of water quality information.**	http://www.gemswater.org/index.html Reports available.
Water Systems Analysis Group (WSAG) – University of New Hamp-	The WSAG is a global hydrology research group within the Institute for the Study of Earth, Oceans, and Space at the University of New Hampshire. Its mission is to serve as a research and advanced training facility for analyzing the global water system, the critical global change issue of its alteration through anthropogenic activities, and the impacts of a changing water system on society. Research themes are: arctic hydrology, humans and the	http://www.wsag.unh.edu/ Data download http://www.wsag.unh.edu/data.html Globally or regional available (GIS), depends on the database. Not site specific Scale of data application: transnational and

Database / Product	Scope / Content	Reference / Availability / Quality
shire	global water cycle, monitoring of inland and coastal waters and land-river-coastal systems. Various databases and tools can be accessed from this web site, for example, the Data Synthesis System for World Water Resources (DSS) - http://www.wwap-dss.sr.unh.edu/download.html , supported by the United Nations Educational, Scientific, and Cultural Organization's International Hydrological Programme (UNESCO/IHP), or the World Water Development Report II - http://wwdrii.sr.unh.edu/download.html -within the World Water Assessment Program. **Evaluation: Heterogeneous database of great use for scientists and specialists. Both data and tools for water resources planning and management processes are provided. Due to wide range of data targeted search without in-depth knowledge is complex. This database supplies further databases (GIS and not GIS information) or related links mentioned and evaluated below.**	national
UNESCO International Hydrological Program (IHP)	IHP is UNESCO's international scientific cooperative program in water research, water resources management, education and capacity-building. Among its primary objectives are to develop techniques, methodologies and approaches to better define hydrological phenomena and to assess the sustainable development of vulnerable water resources. Associated programs are linked to this website, as for example, Ecohydrology and GRAPHIC Program. **Evaluation: Decision makers should use this source to find reports and research studies which deal with similar problematic or provide possible solutions or successfully/ unsuccessfully water management experiences. Specific data are not supplied.**	http://www.unesco.org/new/en/natural-sciences/environment/water/ Global contacts available. No possible to download data.
World Water Assessment Program (WWAP) -	The World Water Assessment Program (WWAP), founded in 2000, is the flagship program of UN-Water. Housed in UNESCO, WWAP monitors freshwater issues in order to provide recommendations, develop case studies, enhance assessment capacity at a national level and inform the deci-	http://www.unesco.org/water/wwap/ Documents available. No GIS data available.

Database / Product	Scope / Content	Reference / Availability / Quality
UNESCO	sion-making process. Its primary product, the World Water Development Report (WWDR), is a periodic, comprehensive review providing an authoritative picture of the state of the world's freshwater resources. UN-Water (www.unwater.org) is a mechanism to strengthen co-ordination and coherence among all UN bodies dealing with water-related issues, from health to farming, environment to energy, food to climate, and sanitation to disasters. It was set up in 2003, through a decision by the High Level Committee on Programmes (HLCP) of the United Nations. **Evaluation: The World Water Development Reports (WWDR) provide a global vision on water status and associated problematic. Indicators, graphics, consulting processes and case study constitute important updated information for water resources planning processes which should be considered by decision makers.**	
WHO/ UNICEF Joint Monitoring Program (JMP) for Water Supply and Sanitation	The goals of the JMP are to report on the status of water-supply and sanitation, and to support countries in their efforts to monitor this sector. The data collected for JMP come from two main sources: assessment questionnaires and household surveys. The web page presents water supply data and sanitation coverage data at different scales (from global to regional), providing both total access and house connections data. **Evaluation: Specific useful information to be considered by decision makers for water resources planning processes that involve water supply and sanitation. If a national database exists, a comparison is possible.**	http://www.wssinfo.org/about-the-jmp/introduction/ Globally available. Not site specific Data available between 1990 and 2004 Scale of data application: transnational and national
World Resources Institute (WRI) – Watersheds of the World	The Watersheds of the World provides maps of land cover, population density and biodiversity for 154 basins and sub-basins around the world. It lists indicators and variables for each of these basins and, where appropriate, provides links and references to relevant information. It further contains 20 global maps portraying relevant water resources issues. The information is provided by the Water Resources eAtlas, a collabourative	http://earthtrends.wri.org/maps_spatial/watersheds/index.php Technical notes: http://earthtrends.wri.org/maps_spatial/watersheds/notes.php Globally available. Not site specific.

Database / Product	Scope / Content	Reference / Availability / Quality
	product of WRI, IUCN, IWMI, and the Ramsar Convention on Wetlands. Furthermore, WRI supplies a database with water related data, maps and also country profiles: http://earthtrends.wri.org/searchable_db/index.php?theme=2 **Evaluation: This database provides information by river basin, depending on country size; data could be applied at regional or national scale. This information refers to global river basin, site specific data are not provided. National water resource planning and management processes should refer to these data in absence of better national monitoring systems.**	Published in 2005 Scale of data application: transnational and national (by river basin)
International Water Management Institute (IWMI)	IWMI is one of 15 international research centers supported by the Consultative Group on International Agricultural Research (CGIAR). Its aim is to improve the management of land and water resources for food, livelihoods and nature. Its research themes are: water availability and access, productivity water use, water quality, health and environment and water and society. Among the tools and resources available in the IWMI website, can be mentioned, for example, the Global Irrigated and Rainfed Areas Mapping (http://www.iwmigiam.org/info/main/index.asp), the Water and Climate Atlas (http://www.iwmi.cgiar.org/WAtlas/) and the Eco-Hydrological Databases (http://dw.iwmi.org/ehdb/wetland/index.asp). IWMI offers also some models or software: Global Environmental Flow Calculator (GEFC), Global Policy Dialogue Model (PODIUM), WATERSIM to understand the key linkages between water, food security and environment; and OASIS (Option Analysis in Irrigation Systems). **Evaluation: The thematic of the supplied data coincide with other databases (e.g. irrigation and water and climate atlas). Location, available technical means and planning objectives will establish the most suitable database. Models and software are provided. Specialized literature should be consulted to support the most appropriate data selection**	http://www.iwmi.cgiar.org/index.aspx Tools, Databases, Models and Softwares: http://www.iwmi.cgiar.org/Tools_And_Resources/index.aspx Globally available (GIS). Site specific or not depending on the data Different publication date. Scale of data application: national and provincial
Project	The specific objectives of the project are to carry out global analyses need-	http://www.usf.uni-kassel.de/watclim/

Database / Product	Scope / Content	Reference / Availability / Quality
WATCLIM	ed to provide water managers and other stakeholders with the latest information about the impact of climate on water resources, which are performed using the WaterGAP model. The WaterGAP model has been developed at the Center for Environmental Systems Research at the University of Kassel in Germany in cooperation with the National Institute of Public Health and the Environment of the Netherlands. The aim of the model is to provide a basis (1) to compare and assess current water resources and water use in different parts of the world, and (2) to provide an integrated long-term perspective of the impacts of global change on the water sector. WaterGAP belongs to the class of environmental models which can be classified as 'integrated' because they seek to couple and thus integrate different disciplines within a single integrated framework. **<u>Evaluation:</u> Since the impact of climate on water resources should be consider in water management processes, the provided information is in particular decisive for future action lines and projects. The application of this model should be carried out by water specialists.**	Globally available. No site specific. Final Report published in March 2003 WaterGAP 2.1 (Water – Global Assessment and Prognosis) http://www.usf.uni-kassel.de/watclim/pdf/watergap_model.pdf Scale of data application: transnational and national
Digital Global Map of Artificially Drained Agricultural Areas	The map was developed by combining national statistics provided by international organizations (e.g. FAO, ICID, CEMAGREF), the "Global Croplands Dataset" (Ramankutty et al. 1998) and the "Digital Global Map of Irrigation Areas" (Siebert et al. 2005). No data on agricultural drainage could be found for 120 countries. Most of them are very small so that their agricultural drainage area may be neglected in global assessments. However, there are also some larger countries (in particular in Africa) where it is known that artificially drained areas are existing but the extent of these areas is unknown (e.g. Mali, Niger, Chad, Mozambique). Therefore the real global extent of agricultural drainage may be underestimated in this inventory. **<u>Evaluation:</u> Because of small scale of data collection this database could be indecisive. In planning and management processes where drained agricultural areas play an important role, the data should be**	http://www.geo.uni-frankfurt.de/ipg/ag/dl/datensaetze/2_agricultural_drainage_map/ind ex.html Feick et al. 2005 http://www.geo.uni-frankfurt.de/ipg/ag/dl/forschung/Global_Drainage_Map/index.html Globally available (GIS) Not site specific (5 arc minutes) Scale of data application: national

Database / Product	Scope / Content	Reference / Availability / Quality
	considered in any case.	
Global Drainage Direction Map	The global drainage direction map DDM30 is a raster map which describes the drainage directions of surface water with a spatial resolution of 30' longitude by 30' latitude. DDM30 is based on (1) the digital drainage direction map with a resolution of 5' of Graham et al. (1999) for South America, Australia, Asia and Greenland, and (2) the HYDRO1k digital drainage direction map (as flow accumulation map) with a resolution of 1 km (USGS, 1999) for North America, Europe, Africa and Oceania (without Australia). The resulting drainage direction map was manually corrected using the vectorized river data sets of ESRI (1992) and ESRI (1993). A possible complementary database is the Global Runoff Data Centre (GRDC) (http://www.bafg.de/GRDC/EN/Home/homepage__node.html), a digital world-wide source of discharge data and associated metadata. GRDC operates under the auspices of the World Meteorological Organization (WHO) and with the support of the Federal Republic of Germany within the Federal Institute of Hydrology. **<u>Evaluation:</u> This database is useful for regional water planning processes (e.g. agriculture or industry) considering production activities. A local or provincial application is restricted due to low resolution of data.**	http://www.geo.uni-frankfurt.de/ipg/ag/dl/datensaetze/3_drainage_direction_map/index.html Döll et al. 2002 http://www.geo.uni-frankfurt.de/ipg/ag/dl/forschung/Global_Water_Modeling/DDM30/index.html Globally available (GIS) Not site specific (30 arc minutes) Scale of data application: regional
Global Lakes and Wetlands Database (GLWD)	See information under section 4 – Wetlands.	http://www.geo.uni-frankfurt.de/ipg/ag/dl/f_publikationen/2004/lehner_doell_JHydrol2004_GLWD.pdf
Global Water System Project Digital Water Atlas	The purpose of the 'Digital Water Atlas' is to describe the basic elements of the Global Water System, the interlinkages of the elements and changes in the state of the Global Water System by creating a consistent set of annotated maps. The project will especially promote the collection, analysis and consideration of social science data on the global basis.	http://atlas.gwsp.org/ Data download http://wiki.gwsp.org/joom/index.php?option=com_content&task=blogcategory&id=34&Itemid=63

Database / Product	Scope / Content	Reference / Availability / Quality
	The content of the Digital Water Atlas is available online with free and open access. Registered users can also download and use the datasets used to produce the maps. An interactive map viewer option is accessible for all users **Evaluation: Digital Water Atlas provides global water related maps. Comparison or example from others country or regions should be taken into account together with concrete conditions and parameters. Decision makers should consider these maps to get an overall situation picture.**	Globally available (GIS), not site specific Different publication date Scale of data application: national
Global Land Data Assimilation System (GLDAS)	The goal of GLDAS is to generate optimal fields of land surface states and fluxes by integrating satellite- and ground-based observational data products, using advanced land surface modelling and data assimilation techniques (Rodell et al. 2004; http://disc.sci.gsfc.nasa.gov/hydrology/overview/GLDAS_summary.shtml#rodell#rodell) Data assimilation techniques for incorporating satellite based hydrological products, including snow cover and water equivalent, soil moisture, surface temperature, and leaf area index, are now being tested and implemented. The output fields support several current and proposed weather and climate prediction, water resources applications, and water cycle investigations. The project is funded by NASA's Energy and Water Cycle Study (NEWS) Initiative. **Evaluation: GLDAS provides weather/climate prediction and water cycle investigations which should be considered by decision makers. For its application and data interpretation specialists and scientists should be consulted.**	http://disc.sci.gsfc.nasa.gov/hydrology/overview Data Download http://disc.sci.gsfc.nasa.gov/hydrology/data-holdings Globally available (GIS), resolution of 1 - 0,25 degree Scale of data application: national and provincial
HydroSHEDS (Hydrological data and	HydroSHEDS has been developed by the Conservation Science Program of World Wildlife Fund (WWF), in partnership with the U.S. Geological Survey (USGS), the International Centre for Tropical Agriculture (CIAT), The Nature Conservancy (TNC), and the Center for Environmental Systems Research	http://hydrosheds.cr.usgs.gov/ Data download http://gisdata.usgs.net/website/HydroSHEDS/

Database / Product	Scope / Content	Reference / Availability / Quality
maps based on SHuttle Elevation Derivatives at multiple Scales)	(CESR) of the University of Kassel, Germany. HydroSHEDS is derived from elevation data of the Shuttle Radar Topography Mission (SRTM) at 3 arc-second resolution (90 m at Equator). The goal of developing HydroSHEDS was to generate key data layers to support regional and global watershed analyses, hydrological modeling, and freshwater conservation planning at a quality, resolution and extent that had previously been unachievable. As opposed to HYDRO1k for the development of HydroSHEDS not only digital elevation models were taken into account, the Global Lakes and Wetlands Database (Lehner and Döll, 2004), the ArcWorld global vectorized river network (ESRI 1992) and Digital Chart of the World (DCW) global vectorized river network (ESRI 1993) are also data source for the generation of HydroSHEDS **Evaluation: HydroSHEDS provides currently the best scaled hydrological data and maps for studies and analyses. Decision makers should consider this database for planning and management processes, especially in high erosion risk areas.**	Documentation: Lehner et al., 2008 http://gisdata.usgs.net/HydroSHEDS/downloads/HydroSHEDS_TechDoc_v11.pdf Globally available (GIS), partially site specific (from 3 arc-second to 5 minute) Published in October 2008 Scale of data application: national, provincial and local
CROPWAT - AQUACROP - CLIMWAT	CROPWAT is a practical tool to carry out standard calculations for evapotranspiration and crop water use studies. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rainfed conditions or deficit irrigation. AQUACROP is a new version of CROPWAT: A tool for (1) predicting crop production under different water-management conditions (including rainfed and supplementary, deficit and full irrigation) under present and future climate change conditions, and (2) investigating different management strategies, under present and future climate change conditions. It can be applied at all locations; agricultural sector; site-specific, but can be extrapolated to larger scale by GIS applications. CLIMWAT is a climatic database to be used in combination with the computer program CROPWAT or AQUACROP and allows the ready calculation	AQUACROP 3.0 (published in January 2009) http://www.fao.org/nr/water/aquacrop.html CROPWAT version 5.7 published in 1992 http://www.fao.org/nr/water/infores_databases_cropwat.html Documentation: Irrigation and Drainage Papers No. 24 and 33 CLIMWAT http://www.fao.org/nr/water/infores_databases_climwat.html New version CLIMWAT 2.0 is compatible with AQUACROP Scale of tool application: national, provin-

Database / Product	Scope / Content	Reference / Availability / Quality
	of crop water requirements, irrigation supply and irrigation scheduling for various crops for a range of climatological stations worldwide. The climatological data included are maximum and minimum temperature, mean daily relative humidity, sunshine hours, windspeed, precipitation and calculated values for reference evapotranspiration and effective rainfall. **Evaluation: Important tools to enhance the decisions in agriculture development and crop selection. Action lines and long run projects/ programs should be designed taking into account future situation and factor interactions. Specialist should be consulted for making use of these tools.**	cial and local
FAOClim – LocClim – Web LocClim	Among the climate information tools presented by AQUASTAT, these are the main once. FAOClim is a CDROM, which contains worldwide agroclimatic data. It covers monthly data for 28100 stations, for up to 14 observed and computed agroclimatic parameters, their averages and also time series for rainfall and temperature. LocClim was developed to provide an estimate of climatic conditions at locations for which no observations are available, and the related web interface, the Web LocClim, offers a local monthly climate estimator. **Evaluation: These tools offer worldwide and local agroclimatic information/estimates that can be helpful for decision makers to decide on cropping systems. However, quality of applied extrapolations strongly depends on the density of climate stations, and in areas with low amount of data, estimations need to be handled caution.**	FAOClim http://www.fao.org/sd/2001/EN1102_en.htm LocCLIM http://www.fao.org/sd/2002/EN1203a_en.htm Web LocClim http://www.fao.org/sd/locclim/srv/en/locclim.home Scale of tool application: national, provincial and local
The Wastewater Database	Developed by the Water Quality and Environment Group, the Wastewater Database contains information on wastewater production, treatment, re-use, as well as economic information provided by member states. The Database information is sorted by region and country containing fields on wastewater production, treatment technologies, and financial/economical parameters by country. **Evaluation: This database provides worldwide information on**	http://www.fao.org/nr/water/infores_databases_wastewater.html Globally available. Not site specific Documentation: Wastewater treatment and use in agriculture – FAO irrigation and drainage paper 47 (Pescod, 1992) http://www.fao.org/docrep/T0551E/T0551E

Database / Product	Scope / Content	Reference / Availability / Quality
	wastewater production and management. Decision maker should consider this information in water planning processes to guaranty benefits and continuity in treatment plant and re-use tasks.	00.htm
Water Indicators and Indices	The use of indicators and indices is a practical approach in water management and analysis. Some of the indices mentioned in text can be consulted directly in internet: - the water scarcity index (http://www.fao.org/nr/water/art/2007/scarcity.html), - the water poverty index (http://earthtrends.wri.org/searchable_db/index.php?theme=2&variable_ID=1299&action=select_countries) and - the water exploitation index (http://www.eea.europa.eu/data-and-maps/indicators/use-of-freshwater-resources/use-of-freshwater-resources-assessment-2) can be consulted directly in internet or through the supplied contacts. **Evaluation: A suitable selection of indicators should be based on specific parameters, locations and targets. Literature and specialist should be consulted for using them in water resources planning and management.**	Documentation Water Scarcity Index: Smakthin et al., 2004. http://www.unep.org/dewa/vitalwater/ Documentation Water Poverty Index: Sullivan, C.2000 ftp://gisweb.ciat.cgiar.org/Agroecosystems/bfp_andes/WP1/Lit%20rev/Poverty/Poverty%20General/CD%20Andrew%20Farrow/sullivan%20-%20water%20poverty%20index.pdf Lawrence et al. , 2003 http://ideas.repec.org/p/kee/kerpuk/2002-19.html Scale of indicators application: national, provincial and local, depending on indicator
Geo Data Portal / UNEP/DEWA-GridEurope	The GEO Data Portal is the authoritative source for data sets used by UNEP and its partners in the Global Environment Outlook (GEO) report and other integrated environment assessments. Its online database holds more than 450 different variables, as national, subregional, regional and global statistics or as geospatial data sets (maps), covering themes like Freshwater, Population, Forests, Emissions, Climate, Disasters, Health and Gross Domestic Product (GDP). The user can display them on-the-fly as maps, graphs, data tables or download the data in different formats (shapefile,	http://geodata.grid.unep.ch/# Globally available (GIS) Not site specific Different dates of publication Scale of data application: transnational and national

Database / Product	Scope / Content	Reference / Availability / Quality
	Adobe PDF, Excel, CSV). **Evaluation: Geo Data Portal provides different data formats on diverse environmental thematic, and required data within a decision making process can be queried.**	
Global Observing Systems Information Center (GOSIC)	GOSIC provides access to data, metadata and information, and also overviews of the structure and programs form the Global Climate Observing System (GCOS), the Global Ocean Observing System (GOOS), and the Global Terrestrial Observing System (GTOS). GOSIC provides access to data and information of these partner programs, but not always to the same level of detail. Due to extensive number of data, a search through "data registry" is recommended (http://gosic.org/Datasets/ds-report.asp) **Evaluation: GOSIC provides general information about water and climate related parameters. A specific search is necessary to extract required data.**	http://www.gosic.org/default.htm http://www.gosic.org/ios/GCOS-main-page.htm http://www.gosic.org/ios/about-GTOS-observing-system.htm Scale of data application: national, occasionally provincial
Center for International Earth Science Information Network / Socioeconomic Data and Application Center	CIESIN's mission is to provide access to and enhance the use of information worldwide, advancing understanding of human interactions in the environment and serving the needs of science and public and private decision making. The Socioeconomic Data and Applications Center (SEDAC) is one of its major ongoing activities. SEDAC's aim is to develop and operate applications that support the integration of socioeconomic and earth science data and to serve as an "information gateway" between the earth sciences and social sciences. **Evaluation: SEDAC provide different data formats on diverse environmental and socioeconomic thematic that can be useful for decision making.**	http://www.ciesin.columbia.edu/download_data.html http://sedac.ciesin.columbia.edu/ Globally and regional / national available (GIS), depends on the data. Scale of data application: national

G-9 Social and Economic Aspects

Database / Product	Scope / Content	Reference / Availability / Quality
World Bank	The World Bank is a source of financial and technical assistance to developing countries around the world. The World Bank is made up of two unique development institutions owned by 187 member countries: the International Bank for Reconstruction and Development (IBRD) and the International Development Association (IDA). The IBRD aims to reduce poverty in middle-income and creditworthy poorer countries, while IDA focuses on the world's poorest countries. The World Bank's Open Data initiative is intended to provide all users with access to World Bank data. The data catalog is a listing of available World Bank datasets, including databases, pre-formatted tables and reports. An important part of the publications are the World Development Indicators available as publications and as online database **Evaluation**: The World Bank Data offers relevant and complete data and information to evaluate social and economic aspects in countries and regions: education, financial sector, health, infrastructure, labour and social protection, poverty. Changes in income or in employment due to bioenergy production might to be analyzed with this database.	World Bank: http://www.worldbank.org/ World Bank´s Open Data: http://data.worldbank.org/data-catalog/world-development-indicators/wdi-2007 World Development Indicators: http://data.worldbank.org/data-catalog/world-development-indicators No GIS. Scale of application: international and national. Yearly updated.
International Labour Organization	The ILO is the international organization responsible for drawing up and overseeing international labour standards. It is the only 'tripartite' United Nations agency that brings together representatives of governments, employers and workers to jointly	ILO Database: http://www.ilo.org/global/statistics-and-databases/lang--en/index.htm ILO Database on minimum wages: http://www.ilo.org/travaildatabase/servlet/minimumwages

Database / Product	Scope / Content	Reference / Availability / Quality
	shape policies and programmes promoting Decent Work for all. This unique arrangement gives the ILO an edge in incorporating 'real world' knowledge about employment and work. The main aims of the ILO are to promote rights at work, encourage decent employment opportunities, enhance social protection and strengthen dialogue on work-related issues. The ILO Database offers labour statistics, standards and guidelines applicable worldwide such as: application of international labour standards, labour based technology, child labour statistics, occupational health and safety regulations, minimum wages, etc. Evaluation: There is not a better collection of labour data. ILO collects national and international data. If national labour data are not available, this is the best available and reliable database.	No GIS Scale of application: international and national Yearly updated.
United Nations Development Programme – World Health Organization	UNDP is the United Nations' global development network, an organization advocating for change and connecting countries to knowledge, experience and resources. UNDP is on the ground in 177 countries, working with people on their own solutions to global and national development challenges. World leaders have pledged to achieve the Millennium Development Goals, including the overarching goal of cutting poverty in half by 2015. UNDP's network links and coordinates global and national efforts to reach these Goals. WHO is the directing and coordinating authority for health within the United Nations system. It is responsible for providing leadership on global health matters, shaping the health research agenda, setting norms and standards, articulating evidence-based policy options, providing technical support to	United Nations Development Programme: http://www.beta.undp.org/undp/en/home.html World Health Organization: http://www.who.int/en/ UNDP/WHO 2009 report "Energy access situation in developing countries": http://content.undp.org/go/cms-service/stream/asset/?asset_id=2205620 No GIS. Scale of application: international and national Regularly updated

Database / Product	Scope / Content	Reference / Availability / Quality
	countries and monitoring and assessing health trends. A large amount of data and sources of data at the global, regional and national levels on energy access are contained in the UNDP/WHO 2009 report "Energy access situation in developing countries". **Evaluation**: UNDP and WHO offers data about development standards around the world. Information about bioenergy and its availability might to be a topic of one of their reports.	

Appendix H:

Biofuels and employment effects: Implications for socio-economic development in Thailand

Thapat Silalertruksa, Shabbir H. Gheewala, Katja Hünecke, Uwe R. Fritsche

Biofuels and employment effects: Implications for socio-economic development in Thailand

Thapat Silalertruksa[1,2], Shabbir H. Gheewala[1,2,*], Katja Hünecke[3], Uwe R. Fritsche[3]

[1]Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Bangkok, Thailand

[2]Center for Energy Technology and Environment, Ministry of Education, Thailand

[3]Öko-Institut, Energy & Climate Division, Darmstadt, Germany

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Abstract

The study assesses the impacts of the biofuels production to the socio-economic development in Thailand. The four kinds of biofuels considered in the analyses are ethanol from cassava, molasses and sugarcane ethanol as well as palm biodiesel. The key elements of socio-economic development including employment generation, economic effects on GDP and trade balance are investigated based on a combination of process and input-output analysis. The results show that producing bio-ethanol and biodiesel require about 17-20 and 10 times more workers than gasoline and diesel as per energy content, respectively. Direct employment in agriculture contributes to more than 90% of total employment. Nevertheless, there are the significant differences in the characteristics of employment in the agriculture and biofuel processing sectors. The overall impacts of bio-ethanol production in Thailand in year 2022 are the employment generation of around 238,700-382,400 persons-year, 5.5 billion THB additional GDP, imported goods worth 58 billion THB but 93 billion THB of imports would be saved if compared to petroleum fuels. The other socio-economic aspects such as agricultural improvement and rural development due to biofuels policy in Thailand and some policy measures that need to be urgently promoted are also discussed in the study.

***Keywords**:* Biofuels; Socio-economic; Input-Output analysis; Employment

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1. Introduction

Emergence of the biofuels industry is expected to bring opportunities for socio-economic development especially in developing countries due to a number of reasons. First of all, investment in the new biofuel sector would result in expenditure in various sectors of the economy through the entire lifetime of the plant. These expenditures will affect other economic sectors and result in an increase in economic activity besides the operation of the biofuels. Employment and income generation at the local level is another expectation from biofuels development because biofuels offer jobs both in agricultural and processing sectors. The labor intensity of biofuels production compares favorably with conventional fuels; a World Bank study reveals that biofuels require about 100 times more workers per joule of energy content produced than the fossil fuel industry [1]. Therefore, to promote production and use of biofuels derived from indigenous feedstocks in developing countries, for which generally agriculture is the most important economic sector and the most labor intensive, would be an important strategy to enhance both the country's energy security and poverty reduction in rural communities.

Today, there is a growing of employment in biomass and biofuel sector. For examples, the estimations of four leading countries in renewable energy i.e. Brazil, USA, China and Germany indicated that around 1.2 of the totaled 2.3 million people employed in renewables in 2006 was in biomass and biofuel sector and half of them are in biofuels and mostly in agriculture [2]. In the United States, the ethanol industry was estimated to employ between 147,000 and 200,000 people from farming to biofuels plant construction and operation [1], and the conservative projections revealed that every billion gallon of ethanol production may create 10,000 – 20,000 jobs [3]. The ethanol industry in Brazil employs about half a million workers, and there are hopes that its biodiesel program launched in 2006 might generate as many as 400,000 jobs [1]. In South Africa, a total of 350,000 direct jobs would be created if 15% of gasoline demand was substituted by bio-ethanol and diesel was replaced by biodiesel. These job figures would be doubled after accounting for indirect employment [4]. Other countries are also hopeful that the biofuels program proposed by the government will create significant employment e.g. in France, Spain, Columbia, Venezuela, Nigeria, Indonesia and Malaysia [2]. Nevertheless, those increased employments from biofuel policies may not enough to show the benefits of biofuels on the social and socio-economic development as the other related aspects such as the quality of jobs, labor rights and working conditions have not yet been investigated. These social aspects are being concerned due to a variety of initiatives and certifications schemes had addressed these issues in the socio-economic standards for sustainable bioenergy and/or sustainable biofuels production [5-8]. This especially needs to be further investigated in the agriculture of developing countries which labor laws or standards related to labor rights, child labor, working conditions and health and safety conditions do not cover to force as compared to the industry.

Thailand is one of the developing countries that highly rely on crude oil import. However, due to Thailand is an agro-industrial based country and is one of the world's leading exporters in agricultural commodities. The benefits of the agricultural sector in Thailand can be foreseen as agriculture contributed to 9% of GDP in 2009 [9]. In addition, the contribution of agriculture to employment accounted for 38% of total employment in 2009 [9]. Therefore, The policy on biofuels promotion has been initiated by the Royal Thai Government (RTG) in order to enhance energy security as also to increase farmer incomes and to boost rural development. The anticipated rising demand for energy crops in the future would be a great opportunity to create employment and value added in this key sector of Thailand's economy [10]. Nowadays, the major liquid biofuels that are being promoted in Thailand are bio-ethanol derived from cane molasses, cassava and sugarcane and biodiesel produced from palm oil derivatives and used cooking oil. In 2010, the average bioethanol production is around 1.1 M.litre/day [11] and bio-diesel production is around 1.5 M.litre/day [12]. The demands for biofuels are likely to increase continuously in foreseeable years according to the recent 15 years national alternative energy development plan (2008/2022). The goals for bioethanol and bio-diesel production in Thailand are set to 9 and 4.5 M.litre per day, respectively, by 2022 [13]. According to these ambitious goals of biofuels development, evaluation of the employment and socio-economic impacts of Thai biofuels policy would be useful to inform policy-makers in the external costs-benefits of biofuels. This would be helpful for more complete comparison on the cost performance of biofuels policy due to the socio-economic externalities could be internalized into the costs-benefits analysis of biofuels.

The study aims to assess employment and other socio-economic impacts of the biofuel production systems in Thailand compared to the petroleum fuel production systems. The key elements of socio-economic development are investigated including employment generation, economic effects on Gross Domestic Product (GDP) and trade balance. The functional unit used in the comparison is 1 TJ of biofuels/fuels. The analysis of employment effects covers the employment generation and characteristics of employment in biofuel production systems. In addition, the study also evaluates the potential number of persons would be engaged if the goals on biofuels development of the 15 years Alternative Energy Development Plan (2008-2022) were achieved. The scope of the assessment includes quantification of direct and indirect employment effects of the existing biofuels in Thailand including bio-ethanol derived from cassava, molasses and sugarcane and biodiesel derived from oil palm. Direct employment is generated in cultivation and harvesting of feedstocks e.g. sugarcane, cassava and oil palm cultivation as well as in the biofuels processing industry. Indirect employment is generated in the industries that produce intermediate deliveries to the agriculture and biofuel processing sectors as shown in **Figure 1**. The results are expected to describe the following questions i.e. (1) the number of persons would be engaged in biofuels production in Thailand; (2) the characteristics of employment; (3) the employment of biofuels production and its implications for social and socio-economic development in Thailand; and (4) the socio-economic effects of biofuels on the GDP and trade balance.

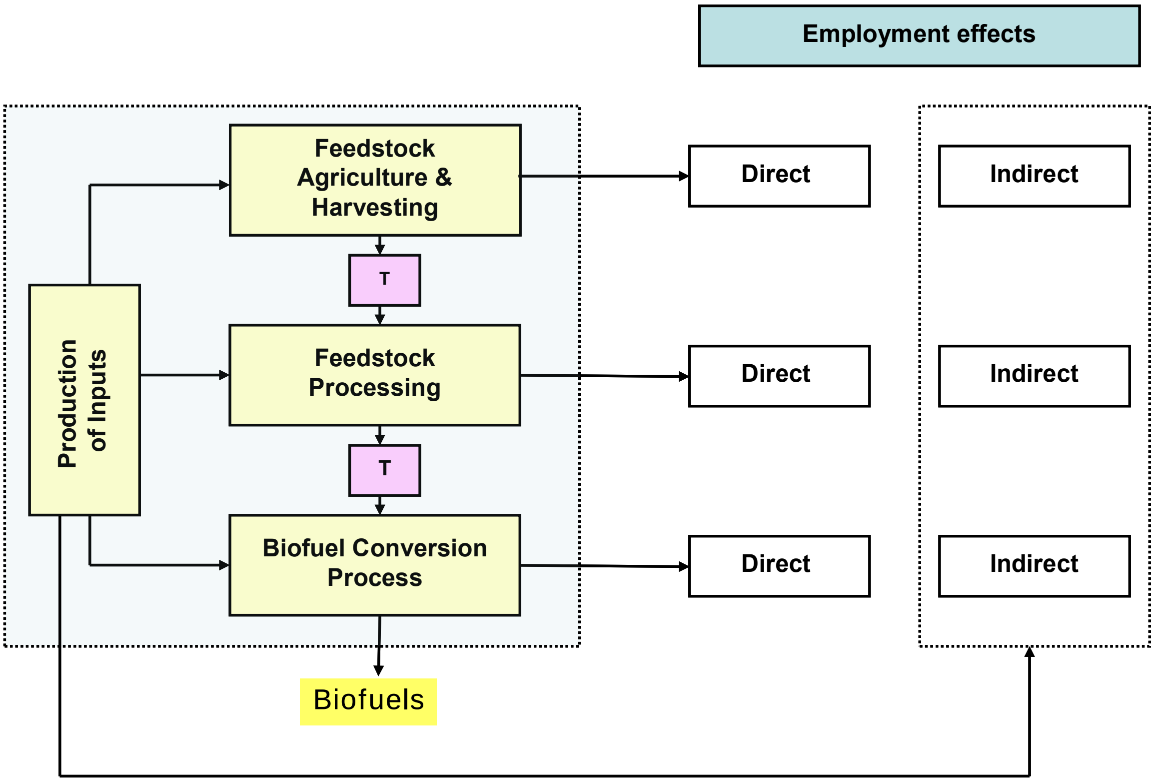

Figure 1 Scope of the employment impacts analysis

2. Methodology and Data sources

A variety of approaches has been used to estimate the employment effects from the economic sectors or the economic activities. For examples, in case of the conventional industries, the data generally tends to be well-collected by the government or the other statistical offices. However, for the newly-emerging sectors such as 'biofuels sector', employment estimates may alternatively be derived from industry surveys, from analytical method to estimate the generated employment coefficients (e.g. employment per investment spending, or per production capacity installed, or per unit of energy produced) [14-17], or from macroeconomic models such as input-output (IO) economic models to capture direct and indirect employment impacts [18-22]. Each approach has its advantages, applications and constraints. The analytical approach is generally accurate to estimate the direct employment effects of the main production stages through "process analysis" but its analysis in the indirect employment generated in the higher order production stages is usually restricted due to lack of data. This contrasts to the use of economic IO models whose strength is that the complete value chain and the interdependence of the different economic sectors are considered. Therefore, all direct and indirect employment effects of the economy from an economic sector will be estimated in a rather complete picture [18]. This study, therefore, prefers to use the "hybrid method", a combination of the analytical approach (micro level) and Input-Output model (macro level), to investigate the employment effects of biofuels production in Thailand. The step-by-steps of assessment are as follows:

2.1. Analysis of direct employment

This step estimates the effects on direct employments of feedstock cultivation and harvesting, feedstock processing and biofuels conversion using the production process analysis. For agriculture, the analysis of the expenditures for labors in cultivation and harvesting of cassava, sugarcane and molasses complemented with the annual wage data is used to determine the employment in feedstock cultivation and harvesting [23]. For the feedstock processing stage and biofuel conversion stage there are known number of producers and direct surveys and interviews have been performed to collect the actual number of employees in each factory. **Table 1** shows the assumptions for the crop productivity and biofuel conversion efficiency used in the study.

Table 1 Baseline crop productivity and conversion efficiency of Thai biofuel production

Feedstocks	Biofuels	Crop productivity (2005-2008)	Conversion efficiency (Litre biofuel/ton feedstock)
Sugar cane	Molasses ethanol	Average : 56.8 ton cane/hectare	250 - 330
	Sugarcane etha-	Range : 46.2 – 68.1 ton cane/hectare	70 – 80

	nol		
Cassava	Cassava ethanol	Average : 21.2 ton roots/hectare Range : 16.9 – 23.8 ton roots/hectare	167 – 180
Oil palm (Fresh fruit bunches: FFB)	Palm biodiesel	Average : 16.2 ton FFB/hectare Range : 15.6 – 17.5 ton FFB/hectare	158 - 182

2.1.1. Direct employment in agriculture

The direct employment effects in agriculture are calculated from the expenditures for goods and services during land preparation, feedstock plantation, treatment and harvesting and their share of labor costs. The potential number of direct employment in agriculture can be quantified by utilizing data on labor costs in feedstocks production divided by the average annual working-hours in agricultural sector in Thailand as following equation.

$$Employment_{agr} = \frac{PC_{feedstock} \times Laborshare}{AWG_{agr}}$$

where $Employment_{agr}$ is the agricultural employment in agriculture (person-year/rai); $PC_{feedstock}$ is the production costs of feedstock (THB/rai); $Laborshare$ is the share of labor cost in $PC_{feedstock}$ and $AWG_{agr}$is the average annual wage per employed person in agricultural sector of Thailand (THB/person-year). The production costs data of cassava, sugarcane and oil palm during from year 2005-2008 are collected from the Office of Agricultural Economics [24]; while, the wage data of agriculture in Thailand is referred from the National Statistical Office [25-27].**Table 2** shows the estimated labor-force requirements for biofuel feedstocks cultivation and harvesting.

Table 2 The estimated direct employment coefficient of feedstocks production in Thailand

	Employment coefficients		
	(Person-yr/hectare)	**(Person-yr/ton)**	**(Person-yr/ML Biofuels)**
Sugar cane	0.38 - 0.56	0.006 - 0.009	81 - 124
Cassava	0.19 - 0.31	0.008 - 0.013	34 - 52
Oil Palm	0.19 - 0.25	0.011 - 0.017	68 - 105

2.1.2. Direct employment in the processing sectors

The study determines the direct employment of feedstock processing and biofuel industries by collecting data about the number of employees and production capacities from 5 sugar mills, 5 dried-chip floors, 10 bio-ethanol plants, 4 palm biodiesel plants and 17 palm oil mills. The estimated employment generation coefficients for the relevant processing sectors in biofuel production systems in Thailand are shown in **Table 3**.

Table 3 Surveys of the employed persons in biofuels production chain

		Employment coefficients	
Stages	**Units**	**Average**	**Range**
Feedstock processing			
Sugar milling	Persons.year/1000 ton cane (TC)	0.36	0.29-0.47
Dried chips processing	Persons.year/Ton chips	0.01	
Palm oil milling	Persons.year/M.ton crude palm oil (CPO)	10.4	5.9-19
Biofuels conversion			
Cassava ethanol	Persons.year/ML	1.3	0.4-2.7
Molasses ethanol	Persons.year/ML	1.7	0.3-3.9
Sugarcane ethanol	Persons.year/ML	2.4	-
Palm oil biodiesel	Persons.year/ML	0.5	0.3-0.6

2.2. Analysis of indirect employment

2.2.1. Input-Output analysis

The concepts of IO analysis have been described in many publications [28-30]; therefore, only the main equations used for IO analysis are stated here. To perform the IO analysis, IO tables are developed by dividing the economy of a specific area (e.g. nation) into a numbers of sectors as a matrix and indicating the monetary flows of goods and services within a sector and to other sectors of the economy within a specific period of time [31]. This is to analyse the relationship between production and consumption as well as the interdependence of industries in a whole economy. The sectors in the IO tables are theoretically defined by homogeneous products (i.e. each production sector produces just one product), homogeneous production technologies (constant return to scale), homogeneity of prices (the product will be sold for each use at the same price) and no substitution (no possibility to substitute the inputs without changing the output) [20].

Let x_{ij} be the elements of a matrix $(n \times n)$of intermediate demand of economic sectors $j = 1, \dots, n$ from sectors $i = 1, \dots, n$ and F be a vector $(n \times 1)$ of final demand from economic sectors $i = 1, \dots, n$. Based on a fundamental concept of IO analysis, the balance of inputs and outputs of goods and services in a whole economy [28], the total demand X_i from sector i can be determined by adding intermediate and final demand as per the following equation:

$$X_i = \sum_{j=1}^{n} x_{ij} + F_i \qquad (1)$$

As the inputs into each sector (including the intermediate deliveries) are proportional only to the level of output of that sector [28], then the “input coefficients” or “technical coefficient of production” (a_{ij}) can be determined as follows:

$$a_{ij} = \frac{x_{ij}}{X_i} \qquad (2)$$

If we let A be an input coefficients matrix $(n \times n)$ which contains the elements of the input coefficients (a_{ij}), the equation (1) can be rewritten in matrix format as follows: $X = AX + F$. Solving for X yields,

$$X = (I - A)^{-1} \times F \qquad (3)$$

where I denotes an $(n \times n)$ identity matrix and $(I - A)^{-1}$ is known as "Inverse matrix or Leontief inverse matrix". If it is now assumed that the technology matrix is representative also for the marginal variation in the total output (ΔX) as a result of a marginal variation in the final demand (ΔF), then

$$\Delta X = (I - A)^{-1} \times \Delta F \qquad (4)$$

The socio-economic effects of biofuels production on the economy can be evaluated by assuming that the inputs needed for the production in the new biofuels industry are requested from the existing sectors of the economy. As the biofuels production industry is new and not yet accounted for in the IO table, its demand for inputs from the intermediate sectors is considered exogenous and is accounted for by an additional final demand vector (F). This vector is determined by splitting the costs of production of biofuels so that each cost item can be assigned to one of the sectors defined for the IO table. Then, equation (4) is applied to assess the impacts on the total output of each of these sectors.

2.2.2. Data preparation

For Thailand, the IO tables are compiled and published by the National Economic and Social Development Board (NESDB) in four formats i.e. 16×16, 26×26, 58×58 and 180×180 sectors to show the inter-industrial linkages and are updated every five years [32]. To assess the indirect employment effects caused by biofuels production in Thailand, the study applies the most disaggregated format (180×180) of 2005 IO tables of Thailand in the analyses by aggregating it into a new format (50×50 major sectors) relevant to the biofuels production as listed in **Appendix 1**. Every cell of transaction value in this newly grouped IO tables is at purchasers' prices wherein the trade margin (wholesale plus retailed), transportation cost and import are included. To quantify the net employment (direct plus indirect employment) of biofuels, the following steps of data preparation have been done.

(1) Determining the Leontief inverse matrix

First of all, the study uses the new aggregated 2005 IO tables (50×50 sectors) to calculate the input coefficient matrix (A) and the inverse matrix $(I - A)^{-1}$. This is to see how many production values of each sector are directly and indirectly necessary (including imports) to produce products worth 1 Million THB.

(2) Determining the direct employment vector

Secondly, the direct employment coefficients i.e. the direct labor requirement per unit of output in each sector are identified to indicate the number of persons employed per unit of output. In this study, the direct employment coefficient is denoted by $l_1, l_2, l_3, \ldots, l_n$ and can be determined as:

$$l_i = \frac{L_i}{X_i} \quad (i = 1,2,3, \ldots, n)$$

where l_i is the direct employment coefficient of sector (i); L_i is the total employment of the sector(i); and X_i is the gross output of the sector(i). These estimated direct labor coefficients will be used to constitute the "direct employment vector", $L = (l_1, l_2, l_3, \ldots, l_n)$ [33]. The number of employed persons (age over 15 years) in each economic sector (L_i) are compiled from the Labor force survey (LFS) in year 2005 [34] and the Industrial Census year 2007 [35] of the National Statistical Office (NSO). The total output of each economic sector (X_i) is referred from the 2005 IO tables. Then, the unit of direct employment coefficient (l_i) would be the number of employment (persons-year) according to a demand of 1 Million THB in that economic sector as shown in **Appendix 1**.

(3) Determining the total employment coefficients

Thirdly, the total direct and indirect employment generated per unit of final demand in a given sector is calculated by multiplying the inverse matrix $(I - A)^{-1}$ with the direct employment vector (L). The sum of each row shows the total employment generated (E_j) by 1 million THB increase in the final demand of sector (j). From this, indirect employment coefficients can also be determined by subtracting the direct employment coefficient from the total employment coefficient of each sector. Thus, the quantity of employment, both direct and indirect, for a demand of 1 Million THB can be estimated as shown in **Appendix 1**. In addition, the employment multiplier (e_j) can be derived as the ratio of total employment generated to the direct employment requirement per unit of output in the given sector. Hence, the employment multiplier can be given by

$$e_j = \frac{E_j}{l_j} \quad (j = 1,2,3,\dots,n).$$

(4) Quantifying the employment impacts of biofuels production

To quantify the employment impacts caused by biofuel production, the final demand vectors (F) of molasses ethanol, cassava ethanol, sugarcane ethanol and palm biodiesel are determined by breaking down their production costs into the cost items; thereafter, each cost item is assigned to one of the sectors defined for the former IO tables. Feedstock costs, the main contributor of biofuel production costs, are referred from the agricultural statistics of Thailand [36]. The breakdown of biofuel conversion costs are obtained from previous studies on life cycle costing of biofuels in Thailand [37-40]. The relevant economic sectors for each cost items are summarized in **Appendix 2**.

3. Results and Discussion

3.1. Employment effects from biofuels development in Thailand

The direct and indirect employments caused by biofuels production in Thailand are estimated based on hybrid approach as shown in **Table 4**. Per M litre of biofuel, palm biodiesel induces the biggest numbers of employment i.e. 128 employed persons followed by sugarcane ethanol, cassava ethanol and molasses ethanol, respectively. However, if the comparison is done on the basis of energy content of biofuels, say based on 1 TJ of biofuels, producing all bio-ethanol products would generate nearly the same employment i.e. 5-6 persons-year; while, palm biodiesel would generate only around 3 persons-year. Direct employment in agriculture is the most essential employment benefits generated from producing biofuels in a developing country like Thailand which is less mechanized than other more developed countries. It contributes to more than 90% of total employment generation **(Table 5**). However, for molasses ethanol, as the cost of molasses is assigned to the sugar milling sector in the IO tables, the obtained employment results from this calculation will consist of the direct employment in sugar milling and the indirect employment in other sectors that deliver materials to the sugar mill; large indirect employment generation is contributed by the employment effects in agriculture (sugarcane cultivation). In other words, this significant employment in agriculture implies that policy to promote production and use biofuels could help spur rural development in Thailand. Nevertheless, two key reasons of the huge numbers of employed persons in agriculture are identified as follows: (1) agriculture is the most labor-intensive sector in the Thai economy as the farmers are generally the small scale and farm operations largely manual; and (2) low productivity due to lack of good agricultural practices.

In comparison with petroleum fuels (based on the average ex-refinery prices of gasoline and diesel during 2006-2008 i.e. 16.27 and 19.44 THB/L; and the energy content of gasoline and diesel are 32.4 and 37.9 MJ/L, respectively), the results show that producing bio-ethanol requires about 17-20 times more workers than gasoline on a per joule of energy content basis. Meanwhile, biodiesel requires about 10 times employed persons as compared to diesel. Nevertheless, only underlying the numbers of employment created by biofuels without a closer look at the characteristics and the role of employment in the biofuels sector would not be enough to interpret the social and socio-economic impacts of biofuels. Therefore, the characteristics and quality of jobs should be clarified and this is discussed further.

Table 4 Employed persons (persons.year) of biofuels production in Thailand

	Per Million litre of biofuels			**Per Terajoule of biofuels**		
	Direct	**Indirect**	**Total**	**Direct**	**Indirect**	**Total**
Cassava ethanol	70	47	117	3.3	2.2	5.5
Molasses ethanol	10	102	112	0.5	4.8	5.3
Sugarcane ethanol	85	36	121	4.0	1.7	5.7
Palm biodiesel	74	54	128	2.0	1.5	3.5
Gasoline	0.3	9.1	9.4	0.0	0.3	0.3
Diesel	0.3	10.9	11.2	0.0	0.3	0.3

Table 5 Classification of employments in biofuel production (%)

	Cassava ethanol			**Molasses ethanol**			**Sugarcane ethanol**			**Palm oil biodiesel**		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Agriculture	96%	79 %	91 %				97%	81 %	94 %	98 %	61 %	92 %
Feedstock processing	0%	8%	3%	51%	92 %	88 %				1%	20 %	4%
Ethanol conversion	4%	13 %	7%	49%	8%	12 %	3%	19 %	6%	1%	19 %	4%

3.2. Characteristics of employment (and Quality of jobs)

Employment in the biofuels sector is better understood when the characteristics of the biofuel-related employment effects in Thailand are investigated and clarified. For biofuels production in Thailand, direct labor/workers involved can be classified into two major groups i.e. holdings in agriculture and workers in the manufacturing sectors for feedstocks processing and biofuel conversion as shown in **Figure 2.** There are the obvious differences in the characteristics of employment and quality of jobs between employed persons in agriculture and the biofuels processing sector. Regarding the Agricultural Census [41], the major groups of laborers in agricultural holdings in Thailand are the group of self employed workers (or unpaid family workers) and the group of occasional workers. This means that the key advantage of biofuels on the creation of direct employment in agriculture as quantified earlier is likely to be of a temporary employment nature. This differs from the direct and indirect employment generated in the biofuel industry or the other intermediate production sectors which the surveys found that they are generally employed as permanent staff. Therefore, laborers in agriculture today are poorly protected by national labor law as compared to employed workers in the industry. For example, there are no national laws or public policies related to working conditions. In addition, as holdings in agriculture are mainly the small scale farmers, therefore, the collective bargaining is often limited to large commercial farms and plantations. Farmers are generally not able to negotiate with the middle man or industry when selling their crops. Therefore, to ensure sustainable biofuel production in the future, the standards of labor rights and working conditions should be considered by the RTG by focusing on the standards for agricultural sector in order to help those small scale farmers, employed persons or even the unpaid family workers to have more opportunity in labor rights and decent working conditions. The fair wages and selling prices of crops should be one of the labor rights criteria for sustainable biofuels production.

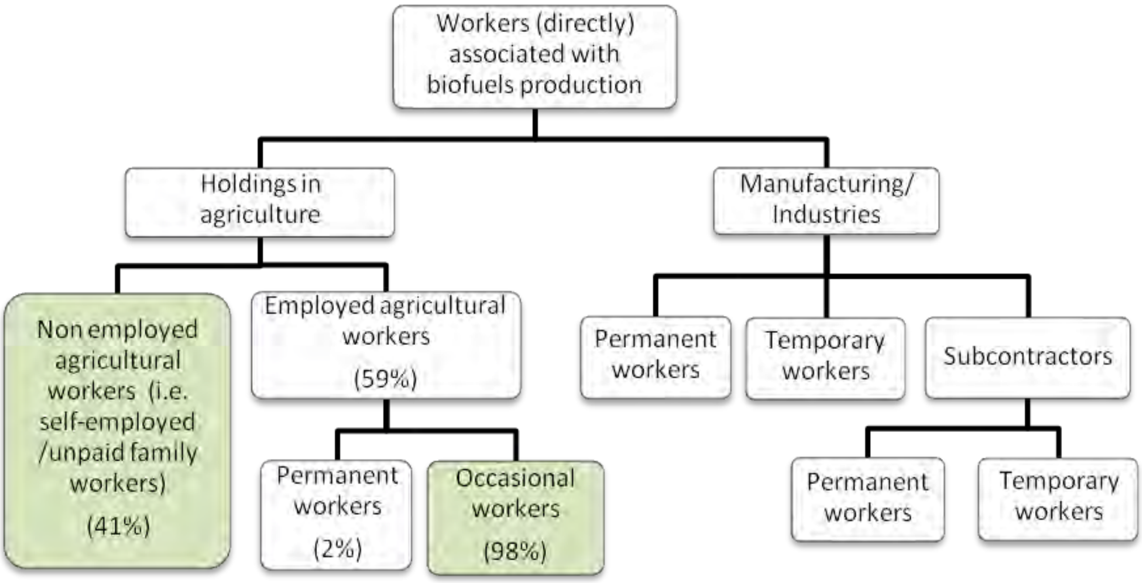

Figure 2 Clarification of labor characteristics in biofuels production

3.3. Employment effects of Thai biofuel targets

Employment generation in the sector of biofuels is a challenge. Effects of biofuel policy to the creation of employment in the future Thai economy depends on several key factors including biofuels production targets, types of feedstocks used and the development of agricultural productivity and biofuels production technologies. For example, if the machinery for harvesting sugarcane were introduced to replace the manual harvesting in the large-scale sugarcane plantations in order to increase yields in the future, this would decrease the numbers of direct labor for harvesting sugarcane which currently is the major proportion of employed persons in sugarcane plantation. This section aims to evaluate the total employment effects of the biofuel development in Thailand based on the 15 years alternative energy development plan (2008-2022) in which the ambitious goals of bio-ethanol production have been set at 9.0 M.litre/day in 2022. According to the installed capacity of current and future ethanol plant that licensed by the government, Silalertruksa and Gheewala (2010) estimated that the future bio-ethanol production system in Thailand (year 2022) would consist of producing 1.72 M.litre molasses ethanol/day, 6.48 M.litre cassava ethanol/day and 0.8 M.litre sugarcane ethanol/day [42].

Four scenarios for increasing feedstocks production to satisfy the increased demand for bio-ethanol in the future are assumed and investigated. The descriptions of the scenarios are as follows:

Scenario 1: To expand the cultivation areas for cassava and sugarcane while maintaining the crops yields of cassava and sugarcane at the current levels i.e. 21.9 ton/hectare for cassava and 70 ton/hectare for sugarcane.

Scenario 2: To follow the government policy of keeping the plantation areas of cassava and sugarcane at the same level as year 2008, cassava and sugarcane yields must be improved to 50 and 125 ton/hectare in 2022, respectively in order to have enough supply for total future demands [42]. These increases in yields will actually affect the increase in labor requirements for regular treatment, for inputting more fertilizers and for harvesting the increased crop products. However, in this scenario, the labor requirements during cultivation and harvesting are assumed to be the same as the current situation since the mechanized system is assumed to be adopted in the future.

Scenario 3: Same as scenario 2, however, the labor requirements for treatment and harvesting during feedstock production are assumed to increase 50% of the rate of increased yields.

Scenario 4: Same as scenario 2, however, the labor requirements for treatment and harvesting as employment for treatment and harvesting are assumed to increase same as the rate of increased yields.

Based on target of producing 9 M.litre of bio-ethanol per day in 2022, the assessment shows that the numbers of persons engaged would be ranged between 238,700 to 382,360 persons (**Table 6**). The variations depend upon the policy on the future crop productivity development for large scale biofuel production. Scenario 2, which represents the case that the requirements for workers to treatment and harvest crops will not increase due to mechanization would result in the lowest numbers of employed persons. Even though the absolute numbers of total employment induced by bio-ethanol policy are large, however, the relative importance of the employment effects is limited. As compared to the total employments in agriculture (year 2009) which is around 14,692,500 people [27], the direct employment effects in agriculture in 2022 would range around 106,100-196,700 persons.

Table 6 Projections of employment caused by bio-ethanol target in year 2022

	Employment coefficients for high yields assumption (Persons-year/ML biofuels)			Employment caused by bio-ethanol target in 2022 (Persons-year)			
	Direct	Indirect	Total	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Molasses	10	46	56	70,374	35,209	35,209	35,209
Cassava	36	40	76	276,839	180,421	216,049	251,677
Sugarcane	47	32	79	35,152	23,075	27,388	31,701
Total				382,365	238,705	278,646	318,586

3.4 Other contributions of biofuels to socio-economic development

Biofuels development can contribute not only employment impacts but other elements of national development such as economic growth through new biofuels sector investment, economic effects on GDP, trade balance and energy security of the country [43]. The other important elements of socio-economic development caused by biofuels production in Thailand are investigated as follows:

3.4.1 GDP development

The gross domestic product (GDP) of a country is an indicator to measure economic performance and the size of the economy. Even though GDP is an economic performance indicator, however, measuring the changes in GDP can indicate the amount of income generated and retained in the country itself [31]. The study determines the effects of biofuels production in Thailand on the total value added or GDP of Thai economy. To perform the analysis, the direct GDP coefficient for each sector is obtained by dividing the direct value added of each sector in the modified IO table by the sector's total output as shown in Appendix 3. Then, the total GDP coefficient can in turn be calculated from the multiplication of the inverse matrix and the direct GDP coefficient vector. Referring to the changes in final demand due to biofuels production, the total impacts of different kinds of biofuels in Thailand on GDP can be estimated as shown in **Table 7**.

The results show that to produce 1 M.litre of cassava ethanol, molasses ethanol, sugarcane ethanol and palm biodiesel contribute around 18, 15, 22 and 23 M.THB to the national GDP, respectively. The main contributors to the changes in GDP of biofuels are the direct impacts from agriculture followed by the indirect impacts from energy and chemicals consumptions. The high share of direct impact stems from the amount of feed-stocks used and their costs which are the largest production cost component of biofuels. The shares of feedstock costs to total GDP effects range around 62-73% of direct impacts or 29- 55% of total impacts on GDP. A special remark for the case of palm biodiesel is that the methanol used would be the second contributor to GDP development. This obtained GDP effects of biofuels can be directly considered as the benefits of biofuels to the GDP of the country. In addition, this increase in GDP or value added can imply a rise in the income of the people as the terms of “total value added” in IO table also include the primary inputs such as wages and salaries.

However, if the induced impacts of increased use biofuels to the decrease in the production amount of petroleum fuels e.g. gasoline and diesel were considered, the results show that those GDP benefits of biofuels would be decreased by around 90%. (based on assumption that 70% of GDP effects in producing petroleum fuels at the same equivalent amount of ML biofuels are decreased). This is because biofuels used in Thailand are in the blended forms between biofuels with conventional fuels. Therefore, there still have several processes in the refinery that still in operation. Thus, the net obtained GDP effects of biofuels would be ranged 1.5-2.3 M.THB per million litre biofuels. To provide the extent of the socio-economic impacts of biofuel policy in Thailand, the target of producing 9 M.litre bio-ethanol were achieved in 2022 with cassava, molasses and sugarcane ethanol as mentioned in section 3.3 will result in an additional GDP of 5,551 M.THB.

Table 7 GDP effects of biofuels in Thailand

	GDP (M.THB) per ML biofuels			GDP (M.THB) per TJ biofuels		
Biofuels	Direct	Indirect	Total	Direct	Indirect	Total
Cassava ethanol	9.39	8.89	18.28	0.44	0.42	0.86
Molasses ethanol	8.89	6.15	15.04	0.42	0.29	0.71
Sugarcane ethanol	10.14	12.01	22.14	0.48	0.57	1.04
Palm biodiesel	17.07	6.08	23.15	0.47	0.17	0.64

3.4.2 Trade balance

Another benefit of import substitution is the improvement of the country's trade balance. Balance of trade is one of the crucial aspects for developing countries in that it measures a country's dependence on other countries and the country's possibilities for generating income from selling to other countries [31]. Therefore, it is necessary to determine the amount of import needs for biofuels production systems in Thailand and comparing with the case of conventional fuels such as gasoline and diesel. IO analysis has been used in the same way as the analyses of impacts on GDP. **Table 8** shows the effects of imports obtained from the multiplication of the final demands for biofuels production and the import coefficients in Appendix 3. The results show that producing 1 TJ of cassava ethanol, molasses ethanol, sugarcane ethanol and palm biodiesel will result in an increase of total imports around 1.05, 0.66, 1.81 and 0.54 M.THB, respectively. Nevertheless, if compared to the cases of producing gasoline and diesel at the same energy performance i.e. 1 TJ, production of biofuels to substitute petroleum fuels could decrease the country's imports by 0.37 – 1.12 M.THB per TJ of bio-ethanol and 1.68 M.THB per TJ of biodiesel.

For imports, the largest contributor are the indirect impacts of chemicals used in the biofuels conversion stage followed by the indirect impacts from energy consumed. The fractions of chemicals consumption to the imports range between 18-57% of indirect impacts or around 13-37% of total imports. In addition, the total imports of chemicals for biofuels production share about 25-68% of total imports. Thus, if the targets of producing bio-ethanol about 9 M.litre/day (or equivalent to 69,642 TJ/day) were achieved in 2022, the bio-ethanol production could help reduce imports by 93,288 M.THB/year.

Table 8 Import effects of biofuels in Thailand

Biofuels	Import (M.THB) per ML biofuels			Import (M.THB) per TJ biofuels			Difference* (M.THB/TJ)
	Direct	Indirect	Total	Direct	Indirect	Total	
Cassava ethanol	6.33	16.00	22.33	0.30	0.75	1.05	- 1.12
Molasses ethanol	3.76	10.26	14.03	0.18	0.48	0.66	- 1.52
Sugarcane ethanol	13.88	24.46	38.35	0.65	1.15	1.81	- 0.37
Palm biodiesel	7.11	12.42	19.53	0.20	0.34	0.54	- 1.68

*Difference = (total import/TJ of bio-ethanol) – (total import/TJ of gasoline) or (total import/TJ of biodiesel) – (total import/TJ of high speed diesel)

3.4.3 Agricultural sector improvement and rural development

To satisfy the demand for biofuels production in the future, the government policies on bio-ethanol development focus on the improvement yields of cassava and sugarcane instead of expansion of cultivation areas. This is in contrast to the policy of biodiesel development where both expansion of cultivated areas and yields improvement are considered. Cassava yields are anticipated to improve as per the government's short-term policy targets as mentioned in the 15 years renewable development plan i.e. increase yield of cassava from 21.9 to 33.7 ton roots/hectare by 2013 and increase yield of sugar cane from 68.7 to 93.8 ton cane/hectare by 2012. These yield improvement rates would be faster than the average annual growth rates of cassava and sugarcane yields during 2000-2008 which are just about 3% and 2%, respectively annually [42]. Nevertheless, to enhance security of feedstocks supply for long-term bio-ethanol production in Thailand, cassava and sugarcane yields must be improved to 50 and 125 ton/hectare by 2022, respectively [42]. This means that more research and development of high yield varieties of cassava and sugarcane is necessary as well as the promotion of good agricultural practices (GAP) such as improved soil quality by using organic fertilizers, good practices in land preparation, plantation, harvesting and regular weed control that could help reaching those yield targets [44]. However, the current varieties of cassava (e.g. Kasetsart 50, Rayong 5, Rayong 72 and Rayong 9) and sugarcane (e.g. K 84-200, U thong 3 and K 90-54) being recommended to Thai farmers have the potential to yield about 31.2 - 50 ton/hectare for cassava and 93.8 – 112.5 ton/hectare for sugarcane if cultivated in appropriate soil with good agricultural practices [44]. This is a little different from the case of palm biodiesel where both increase in FFB yields and expansion of new oil palm plantation need to be promoted urgently by the government to avoid the shortage of CPO supply for future food and fuel production.

Besides, the creations of direct employment in agriculture which in turn results in the generation of income to workers or farmers in rural areas, some policies of the RTG to promote biofuels/bio-energy are also expected to boost rural development and raise the living standard of people in rural areas. For example, the RTG has a plan to encourage community-based biodiesel production and use in 72 communities across the country in order to reduce local communities' expenses on energy by using biodiesel derived from used cooking oil or oil plants grown in the community such as jatropha to substitute diesel in agricultural machines. Technical assistance is also provided through learning centers, financing pressing and biodiesel processing machines, as well as conducting training and information sharing on farming oil crops [45]. In addition, the increased demand for crops to produce biofuels in the future is also anticipated to raise and stabilize the selling prices of crops and this may be beneficial to farmers for a having more credit to access banks in the future. However, the nature of small farm holdings in the agricultural sector of Thailand lead to the limitation of farmer's ability to negotiate with middle man or industry for receiving the most appropriate prices of crops. Therefore, the policy instruments to protect the small scale farmers through collective bargain are required and the formation of cooperatives would be a helpful approach to negotiate fairly with middlemen or industry. In addition, there are other social and/or socio-economic benefits and risks of biofuels policy relevant to Thai society and need further investigation. For example, biofuels policy can help security of energy supply and diversification of energy sources for the country. However, the rapid increase in demand for biofuels might have adverse impacts to people and environment in rural areas such as the trespassing on the reserve land, the poorer/small-scale farmers losing their ability to access the land to the large-scale investors and children may become permanent farm laborers since an early age. Measures to protect against those risks need to be implemented to guarantee the sustainability of biofuels in the social and socio-economic dimension.

4. Conclusions

The study concludes that the policy to promote bio-ethanol in a developing country such as Thailand has a significant impact to the economy and socio-economic development. At the current crude oil prices, the production costs of biofuels are higher than petroleum fuels, either in pure or blended form and policy instruments such as tax exemptions are required from the government to promote biofuels in commerce. However, the results reveal that promotion of biofuels production and consumption in Thailand could result in various positive externalities to the economy. For example, producing bio-ethanol in Thailand would generate employment of about 5-6 persons-year/TJ or 17-20 times more workers than gasoline production. Producing palm biodiesel on the other hand would generate about 3 persons-year/TJ or about 10 times more workers than diesel. Direct employment in agriculture is the most essential employment benefit contributing more than 90% of the total employment generation. Nevertheless, there are the obvious differences in the characteristics of employment and quality of jobs between persons employed in agriculture and the biofuel processing sector in Thailand.

For GDP development, to produce 1 M.litre of biofuels contribute an additional GDP of around 1.5 - 2.3 M.THB after accounting for the induced impacts of increased use biofuels to the decrease in the production amount of petroleum fuels. The main contributor to the changes in GDP of biofuels is direct impacts from agriculture which originate from the amount of feedstocks used and their costs. These GDP developments imply the rise in people’s income as the terms of “total value added” in the IO tables also include the primary inputs such as wages and salaries. For balance of trade, production of biofuels to substitute petroleum fuels would decrease the country's imports by around 0.37 – 1.12 M.THB per TJ for bio-ethanol and 1.68 M.THB per TJ for biodiesel. Those socio-economic impacts would raise the attractiveness of biofuels and could make biofuels competitive with petroleum fuels in terms of net social benefits. However, there are several socio-economic aspects such as measures to improve agricultural productivities through good agricultural practices and measures to protect small scale farmers from unfair trade which need to be urgently promoted to realize adequate benefits.

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Appendix 1.

Employment coefficient of each sector for 1 Million THB spending in each sector (persons-year/M THB)

No.	Economic sectors	Employment coefficients			Employment multiplier (e_j)
		Direct (l_i)	Indirect	Total	
001	Paddy, Maize, Cereals	14.11	1.89	16.00	1.13
002	Cassava and other root crops	14.11	4.91	19.01	1.35
003	Sugarcane	14.11	3.22	17.33	1.23
004	Oil Palm	14.11	1.54	15.65	1.11
005	Rubber	14.11	0.52	14.63	1.04
006	Beans, Nuts, Vegetable, Fruits and other agriculture	14.11	2.50	16.61	1.18
007	Livestock				

No.	Economic sectors	Employment coefficients			Employment multiplier (e_j)
		Direct (l_i)	Indirect	Total	
		14.11	5.74	19.85	1.41
008	Forestry	14.11	1.43	15.54	1.10
009	Fishery	3.21	1.77	1.78	0.55
010	Coal and Lignite	0.18	0.48	0.67	3.64
011	Petroleum and Natural Gas	0.18	0.48	0.66	3.60
012	Metal Ore	0.18	0.72	0.90	4.92
013	Non-metal Ore	0.18	0.78	0.96	5.24
014	Slaughtering, Palm oil and food processings	0.80	8.85	9.65	12.03
015	Rice, Tapioca, Maize and Other Grain Milling	0.68	12.57	13.25	19.51
016	Sugar	0.37	6.69	7.06	19.10
017	Other food products	1.44	5.13	6.56	4.57
018	Animal feed	0.71	8.79	9.50	13.37
019	Distilleries and beverages	0.28	1.76	2.04	7.27
020	Tobacco processing and products	0.19	1.16	1.35	7.24
021	Spinning, Weaving, Bleaching and Textile products	1.25	2.72	3.97	3.19
022	Saw mills and Wood products	1.30	3.95	5.25	4.03
023	Pulp, Paper products and Printing	1.09	2.20	3.29	3.03
024	Basic Industrial Chemicals	0.74	1.30	2.04	2.76
025	Fertilizer and Pesticides	1.15	1.78	2.93	2.54
026	Resins, Plastics and Other Chemical Products	0.55	1.69	2.24	4.08
027	Petroleum Refineries and Other petroleum products	0.02	0.56	0.57	36.60
028	Rubber Sheets, Block Rubber, Tyre and other rubber products	0.52	7.57	8.09	15.51
029	Cement and concrete	0.82	0.75	1.57	1.91

No.	Economic sectors	Employment coefficients			Employment multiplier (e_j)
		Direct (l_i)	Indirect	Total	
030	Ceramic, Glass and Other non-metallic products	0.83	1.36	2.19	2.64
031	Iron and Steel products	0.20	0.94	1.14	5.69
032	Non-ferrous Metal	0.66	0.86	1.52	2.30
033	Hand Tools and Fabricated Metal Products	1.44	1.04	2.48	1.72
034	Engines, Agricultural and Industrial Machinery	0.74	1.45	2.19	2.96
035	Electrical Machinery & Apparatuses	0.33	1.53	1.86	5.58
036	Motor vehicle	0.30	1.63	1.93	6.42
037	Other transport equipment	0.09	1.18	1.27	14.67
038	Scientific Equipments and Other Manufacturing Goods	0.96	1.83	2.79	2.90
039	Electricity	0.14	0.50	0.64	4.72
040	Pipe Line	0.14	0.63	0.76	5.66
041	Water Supply System	0.14	0.43	0.57	4.21
042	Contruction	3.30	1.53	4.83	1.46
043	Trade	2.32	0.53	2.85	1.23
044	Restaurant and Hotel	3.53	4.00	7.52	2.13
045	Transport	0.96	1.13	2.09	2.17
046	Post and Telecommunication	0.96	0.75	1.71	1.78
047	Bank & Inssurance Services	0.66	0.70	1.36	2.06
048	Silo, Real-estate and Other Services	1.22	1.26	2.48	2.04
049	Education, Hospital and Public Services	3.16	0.66	3.82	1.21
050	Other Services & Unclassified	2.52	2.17	4.69	1.86

Appendix 2.

The breakdown of biofuels production costs in Thailand

	Inputs to biofuels production in Thailand (THB/L biofuel)				**Related sectors in IO tables**
	Cassava ethanol	**Molasses ethanol**	**Sugarcane ethanol**	**Palm bio-diesel**	
Feedstock cost					
Cassava (fresh roots)	10.53				002
Molasses		14.00			016
Sugarcane			11.01		003
FFB				22.34	004
Feedstock processing cost					
Dried chips	0.44				015
CPO				2.21	017
Labor cost at ethanol plant	0.59	1.18	0.10		019
Labor cost at biodiesel plant				0.51	027
Energy	2.38	1.60	3.26	0.82	039
Water	0.06	0.06	0.72	0.05	041
Wastewater treatment	0.58	0.77	0.77	0.10	048
Chemicals	1.54	0.30	2.25	0.93	024
Methanol				3.95	019
Maintenance	0.35	0.30	0.07	0.02	050
Depreciation	1.22	1.15	1.15	0.65	034
Admin & Selling	0.50	0.59	0.13	0.25	050
Miscellaneous e.g. insurance, interest	0.12	0.18	0.03	0.38	047
Total	**18.32**	**20.13**	**17.53**	**32.20**	

Appendix 3.

The GDP and Import coefficients of each sector

No.	GDP coefficient (THB value added/THB output)			Import coefficient (THB import/THB output)		
	Direct GDP	Indirect GDP	Total GDP	Direct Import	Indirect Import	Total Import
001	0.67	0.40	1.07	0.06	0.21	0.27
002	0.55	0.15	0.70	0.01	0.02	0.03
003	0.58	0.26	0.84	-	0.03	0.03
004	0.57	0.03	0.60	0.01	0.02	0.03
005	0.84	0.13	0.97	0.00	0.10	0.10
006	0.60	0.59	1.19	0.19	0.27	0.46
007	0.42	0.18	0.60	0.02	0.13	0.16
008	0.78	0.15	0.93	0.36	0.12	0.48
009	0.53	0.17	0.71	0.01	0.11	0.12
010	0.68	0.13	0.80	1.51	0.50	2.00
011	0.68	2.41	3.09	3.23	4.19	7.43
012	0.66	0.26	0.91	4.82	2.24	7.06
013	0.61	0.30	0.91	0.17	0.53	0.70
014	0.20	0.40	0.60	0.21	0.26	0.47
015	0.15	0.20	0.36	0.01	0.22	0.22
016	0.44	0.11	0.55	0.02	0.06	0.08
017	0.33	0.14	0.47	0.14	0.07	0.21
018	0.14	0.31	0.45	0.13	0.08	0.21
019	0.53	0.12	0.65	0.12	0.06	0.18
020	0.80	0.09	0.89	0.35	0.04	0.38
021	0.32	0.47	0.79	0.16	0.55	0.71

No.	GDP coefficient (THB value added/THB output)			Import coefficient (THB import/THB output)		
	Direct GDP	Indirect GDP	Total GDP	Direct Import	Indirect Import	Total Import
022	0.37	0.21	0.58	0.15	0.21	0.35
023	0.32	0.77	1.09	0.45	1.06	1.51
024	0.37	1.73	2.10	5.42	6.25	11.67
025	0.23	0.96	1.19	2.24	0.53	2.77
026	0.30	1.60	1.90	0.54	2.74	3.27
027	0.18	2.09	2.28	0.17	4.17	4.33
028	0.21	0.11	0.31	0.10	0.13	0.23
029	0.40	0.13	0.53	0.00	0.07	0.07
030	0.29	0.15	0.44	0.27	0.22	0.49
031	0.22	1.97	2.19	1.40	5.17	6.57
032	0.27	0.48	0.75	4.66	2.04	6.70
033	0.28	0.57	0.85	0.70	0.81	1.51
034	0.26	0.81	1.08	1.38	1.95	3.33
035	0.19	1.08	1.27	0.72	2.15	2.86
036	0.28	0.12	0.40	0.29	0.14	0.44
037	0.34	0.14	0.48	0.95	0.32	1.27
038	0.26	0.32	0.58	0.52	0.48	1.00
039	0.48	1.06	1.55	0.00	1.93	1.93
040	0.21	0.38	0.60	0.00	0.62	0.62
041	0.66	0.05	0.71	0.00	0.08	0.08
042	0.23	0.04	0.27	0.00	0.06	0.06
043	0.75	0.32	1.06	0.00	0.73	0.73
044	0.40	0.16	0.56	0.17	0.23	0.40

No.	GDP coefficient (THB value added/THB output)			Import coefficient (THB import/THB output)		
	Direct GDP	Indirect GDP	Total GDP	Direct Import	Indirect Import	Total Import
045	0.33	0.53	0.86	0.10	1.33	1.43
046	0.61	0.48	1.09	0.16	0.66	0.81
047	0.71	1.06	1.77	0.02	1.39	1.41
048	0.61	0.89	1.50	0.10	1.74	1.84
049	0.80	0.06	0.85	0.03	0.08	0.11
050	0.37	0.49	0.86	0.12	0.59	0.70

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Appendix I: Social and socio-economic impacts of cassava and sugarcane ethanol production in Thailand

Nowadays, many sustainability standards and indicators are set in order to ensure that bioenergy/biofuels production shall not threaten the quality of ecosystems and social and economic interests of relevant stakeholders. This section aims to analyze the social and socio-economic effects associated with ethanol fuel production in Thailand and to discuss the situation and possibility to implementing the socio-economic standards and indicators for sustainable bioenergy production in Thailand. The analyses focus on the case of ethanol derived from cassava and sugarcane in Thailand. The six key social/socio-economic issues addressed in the Global Bioenergy Partnership (GBEP) sustainability indicators for bioenergy production and other standards/initiatives for sustainable bioenergy are used to assess the effects of cassava and sugarcane ethanol production in Thailand. The six major socio-economic issues are (1) land tenure, (2) rural and social development, (3) employment, wages and labor conditions, (4) human health and safety, (5) energy security and access and (6) food security.

1. Land use, Land tenure/ access and displacement

Related Indicator	GBEP-I9: Allocation and tenure of land for new bioenergy production
Indicator descriptions (ID)	Percentage of land – total and by land-use type – used for new bioenergy production where: • a legal instrument or domestic authority establishes title and procedures for change of title; and • the current domestic legal system and/or socially accepted practices provide due process and the established procedures are followed for determining legal title • problems with displacement • land ownership due to high or low income farmers etc.

A rapid expansion of bioenergy production brings about concerns over land use and land tenure issues e.g. the trespassing on reserve land and the poorer/ small-scale farmers losing access to the land due to large-scale investors (Cotula et al., 2008). This may especially have a significant effect in developing countries where the laws and regulations for land tenure are generally not in place or there is a lack of effectiveness in enforcement. Several standards for sustainable bioenergy production such as Global Bioenergy Partnership (GBEP), Roundtable on Sustainable Biofuels (RSB) and Renewable Transport Fuel Obligation (RTFO) have included criteria and indicators on the land tenure issue in order to ensure that bioenergy operations shall respect land rights and land use rights and do not adversely affect existing land rights and community relations.

1.1 Allocation of land-use in Thailand

1.1.1 Overview of land use in Thailand

Thailand has the total land area of around 51.312 million hectares which can be classified into three main categories i.e. forest land, agricultural land and other land (land for non-agricultural purpose) around 33%, 41% and 26%, respectively as shown in **Table 1.1**. Forest land means the area under forest as defined by the Royal Forest Department. Agricultural land means the total area of every piece of land held by farmers for agriculture. This includes the lands owned or held by farmers with or without rent. The other land means the residual area after reduction of forest and agricultural areas from the total areas of the country. This includes degraded forest areas, municipal areas, non-farmer residence, business and industrial areas, school, hospitals, roads, railways, airports, water ways, swamps, reservoirs, public areas and other non-agricultural areas (OAE, 2009). The statistics reveal that the agricultural land which is a limited and essential natural resource for producing food, feed, fibre and currently must also include fuel has increased slightly as also the forest land. However, there was a little decrease in total area of non-agricultural land as well due to the several national plans and acts in Thailand to protect and promote reforestation and the Land Reform for Agriculture Act which are the main laws to allocate land in non-agricultural group to farmers for cultivation. The lands covered under this reform program are both public and private lands e.g. lands for government own use such to Ratchapatsadu and army area, deteriorated land or classified land according to the resolution of the cabinet and deteriorated forest.

The allocation of agricultural land classified by main activities is shown in **Figure 1.1** The major agricultural land use in Thailand is for rice farming contributing around 50% of the total agricultural land, followed by field crops, fruit and standing timber, vegetable and ornamental plants and pasture land which are 21%, 21%, 0.9% and 0.8%, respectively (based on year 2009). The remaining areas are idle land which means the areas that left unused for more than 5 years, residential area and other lands in agricultural areas which mean the areas in the farms that allocated for non-production purposes such as roads, paths, ditches, ponds, wells, etc. Cassava and sugarcane, the two main feedstocks used for ethanol production in Thailand, are classified as field crops so their plantation areas are accounted into the category of land use for field crops.

Table 1.1 Classification of land areas in Thailand (OAE, 2009)

		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Forest	M.ha	17.01	16.10	17.01	17.01	16.76	16.76	16.76	15.86	17.16	17.16
	%	33%	31%	33%	33%	33%	33%	33%	31%	33%	33%
Agricultural Land	M.ha	20.99	20.97	20.94	20.91	20.88	20.84	20.85	20.86	21.08	21.05
	%	41%	41%	41%	41%	41%	41%	41%	41%	41%	41%
Other land (Non-agricultural)	M.ha	13.31	14.24	13.36	13.39	13.68	13.71	13.71	14.59	13.07	13.10
	%	26%	28%	26%	26%	27%	27%	27%	28%	25%	26%

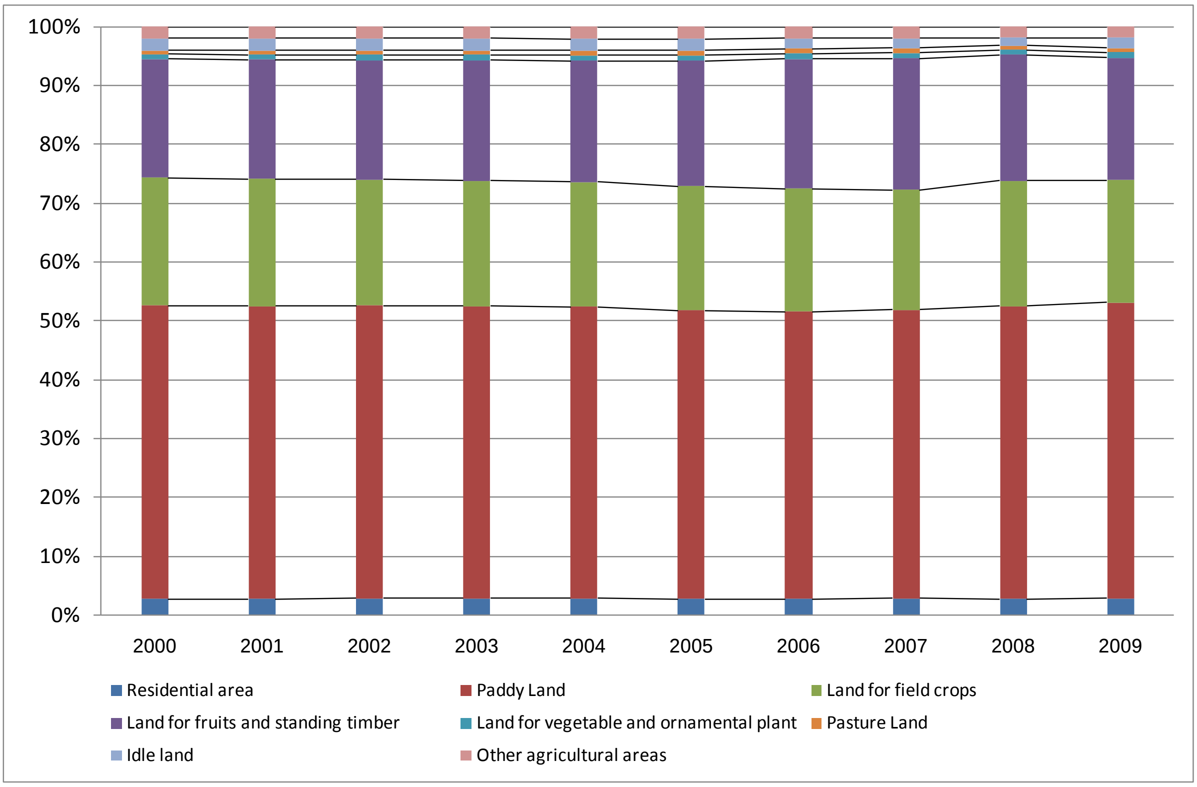


Figure 1.1 Allocation of agricultural land use in Thailand (OAE, 2011)

1.1.2 Allocation of land-use for ethanol production in Thailand

The harvested areas of cassava and sugarcane classified by region in Thailand are shown in **Table 1.2**. The Northeastern region is the main region for growing cassava in

Thailand contributing 53% of the total planted areas of cassava in 2009. Sugarcane is widely planted in the Northeastern and Central regions of Thailand; the total planted areas from both regions contributing around 70% of the total planted areas of sugarcane in Thailand (35% for each region). This implies that ethanol development policy in Thailand would have the most effects to socio-economics of farmers/people in rural areas of the Northeastern region as cassava and sugarcane are widely grown in this region. Also, the new cassava and sugarcane ethanol plants are generally located in the Northeastern and Central region as well. Contrary to ethanol, promotion of biodiesel in Thailand will have the most influence to the rural areas in the Southern region of Thailand as oil palm, the major feedstock for biodiesel production, is mainly cultivated in the south. Nevertheless, as the demand for crude palm oil increases, the government is promoting oil palm cultivation to other regions as the small figures of planted areas of oil palm in Northern and Northeastern region in **Table 1.2** show.

Table 1. 2 Planted areas of major feedstocks for biofuels production in Thailand (Unit: 1000 hectare)

	Whole country		Region							
			Northern		Northeastern		Central Plain		Southern	
Crops	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**	**2008**	**2009**
Cassava	1,240	1,373	185	234	**679**	**722**	376	417	-	-
Sugar cane	1,054	964	288	285	**403**	**339**	363	340	-	-
Oil palm	588	622	1	1	7	7	61	66	**519**	**547**
Major rice	9,188	9,200	2,017	2,045	**5,291**	**5,281**	1,571	1,573	308	300
Second rice	2,048	1,984	716	700	202	234	**1,076**	**989**	54	62

In Thailand, currently, there are 47 ethanol plants licensed by government to produce biofuel ethanol with a total capacity of 12.295 million liters (ML)/day. The two major feedstocks used for ethanol production are cane molasses and cassava (*Manihot esculenta Crantz*). The 47 ethanol plants consist of four categories classified by feedstocks used including (1) 5 molasses ethanol (MoE) plants (with a total capacity of 0.675 M.litre/day); (2) 10 molasses/sugarcane ethanol (MoE/SCE) plants (2.01 M.litre/day); (3) 8 molasses/cassava/sugarcane ethanol (MoE/CE/SCE) plants (1.22 M.litre/day) and (4) 24 cassava ethanol (CE) plants (8.39 M.litre/day) (Silalertruksa and Gheewala, 2010). However, as of year 2010, there are only 18 ethanol plants in operation with a total capacity of about 1.9 M.litre/day. Out of the existing ethanol plants, 12 use molasses (with a total capacity of 0.92 M.litre/day), 5 cassava (with a total capacity of 0.78 M.litre/day), and only one plant uses sugarcane juice with a total production capacity of 0.2 M.litre/day. The low number of licenses to produce ethanol from sugarcane juice is because the use of sugarcane juice is limited by a profit sharing system between farmers and sugar mills legally regulated by the Sugar and Cane Act. Moreover, due to the perishability of cane stalks after harvest, sugarcane juice is typically preserved as raw syrup and then used as the secondary feedstock in some factories (Sriroth et al., 2010). Based on the existing ethanol plants, the estimated percentages of total land used for cassava and sugarcane ethanol production in Thailand can be estimated as shown in **Table 1.3**. The results show that in 2009, the contributions of cultivated land for cassava and sugarcane to produce ethanol are still very low i.e. just around 2% and 0.2% of total harvested areas of cassava and sugarcane, respectively. However, if molasses, the viscous by-product of the sugar-milling is accounted for, the percentage of harvested areas of sugarcane for producing ethanol in 2009 would be 28% of total harvested areas of sugarcane in Thailand.

A study of net feedstocks balance for bioethanol production in Thailand done by Silalertruksa and Gheewala (2010) based on assumptions that (1) the policy targets set by the government i.e. producing about 3.0, 6.2 and 9.0 M.litres ethanol.day^{-1} by the years 2011, 2016 and 2022, respectively were achieved; (2) all 47 ethanol plants licensed by the government could start operation in accordance with the proposed schedule (as updated in September 2009) and are fully operational by year 2016; (3) plantation areas of cassava and sugarcane are maintained the same as year 2008 as per the government target; and (4) the crop yields are projected to continue growing as usual i.e. the annual growth rates of cassava and sugarcane yields are about 3% and 2%, respectively. The results show that cassava and cane molasses will confront the problem of supply availability for ethanol in the future after accounting for the increased demands of cassava and molasses (both domestic use and exports) for food and other related industries. This means that either expansion of cultivation area or added yields improvement will be required to fulfil the ethanol production target in the future. Nevertheless, yields improvement approach is suggested instead of expanding additional plantation areas which may lead to other consequences to the environment such as GHG emissions from LUC. An increase of sugarcane yield to 93.75 ton/hectare as per the current policy on biofuels development is necessary to attain security of molasses supply. Otherwise, decreased export of molasses of around 16% would be required in 2022 to satisfy the bio-ethanol demand. For cassava, the yield should be improved to at least 39.3 ton/hectare by 2016 and 50.16 ton/hectare by 2022 (Silalertruksa and Gheewala, 2010). The current land use for cassava and sugarcane cultivation in Thailand classified by land suitability class and the potential to increase cassava and sugarcane yields in the future are presented in the next section.

Table 1.3 Planted and Harvested areas, Production and yields of cassava and sugarcane and the estimated allocation of land use for ethanol production in Thailand

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Cassava										
Planted Area[1] (1000 ha)	1,185	1,107	996	1,029	1,081	1,044	1,041	1,174	1,184	1,327
Harvested Area[1] (1000 ha)	1,131	1,049	988	1,022	1,057	986	983	963	954	966
Production[1] (M.ton fresh cassava)	19.1	18.9	15.5	23.8	20.2	17.5	24.6	27.9	23.8	27.8
Yield (ton/ha)[1]	16.9	18.0	15.7	23.3	19.1	17.8	25.0	29.0	24.9	28.7
Planted area/Total land for field crops (%)	26.0%	24.5%	22.2%	23.0%	24.3%	23.8%	23.9%	27.6%	26.3%	30.3%
Estimated cassava requirement for ethanol production (M.ton/year)[2]	-	-	-	-	-	-	-	-	0.15	0.55
Estimated harvested areas for ethanol production (1000 ha)[2]	-	-	-	-	-	-	-	-	6.02	19.16
Percentage of land use for ethanol (%)	-	-	-	-	-	-	-	-	1%	2%
Percentage of land use for food and others (%)	100%	100%	100%	100%	100%	100%	100%	100%	99%	98%
Sugarcane										
Planted Area[1] (1000 ha)	918	1,054	1,189	1,194	1,122	1,067	965	1,010	1,054	964
Harvested Area[1] (1000 ha)	887	1,021	1,150	1,156	1,086	1,033	934	990	1,033	944
Production[1]	46.0	50.9	61.7	81.7	69.8	43.7	56.9	47.8	76.6	74.8

(M.ton cane)										
Yield (ton/ha)[1]	51.9	49.9	53.7	70.7	64.3	42.3	60.9	48.2	74.1	79.2
Planted area/Total land for field crops (%)	20.1 %	23.3 %	26.5 %	26.7 %	25.2 %	24.3 %	22.1 %	23.7 %	23.4 %	22.0 %
Estimated sugar-cane requirement for ethanol production (M.ton/year)[2]	-	-	-	-	-	-	-	-	-	1.6
Estimated harvested areas for sugar-cane ethanol production (1000 ha)[2]	-	-	-	-	-	-	-	-	-	1.69
Percentage of land use for ethanol (%)	-	-	-	-	-	-	-	-	-	0.2%
Percentage of land use for food and others (%)	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	99.8 %

[1]Data from the Office of Agricultural Economics (OAE, 2009)

[2] Estimated from projected cassava ethanol production by installed capacity (Silalertruksa and Gheewala, 2010)

1.1.2 Allocation of land-use for cassava and sugar cane cultivation in Thailand classified by land suitability class

The allocation of arable land for food and biofuels in the future will rely highly on crop productivity. The crop yields depend on various factors, the two most important being (1) suitability of land use for those crops and (2) good agricultural practices. For Thailand, the Land Development Department (LDD) has carried out a land suitability assessment (LSA) for key biofuel crops i.e. cassava and sugarcane and the attainable yield by each suitability class of land. The study divides the classes and the potentially achievable yield as compared to the maximum attainable yield based on existing agricultural practices and levels of inputs. Details are shown in **Table 1.4**.

Table 1.4 Attainnable yield by suitability class for cassava and sugarcane in Thailand (FAO, 2010a)

Suitability Class	Achievable yield*	Cassava	Sugarcane
	(%)	(ton/ha)	(ton/ha)
Very suitable	95-100	27.6-29.0	69.6-73.3
Suitable	60-95	17.4-27.6	44.0-69.6
Moderately suitable	40-60	11.6-17.4	29.3-44.2

Marginally suitable	0-40	<11.6	< 29.3

Remark: Suitability classes and achievable yields are referred from the LDD (FAO, 2010a)

(1) Cassava

The LDD study reveals that based on the agro-ecological conditions observed, the total planted area of cassava in Thailand is around 1.6 M.ha, around 55% of which is classified as marginally suitable with potential yields below 12 ton/ha (FAO, 2010a). However, the assessment found that land currently under cassava cultivation could feasibly advance by at least one suitability class (FAO, 2010a). In addition, due to the continual development of genetic technology, there are various high yield varieties of cassava that would nearly and possibly reach those yield targets when grown in appropriate soil and following good agricultural practices such as improved soil quality by using organic fertilizers, good practices in land preparation, plantation, harvesting and regular weed control (Vichukij, 2007; FCRI, 2005; FCRI, 2007). For example, the current varieties of cassava (e.g. Kasetsart 50, Rayong 5, Rayong 72 and Rayong 9) being recommended to Thai farmers have the potential to yield about 31.2-50 tons cassava/hectare. Intensification of fertilizers could be another way to quickly improve yields but it needs carefully control because it may create adverse impact on ecosystem and GHG emissions (Snyder et al., 2009).

(2) Sugarcane

Based on the agro-ecological conditions observed by the LDD, currently, 45 percent of planted sugarcane are under the land which is classified as marginally suitable land with yields of less than 29 tons/ha. An additional 35 percent is being grown on suitable lands where higher yields between 44 and 69 tons/ha are achievable (FAO, 2010a). One of the problems why the very suitable and suitable lands for sugarcane cultivation did not be used for sugarcane because they are used for growing other crops such as rice, rubber and maize that can give higher return to farmers (FAO, 2010a). Nevertheless, there is potential to improve the yields of existing land used for sugarcane production by promoting good agricultural practices. The current varieties of sugarcane (e.g. K 84-200, U thong 3 and K 90-54) being recommended to Thai farmers have the potential to yield about 93.75-112.5 tons cane/hectare if they were cultivated in appropriate soil with good agricultural practices (NCGEB, 2009).

Nevertheless, to undertake the good agricultural practices, some measures such as regular treatment and fertilizer input require investment; thus their implementation also depends upon the demand and prices for cassava and sugarcane output.

1.2. Legislation regarding land use, land ownerships and land use rights in Thailand

Expansion of energy crop plantations such as cassava and sugarcane to satisfy the ambitious targets of ethanol promotion in Thailand in 2022 requires sound legal and regulatory frameworks for ensuring that long-term biofuels production in Thailand will not cause any risks of negative impacts such as trespassing on reserve land, the poorer/small-scale farmers losing access of land to the investors, etc. This section explores the existing laws and regulations in Thailand related to land-use for energy crop production. The reviews showed that there are several policies and acts relevant to the future expansion of energy crops plantation in Thailand. The first is forest policies; for example, the National Forest Policy (1985) established targets for maintaining 40 percent forested land further divided into 25 percent for economic forests and 15 percent for conservation forests. Following the national ban on logging established in 1989, these targets were reversed to 25 percent for conservation forests and 15 percent for economic forests (Morgera et al., 2009). The Tenth National Economic and Social Development Plan (2007–2011) ensures that forests are maintained at no less than 33 percent, with no less than 18 percent for protected forests; and the Community Forest Bill (2007) grants legal rights to forest communities to preserve and manage their surrounding forest lands. The second is land reform policies such as Land Reform for Agriculture Act (1975) which was passed to accelerate land reform as well as land allocation in degraded forest reserves (Morgera et al., 2009). According to this land reform policy, the allocation of land to farmers is one of the three main stages of land reform implementation. Land to be brought under land reform program include common use land, lands for the government's own use such as Ratchphatsadu and army area, deteriorated land as classified land according to the resolution of the cabinet and deteriorated forest. This policy leads to various types of land certificates available in Thailand ranging from land use permits to firm land titles. In addition, the agricultural census also revealed that landlessness and renting of land for cultivation are not very significant in Thailand as 74% of farmers own their land (as shown in **Figure 1.2**).

1.2.1 Current legal system for determining legal title in Thailand (Thai law online, 2010)

In Thailand, there is a variety of land title document types issued by the Land Department (LD) and other government departments that farmers can use to show the ownership or to claim of use or possession. But only the title deed (or namely Chanode or NS4) issued by the LD can be used to confirm the true ownership of the land. Nevertheless, in practice, apart from the title deed or NS4, the land titles NS3 and NS3K are the two other titles issued by the LD that can be used for lease or purchase. The other titles allow a certain private use and grant certain rights to use, possess or transfer with a limitation depending on the different conditions. This section describes the existing land title document systems in Thailand which can be divided into 6 categories of land titles issued by the Land Department and 5 categories of land titles issued by the other government departments in Thailand as all these titles can be used to claim the land rights for growing crop for bioenergy production in the future if the sustainability standards were adopted. Descriptions of available titles in Thailand are as follows:

1.2.1.1 Land title documents issued by the Land Department (Wannasia and Shrestha, 2008; Thai law online, 2010)

(1) Title Deed (or namely Chanode or NS4): is the only document that can be shown as a land freehold title. This Title Deed will be issued by the Land Department in the province or the Central Land Office to state formally the approved legal ownership. The document contains several pieces of information i.e. a deed plan showing the position of boundary corner stones surveyed by ground method or based on rectified aerial photomaps, particulars of the land and owner and an index of subsequent dealings such as transfer, lease or mortgage.

(2) Claim certificate (or namely SK1): is a notification form of land possession issued by the district offices without any formal inspection of the land. As the boundaries of land shown in SK1 are not surveyed formally and inspected precisely, the SK1 document therefore does not vest with its holder any claim of ownership. It is merely to show his prior claim of occupancy and to give him a chance to pay taxes upon the land and put the land to productive use. This document entitles the holder to occupy and utilize the SK1 land. SK1 land may be sold or transferred to another if the holder abandons the intention to possess the land and delivers SK1 land to the transferee. It also may be passed on by inheritance. Depending on the land's location, this document may be upgraded to NS3, NS3K or NS4 (Chanode). However, an SK1 has never been issued since 1972 and the time to upgrade this notification or apply for a proper title at the Land

Department has expired since February 2010. The upgrading from now on is only possible through a Court procedure.

(3) Pre-emptive certificate (or namely NS2): is a consent letter issued by the Land Department to the holder. The NS2 is a certificate authorizing temporary occupation of land in which the land is described by meters and bounds. The document entitles the holder to occupy and utilize the land for a temporary period, the holder has to commence occupation and utilization on the NS2 land within 6 months and complete the utilization on the NS2 land within 3 years from the receipt of NS2. The certificate is not transferable except by way of inheritance. Depending on the land's location, this document may be upgraded to NS3, NS3K or NS4. However, even after upgrade, the prohibition for sale or transfer is still effective in full force.

(4) Certificate of utilization consists of two forms i.e. NS3 and NS3K: The NS3 is a document certifying that the land has been utilized by the person who holds the NS2 and all the conditions as mentioned in NS2 are fulfilled. This will lead to the establishment of his right to land. The certificate will be issued by the district land department and is divided into two forms depending on the method used for survey of its boundaries i.e. NS3K in which the boundaries are taken from maps prepared from rectified aerial photography: and NS3 in which the boundaries are measured in isolation by the triangle method (chain survey method).

(*5) NS5:* is a document showing the verification of the rights of the holder in the NS5 land. If the holder has NS5 land along with utilization certificate, it indicates that the district officer has confirmed the utilization on such NS5 land. The NS5 land with the utilization certificate can be sold or transferred to another person by registration at the land office. However, if the holder has NS5 with SK1 or only NS5 without any other supporting evidence, it indicates that the district officer has not yet confirmed the utilization on such NS5 land and this NS5 may not be sold or transferred except for inheritance.

1.2.1.2 Land Title documents issued by other government departments (Wannasia and Shrestha, 2008; Thai law online, 2010)

(1) SPK4-01: is an allotment of land from the Land Reformative Committee, and under no circumstance may this land be bought or sold. It confers the right to occupy only and be transferred only by inheritance. The land may only be used for agriculture and is usually found in rural areas. Government land is transferred for agricultural purposes to poor families. Residence is allowed on a portion of the land.

(2) STK: is an instrument issued only in the zone of national reserved forest, the holder of this title document has the right to reside and live on the STK land. STK land is prohibited for sale, however, the right of the holder to reside and live on the STK land can be passed on by inheritance. This document issued by the forest department.

(3) PBT5 or PBT6: is an evidence to show that the occupier of a plot of land has been issued a tax number and has paid tax for using the benefit of the land. This confers no right at all but was formerly used to establish that the holder was occupying a plot of land and could apply for a SK1. A receipt authorizing use of land is issued on payment of tax to the district land office and it is not transferable.

(4) NK1 or NK3: is a utilization certificate issued under the act of land allocation for living B.E. 2511. This document is issued only for members of self-help settlements. License issued in settlement schemes administered by the Public Welfare Department and the Co-operative Promotion Department; not transferable other than by way of inheritance.

(5) KSN5: is a utilization certificate issued under the act of land allocation for living B.E. 2511. This document issued only for members of cooperative settlements.

1.3 Types of land tenure for holdings in agricultural sector of Thailand

The characteristics of land tenure of holdings cultivating cassava and sugarcane in Thailand can be indirectly revealed by the Agricultural Census of the National Statistical Office (NSO, 2004). A holding is an economic unit of agricultural production (cultivating crops, rearing livestock and culturing fresh water) under single management comprising all livestock kept and all land used wholly or partly for agricultural purposes. The total number of holdings is about 5.8 million, 45.6% of which are located in the Northeastern region of Thailand. The others are located in the Northern, Central and Southern regions with 23.6, 15.6 and 15.2%, respectively. In terms of the total area occupied by the holdings of around 114.5 million rais [1 rai = 0.16 hectare], the Northeastern region is also the largest contributor with 51.9 million rais (45.4%), followed by the Northern, Central and Southern Regions with 22.1, 19.1 and 13.4% respectively. **Figure 1.2** shows the distribution of holdings in Thailand by land tenure as the agricultural census in 2003. It was found that the majority of holdings operated under own land only (74.0%), 14.8% of the holdings operated not only under own land but also under other land and 11.2% of the holdings operated under other land. For the documentation of right, the data show that most of the holdings with own land had Title deed, NS5, NS3, NS3k (73.6%). Detailed information of land tenure classified by region is shown in **Table 1.5**.

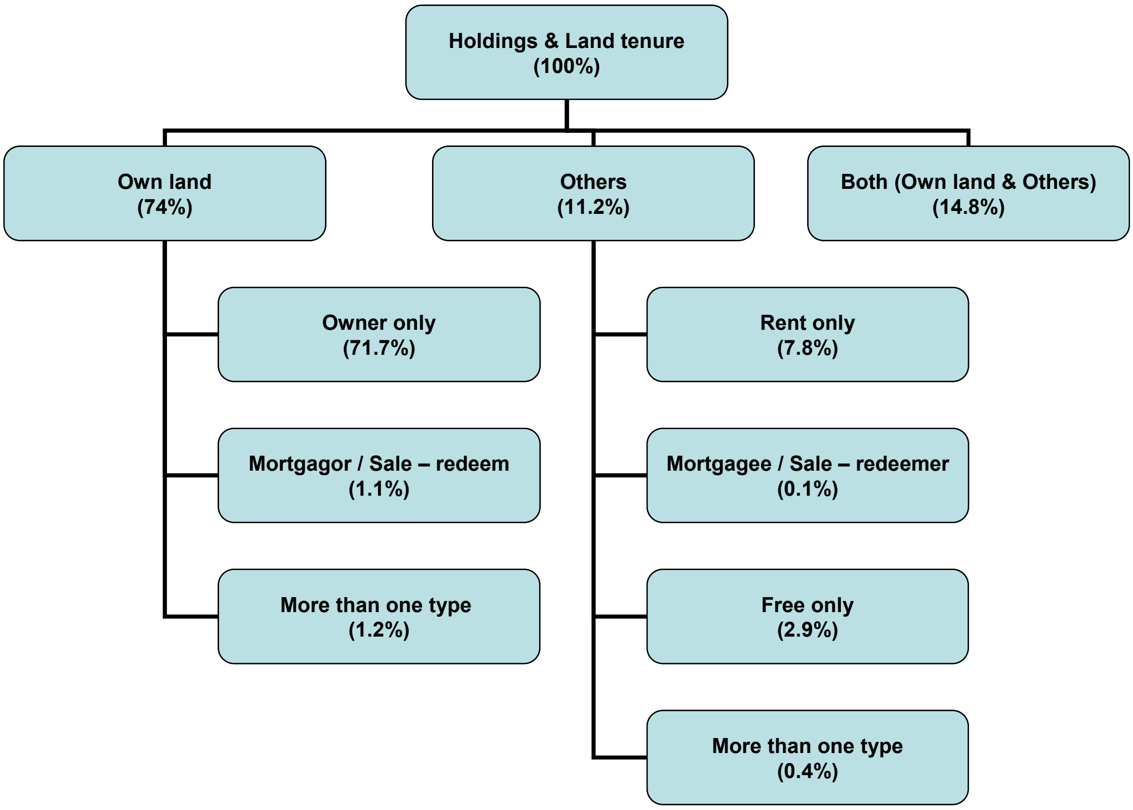


Figure 1.2 Type of farm holding land of Thailand

Table 1.5 Percentage of holdings in the agricultural sector in Thailand classified by land tenure and documentation of rights

Item	Total	Central	Northern	Northeastern	Southern
Land tenure	**100**	**100**	**100**	**100**	**100**
Own land	74	59.5	63.2	78.6	91.5
Owner only	71.7	57.9	61.5	76.6	86.9
Mortgagor / Sale - redeem	1.1	1	0.9	0.8	2
More than one kind	1.2	0.6	0.8	1.2	2.6
Others	11.2	22.6	16.1	7.5	3.1
Rent only	7.8	18.5	11.7	4.5	1.2
Free only	2.9	3.6	3.7	2.6	1.7
Mortgagee / Sale - redeemer	0.1	0	0.1	0.1	0.1
More than one kind	0.4	0.5	0.6	0.3	0.1
Own land and others	14.8	17.9	20.7	13.9	5.4
Documentary of right*					
(own land only)					
Title deed/NS5/NS3/NS3k	73.6	79.9	67.1	75.2	72.5
SPK 4-01/NK/STK/KSN	17.9	9.6	19.8	21.1	13.1
NS2/ SK1	2.3	0.9	1.6	2.6	3.5
Others	18.8	12.7	26.5	14.6	25.5

*One holding may report more than one type of documentary of right

Source: NSO, 2004

1.4 Summary of land tenure/ access and ownership caused by ethanol production in Thailand

The reviews and assessment showed that there are a variety of acts and regulatory frameworks related to expansion of expansion of energy crop cultivation in Thailand in order to conserve forest land and to promote use of degraded forest land and deteriorated land for agriculture by allocation of those to small farmers. The landlessness and renting of land for cultivation are not very significant in Thailand as 74% of farmers own their land, however, farmers in Thailand as well as cassava and sugarcane cultivations are generally small-scale (about 0.5-2 hectare) and the crop products are typically collected from a large number of small farmers and transported to convertors in processing areas. As farmers in Thailand have their own plantation areas, therefore, it is possible to verify the land tenure of farmers. Nevertheless, the actual verification process of land tenure might need further establishment as there are various types of land certificates available in Thailand ranging from land use permits to firm land titles. If the standard on verification of land tenure of feedstocks cultivation for bioenergy production has to be established, criteria regarding the type of certificates will be required. In addition, as in Thailand, some certificates are very old and many documents are not transferable, the formal verification of land titles and land use rights will also be required in some cases in order to ensure that there is no illegal use of land rights by large scale investors. The general process to verify the land areas specified in the titles and to verify the land rights of the title's holders in Thailand is that the documents must be proven and guaranteed by the group of assigned persons from the land department, local government, representatives from local communities and the relevant organizations e.g. the forest department, the land reform department, etc.

As small-scale farmers in Thailand are poor and badly in debt, therefore, there is the possibility of those farmers to lose their land ownership (by mortgage or selling the land) in the future. The three main problems of Thai farmers are the low crop productivity, the low and uncertain crop prices, and the increase of daily living costs. To protect small-scale farmers on their land ownerships in future, government policy to protect against those risks may be helpful. An example is the government policy to help small scale farmers such as the "Social Fuel Seal" scheme in Brazil that promotes biofuel producers to give priority to small scale farmers in the focused rural region. To encourage contract farming between farmers and the industry under reasonable price and conditions is also another approach that may help small farmers receive reasonable crop prices and continually increase their productivity. The government promotion policy to increase crops productivity through improved R&D, genetic technology, improvement facilities, GAP promotion, etc. is also necessary not only to help farmers but also to minimize land use and to ensure food security in the future. The strengthening of co-operative systems in Thailand is very import to help Thai farmers and this would also help and be easier for small scale farmers to implement good agricultural practices or any other International standards on bioenergy in the future through group verification and certification (as FSC scheme). In addition, cooperatives can help increase negotiation power of small scale farmers to middle man and industries. Due to the increased demands for cassava and sugarcane in the future, the policy to improve crop yields are necessary as well as the plan to specify the areas suitable for growing cassava and sugarcane in Thailand in order to achieve the maximum attainable yields if expansion of cultivation areas is necessary.

2. Employment, wages and labor conditions

The agricultural sector is the most labor-intensive sector in Thailand. Emergence of the biofuels industry in Thailand, therefore, is expected to bring opportunities for employment and income generation in the rural areas and in the vicinity of new ethanol factories. Estimations show that per M.litre of ethanol production in Thailand, sugarcane ethanol, cassava ethanol and molasses ethanol could induce around 121, 117 and 112 persons-year (including both direct and indirect employment); direct employment in agriculture contributing more than 90% of this total employment generation (Silaleteruksa et al, 2011). One of the reasons for the high employment generation in agriculture is that the agricultural sector in Thailand is less mechanized than other more developed countries. In addition, as compared to gasoline on a per joule energy content basis, ethanol production generates about 17-20 times more jobs (Silaleteruksa et al, 2011). Nevertheless, employment generation numbers do not necessarily reflect the real social benefits to employed workers if their rights to gain fair wage and appropriate working conditions are not included in the consideration. The aspect of labor rights and working conditions, therefore, has been addressed in several standards and/or initiatives such as the Roundtable on Sustainable Biofuels (RSB), Testing Framework for Sustainable Biomass ("Cramer Criteria") and Global Bioenergy Partnership (GBEP) to ensure that emerging of bioenergy production shall not violate human or labor rights e.g. use of forced labor, freedom for collective bargaining of farmers, free of discrimination, etc and shall promote decent work and the well-being of workers. An example of related indicators and descriptions are presented below:

2.1 Contribution of ethanol production in Thailand to the change in income

Relevant indicator	GBEP-I 11: Change in income

Indicator descriptions (ID)	Contribution of the following to change in income due to bioenergy production: •wages paid for employment in the bioenergy sector in relation to comparable sectors; •net income from the sale, barter and/or own-consumption of bioenergy products, including feedstocks, by self-employed households/individuals

2.1.1 Characteristics of employment generation related to ethanol production in Thailand

For bioethanol production in Thailand, employment generation can be classified into two major groups i.e. (1) workers/holdings in agriculture; and (2) workers in the manufacturing sectors for feedstocks processing and bioethanol conversion as shown in **Figure 2.1.** The Agricultural Census (NSO, 2004) revealed that the group of self employed workers (or unpaid family workers) and the group of occasional workers are the major groups of laborers in agricultural holdings in Thailand contributing around 41% and 57% of total holdings in agriculture. This, therefore, implies that the advantage of biofuels on the creation of direct employment in agriculture as quantified earlier is likely to be of a temporary employment nature. This contrasts to the workers in biofuel industry who are generally employed as permanent staff. Therefore, laborers in agriculture today are poorly protected by national labor law as compared to employed workers in the industry. For example, there are no national laws or public policies related to working conditions. In addition, there are the obvious differences in the characteristics of employment and source of income between self employed family workers and employed workers in agriculture and in processing sectors. For example, the income of self employed family workers will come from the sale, barter and/or own-consumption of their crop products while the income of employed workers will come from the wage paid by employers.

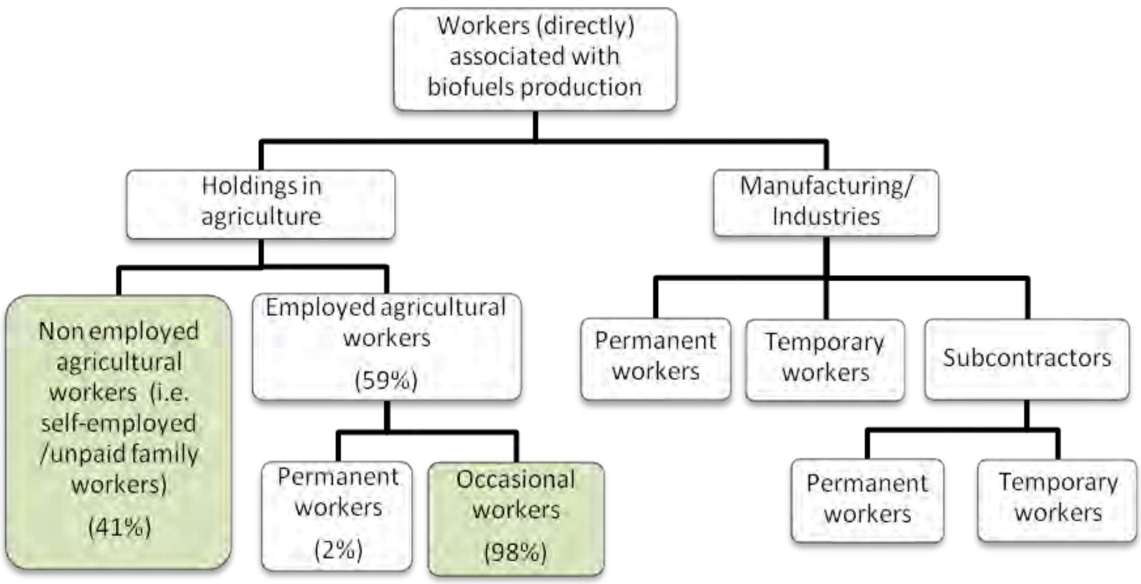


Figure 2.1 Clarification of labor characteristics in biofuels production

The indicator of GBEP to assess the contribution of bioenergy production to the change in income of labor and self-employed households in agricultural sector would be useful to ensure socio-economic sustainability of future biofuels production in Thailand. The discussions on adopting these indicators are explained by referring to the case of cassava and sugarcane ethanol production in Thailand as follows:

2.1.2 Change in the net income from the sale of cassava and sugarcane for ethanol production in Thailand

(1) Cassava

In this study, the net income to farmers from selling cassava is estimated from the difference in farmgate price of cassava and production costs as shown in **Table 2.1**. Over the past 5 years (2006-2010), the price of fresh cassava root (based on 25% starch content) has increased at an average rate of around 13.3% (OAE¸2010a). In addition, the recent cassava price as of March 2011 shows that the cassava price at farm in Nakorn Ratchasima province, the largest cassava cultivation province in Thailand, is around 3.03- 3.32 THB/kg [1US$ (2010) = 31.87 THB] and the country average price is 2.93 THB/kg (OAE, 2011b). The increase in cassava price is due to a number of factors. The main factor is the widespread attack by insect pests such the pink mealy bug (*Phenacoccus manihoti Matile-Ferrero*) in year 2009-2010 which caused severe damage to young plants of susceptible varieties. Some farmers, therefore, had to cut the cycle by changing their farming to sugarcane and maize. Another factor is the increased demand for cassava to produce food, animal feed and also ethanol fuel. The cassava demand for ethanol production has increased from 89 M.litres in 2009 to 148 M.litres in 2010 contributing about 22% and 35% of the total ethanol production in 2009 and 2010, respectively. Nevertheless, this ethanol production still required only about 2% and 7% of total amount of cassava that produced in 2009 and 2010. The main proportion of cassava consumption is from the starch industry contributing around 59% followed by dried chips and animal feed industries at 30% and 4%, respectively (OAE, 2011c).

Anyway, the analyses of government under the cassava price insurance program revealed that in year 2010/2011, the average buying price of cassava (25% starch) by ethanol industry is 3.07 THB/kg and is higher than the buying prices of starch, animal feed and dried chip industries whose average buying prices from farmers are 2.98, 2.80 and 2.36 THB/kg, respectively (OAE, 2011c). Therefore, this implies that the bioethanol industry in Thailand today can help increase income for farmers both directly i.e. buying cassava at higher price as compared to other industries and indirectly i.e. to increase of cassava demand in the market which will affect to the rise of cassava price.

Table 2.1 Farmgate price of cassava and the estimated net income to farmers

Prices of cassava products	2006	2007	2008	2009	2010	Increasing rate (%)
Farm gate price of fresh cassava (THB/kg)	1.21	1.38	1.73	1.32	2.31	13.3
Wholesale price of dried chip in BKK (THB/kg)	3.73	4.2	5.01	4	5.95	9.26
Wholesale price of flour/starch in BKK (THB/kg)	8.12	11.07	12.93	11.88	17.47	17.39
Export price of pellet (THB/kg)	4.09	4.32	5.81	4.89	5.33	6.75
Export price of dried-chip (THB/kg)	4.12	4.3	5.5	4.51	6.24	9.18
Export price of flour/starch (THB/kg)	8.27	9.64	11.76	9.2	14.49	11.35
Average production costs (THB/kg)	***0.843***	***0.824***	***1.079***	***1.229***	***1.596***	
Estimated net income						
Net income to farmers (THB/kg)*	0.367	0.556	0.651	0.091	0.714	
Average cassava yields (kg/rai)*	3,375	3,668	3,401	3,628	3,005	
Net income to farmers (THB/rai)	1,239	2,039	2,214	330	2,146	

*1US$ (2010) = 31.87 THB and 1 rai = 0.16 hectare

Source: OAE¸2010a

(2) Sugarcane

Contrary to cassava, sugarcane plantations and sugar production in Thailand are controlled by the Office of Cane and Sugar Board due (OCSB) due to the Sugar Act of 1984. Under this Sugar Act, the income of cane growers relies on the revenue-sharing system i.e. cane growers receive a 70 percent share of revenue from sugar and molasses sales in both the domestic and export markets after deducting all costs and taxes, and mills earn the remaining 30 percent (NaRanong, 2000; FAO, 1997). As per this revenue-sharing system, the income of cane growers in Thailand will not only depend on the demand and supply of sugar in the market but also on the currency exchange rate because more than 70% of the sugar produced will be exported. Therefore, the decrease in value of US$ compared to THB will affect the revenue from exporting sugar which will in turn affect (decrease) the sugarcane price of farmers. In addition, this revenue-sharing system is also a limitation to expand sugarcane ethanol production in Thailand because if the sugar mills utilize sugarcane juice to produce ethanol, this revenue-sharing system needs to be adjusted. This is still a controversial issue among various stakeholders. The basic calculation can be done by converting the amount of sugarcane juice used for producing ethanol into sugar equivalent and bring this obtained amount of sugar equivalent into the revenue-sharing system of 70:30. However, the results obtained must be verified and revised again after trial implementation by OCSB and other parties such as the Ministry of Energy and Ministry of Agriculture and Cooperatives in order to make the appropriate methodology that can give reasonable benefits to both millers and farmers. Thus, nowadays the changes in sugarcane price at factory gate as shown in **Table 2. 2** are originated from the change in prices of sugar and molasses products in the market. Only molasses ethanol production affects the change in income of cane growers due to increase of molasses price in the market.

Currently, there is only one ethanol plant with the installed capacity about 0.2 M.litre/day that started operation since the end of 2009. This factory located in Tak province and will mainly use sugarcane feedstock directly from the promotion of new sugarcane plantation areas in the Tak province and its neighboring provinces which currently have no sugar milling. Therefore, the Sugar Act will not legally affect this factory. As the plant has just started operation in 2009/2010; therefore, only 0.16 M.ton cane has been processed by the factory as compared to total capacity which can support for 0.8 M.ton can/year. However, the production is expected to expand in the year 2010/2011 to 0.42 M.ton cane (Silalertruksa and Gheewala, 2010). The reviews of sugarcane price at ethanol factory gate showed that in 2009/2010, the average sugarcane price was 950 THB/ton and the prices were also classified into 900 THB/ton for burnt cane and 970 THB/ton for unburnt cane. This price is a little lower than the sugarcane price at sugar milling factory gate as shown in **Table 2.2**. In addition, the recent news show that there is a request to the ethanol factory from farmers to buy their sugarcane products based on the Commercial Cane Sugar (C.C.S.) same as sugar mills and the farmers also requested the factory to offer them the additional compensation of about 200 THB/ton cane in order to increase their income (INN News, 2011).

Table 2.2 Farmgate price of sugarcane

	2005/2006	**2006/2007**	**2007/2008**	**2008/2009**	**2009/2010**	**Increasing rate (%)**
Sugarcane price at factory gate (THB/ton cane) (based on 10% C.C.S.)	929	783	758	918	1094	4.98

Average production costs (THB/ton cane)	571	572	607	673	690
Estimated net income					
Net income to farmers (THB/ton cane)	358	211	151	245	404
Average sugarcane yields (ton cane/rai)	7.90	10.19	11.16	11.09	10.91
Net income to farmers (THB/rai)	2,828	2,151	1,685	2,718	4,406

*1US$ (2010) = 31.87 THB and 1 rai = 0.16 hectare

Source: OAE, 2010b

2.1.3 Wages paid for employment in the ethanol sector in Thailand

In Thailand, there is no specific or special wage rate paid for employment in the ethanol sector as compared to other industries and even compared to the wage for workers employed in agriculture. The minimum wage paid for both employed workers in agricultural sector and also for workers in biofuels production can be generally referred to the minimum wages of Thailand which are set by "Thailand's wage committee" as shown in **Table 2.3**. However, as many factors will be considered as criteria e.g. inflation, living costs in each region, etc., therefore, it is difficult to conclude directly that the change of wage is because of biofuels production. Nevertheless, due to the characteristics of workers in processing sectors which are permanent staff, therefore, they will usually have the additional benefits e.g. health insurance, provident fund, etc. as compared to those employed in agriculture as the latter are mainly occasional workers.

Table 2.3 Average minimum wage rate classified by region in Thailand during 2001-2011 (THB/day)

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Bangkok	165	165	169	170	175	184	191	194	206	206	215
Central	140	141	143	145	149	157	162	165	172	172	182
North	134	134	134	135	139	143	147	148	154	154	164
Northeastern	134	134	134	135	139	143	148	149	155	155	164
Southern	137	137	138	139	143	149	153	156	161	161	173

Source: MOL, 2011

2.2 Training and re-qualification of the workforce

Relevant indicator	I21: Training and re-qualification of the workforce
Indicator descriptions (ID)	Percentage of trained workers in the bioenergy sector out of total bioenergy workforce, and percentage of re-qualified workers out of the total number of jobs lost in the bioenergy sector

Situation in Thailand

In Thailand, the employees in processing sectors related to bioethanol production such as ethanol factory, sugar mill, or dried chip processing plant are generally trained in a short course to familiarize them about company rules, allowance, computer system and specially health and safety standards for the technical staff in production line. As per the Ministerial Regulation (B.E. 2542) issued pursuant to the Factory Act B.E. 2535, the ethanol industry is also forced by the regulation to perform the risk assessment, hazard identification and also to propose the risk management program. With this risk management program, the control measures regarding occupational health and safety such as training, safety audit, developing work procedures, machinery maintenance program, implementing Code of Practice, accident record, etc. are required. Therefore, the record regarding the percentage of trained workers in bioenergy workforce especially in the processing industries is available.

However, after the orientation, the workers are generally trained again in practice through learning by doing by their supervisors. A probation period of around 3 months is used to evaluate whether the workers are qualified to work with the factory. There is no system regarding re-qualified workers after passing any training course. Therefore, the percentage of re-qualified workers out of the total number of jobs lost in bioenergy sector may not be a practical indicator for Thai context.

2.3 Labor conditions due to the ILO standards

Relevant indicator	Labor conditions due to the ILO Standards: wages, working hours, children work, working conditions for women etc.

Situation in Thailand

To ensure that emerging of bioenergy production shall not violate labor rights and shall promote decent work and the well-being of workers (EPFL, 2011), many sustainability standards on bioenergy have used the ILO standards as the criteria that all stakeholders in bioenergy production chain should comply with. Thailand is one of founding members of the ILO actively working on rights issues in particular the freedom of association and collective bargaining, discrimination, child labor and trafficking and the rights of migrant workers. Nowadays, Thailand has ratified 15 ILO conventions, four of which are core conventions i.e. C.100 on equal remuneration, C.138 on minimum age, C.182 on worst form of child labor and C.159 vocational rehabilitation and employment (disabled persons) (ILO, 2011). The ILO work program to promote decent work in Thailand was also designed within the 10th National Development Plan (2007-2011). In addition, there is an existence of national laws and regulations especially the Factory Act B.E. 2535 to control the industries in Thailand to comply the environmental, occupational health and safety standards including assigning environmental and safety officers in the factory, identification of health and safety risks and having effective procedures in place to address these risks, provision of appropriate personal protective equipment to workers and regular training. Therefore, it can be concluded that the labor conditions and worker rights in the processing sectors in the chain of ethanol production in Thailand are protected at least by the various regulations and standards. However, those standards are not fully applicable to the agriculture sector. To improve and to implement the standards and indicators, labor rights and conditions for laborers in agriculture are necessary to ensure that the expanding feedstocks cultivation for biofuels in the future will not create the problems on workers' rights and will help rural development as much as expected from the social benefits of biofuels

3. Rural and social development

Relevant Indicator	GBEP-I 13: Change in unpaid time spent by women and children collecting biomass
Indicator descriptions (ID)	Change in average unpaid time spent by women and children collecting biomass as a result of switching from traditional use of biomass to modern bioenergy services

3.1 Rural and social development in Thailand

Thailand is one of the developing countries having a continual increase in the Human Development Index (HDI) of UNDP i.e. from 0.483 in 1980 to 0.654 in 2010 or annual increase of 1% (UNDP, 2011). The 2010 HDI brings the country a rank of 92 out of 169 countries with comparable data and is above the average value of East Asia and the Pacific region which is 0.650 (UNDP, 2011). The HDI is evaluated via the progress in three major dimensions of human development i.e. a long and healthy life, access to knowledge and a decent standard of living. The incidence of poverty reduced from 27% in 1990 to 11.3% in 2004, and the proportion of underweight children also decreased by nearly 50% (UNDP, 2007). More children enrol in school, and more stay longer (UNDP, 2007). The progress and success of social development in Thailand are due to the effects from many factors and policy instruments e.g. industrial development, public investment in social services and domestic and global economic growth.

The policy to promote bioethanol in Thailand is expected to be one of the tools to spur rural and socio-economic development. Nevertheless, there are still concerns over issues such as income equality, lack of social protection and access to services especially for the holdings in agricultural sector in Thailand which generally be small scale farmers. Today, around 20 million or about 30% of total population of Thailand are involved in the agricultural sector as farmers and laborers (FAO, 2010a). However, the numbers of agricultural population are declining due to the development of agro-industries and technologies. Even though the income of farmers and laborers in agriculture in rural areas is likely to increase with increased demand for food and energy crops, in fact they still remain among the poorest part of the population. This is especially so for the farmers in the rural northeast, far north and far south of the country (UNDP, 2007).

3.2 Female and Child labor

As holdings in the agricultural sector in Thailand are mainly small scale or family farmers, female, children and young laborers, therefore, are directly involved in the ethanol production chain as self employed or unpaid family workers for feedstocks cultivation and harvesting. Female workers comprise almost half of total employed workers in agriculture; the Northeastern region, the major location of cassava and sugarcane cultivation in Thailand, shows the highest percentage of female workers at about 52% (OAE, 2010).

Even though the indicator regarding the change in average unpaid time spent by women and children collecting feedstocks as a result of bioethanol production is essential and would be beneficial to ensure social sustainability, there is not yet any survey in Thailand and it is quite hard to measure this in practice. Indirect measuring by using the changes or the increase in income to farmers or agricultural holdings, therefore, may be used to imply that women and children would potentially have positive change in unpaid time spent due to the increased income. Moreover, to guarantee a fair compensation for time spent by women and children collecting feedstocks for bioethanol production in Thailand, standards, regulation or special measures to protect women and youth labors and also small scale farmers in fair trading should be implemented. Nevertheless, the rate of female laborers shows a slightly declining trend in rural areas, but rising trend in urban areas due to the increase in the share of output from the manufacturing and services sectors and the increase in the proportion of female workers who work as employees in those sectors as compared to those who work as unpaid family workers, or are self-employed in agriculture.

As well as female labor, children and young laborers are still rife in the rural agricultural sector of Thailand as unpaid family workers. From time to time, children have to help their family to cultivating and harvesting. However, in Thailand today, the National Education Act and government policy try to encourage all Thai people to have rights for basic education at least 12 years (6 years with full support by government). Nevertheless, in the future, periodic monitoring of the impacts of bioethanol on access to education for children should be performed to ensure that that they have the chance to acquire the knowledge and skills that would equip them for better employment as adults instead of early enter to the labor market.

In addition, some biofuel policies in Thailand can significantly help rural development in access to energy. For example, the Thai government has promoted biodiesel production and use in local communities across the country to reduce local communities' expenses on energy by producing and using biodiesel from used cooking oil or other oil plants grown in the community, such as Jatropha to replace diesel use. Technical assistance was also provided through learning centers, financing pressing and biodiesel processing machines, as well as conducting training and information sharing on farming oil crops. The two main benefits of this policy are (1) increase ability to access energy of local communities and (2) boosting agricultural productivity of farmers which will help increase in their income respectively.

4. Human health and safety

Relevant Indicator	GBEP-I 15: Change in mortality and burden of disease attributable to indoor smoke
Indicator descriptions (ID)	Change in mortality and burden of disease attributable to indoor smoke from solid fuel use, and changes in these as a result of the increased deployment of modern bioenergy services, including improved biomass-based cookstoves

4.1. Key human health issues

Many sustainability standards for bioenergy production and use have emphasized on the human health effect caused by indoor smoke from solid fuel use. However, for bioethanol in Thailand, the key human health and safety issues with respect to the production chain of cassava and sugarcane ethanol that should be of concern are as follows:

(1) Human health effects due to intensive agrochemical and chemical fertilizer used for increasing crops productivity to satisfy future demand for food and fuel. Sustainable management and harvesting practices need to be encouraged. The practices should also include waste management of active ingredients packaging to avoid unexpected harm to local people.

(2) Indoor air quality for feedstocks processing industries and ethanol plants which have their own steam boilers and power generation plant. The reason is that various kind of solid fuels are used in the boilers. For example, bagasse is used as fuel for boilers in sugar milling and sugarcane ethanol plant to produce steam and power. Some ethanol plants use other biomass fuels such as rice husk and corncob while some plants are use imported coal. One of the health risks to workers who handle these solid fuels (both biomass and coal) is the particulate matter. Therefore, safety gear should be provided as well as the production system must be controlled properly.

(3) Safety standards are required for high risk unit operation such as steam boiler and ethanol process. For steam boiler, the Factory Act in Thailand has enacted that the factories which install steam boiler must have a controller with formal license from authorized organizations. In addition, the preventive maintenance plan, emergency plan, etc. are also required by the regulation. Another important safety issue is the fire and explosion prevention and emergency plan for ethanol plant. The fire protection standard from the Department of Industrial Works (DIW) has been suggested to ethanol factories through Code of Conduct manual.

4.2 Incidence of occupational injury and labor conditions in respect to health issue

Relevant Indicator	GBEP-I16: Incidence of occupational injury, illness and fatalities;
Indicator descriptions (ID)	ID: Incidences of occupational injury, illness and fatalities in the production of bioenergy in relation to comparable sectors
	Health regarding labor conditions, like health insurance, medical support for field workers etc.

Accident records on occupational injuries, illness and fatalities are widely adopted by the Thai industries including bioethanol factories and upstream processing such as sugar mills. However, it is rarely found in agricultural processing such as cassava dried chip processing as its process is very simple (just drying by sunlight and cutting in chips) and producers are generally small and medium enterprises. The reviews from record of DIW regarding major incidences in occupational injury, illness and fatalities in Thai industry show that there is no serious record on human health from ethanol industry as compared to chemical industries.

For ethanol factories in Thailand today, apart from salary, employers also provide the other allowances to workers such as the necessary medical treatment free of charge in case of accidents during work or any case of illness during the period of the employee's contract. The employer will also pay for regular wages and compensation to the employee as required by the local labor law. Safety gear must be enough to provide for all workers involved in the production process. The situation regarding conditions for worker's health and safety in the ethanol industry is the same as for other agro-based industries such as the starch industry but it is generally less than petroleum refinery which is a very large scale industry with very high profits. However, the allowances mentioned above are not available for the workers in agriculture.

5. Energy security and access

Relevant Indicator	GBEP-I 14: Bioenergy used to expand access to modern energy services;
Indicator descriptions (ID)	• Total amount and percentage of increased access to modern energy services gained through modern bioenergy (disaggregated by bioenergy type), measured in terms of energy and numbers of households and businesses • Total number and percentage of households and businesses using bioenergy, disaggregated into modern bioenergy and traditional use of biomass
Relevant Indicator	I 18: Net energy balance
Indicator descriptions (ID)	Energy ratio of the bioenergy value chain with comparison with other energy sources, including energy ratios of feedstock production, processing of feedstock into bioenergy, bioenergy use; and/or lifecycle analysis
Relevant Indicator	I 22: Energy diversity;
Indicator descriptions (ID)	ID: Change in diversity of total primary energy supply due to bioenergy
Relevant Indicator	I 20: Change in the consumption of fossil fuels and traditional use of biomass

Indicator descriptions (ID)	Substitution of fossil fuels with domestic bioenergy measured by energy content and in annual savings of convertible currency from reduced purchases of fossil fuels •Substitution of traditional use of biomass with modern domestic bioenergy measured by energy content

5.1 Net energy balance of bioethanol in Thailand

For assessing energy efficiency of bioethanol, the Net Energy Balance (NEB) for the entire cassava, cane molasses ethanol and sugarcane ethanol production systems in Thailand were assessed in terms of the difference in energy content of the biofuel and fossil fuels and other energy sources required to produce it (Silalertruksa and Gheewala, 2009). However, the solar energy captured by biomass is considered energetically free and excluded in the NEB analysis. The Net Energy Ratio (NER) and Renewability are two indicators obtained from the NEB calculations used in the study to identify net energy efficiency and net replaced fossil energy of bioethanol. The results are as follows:

5.1.1 Cassava ethanol

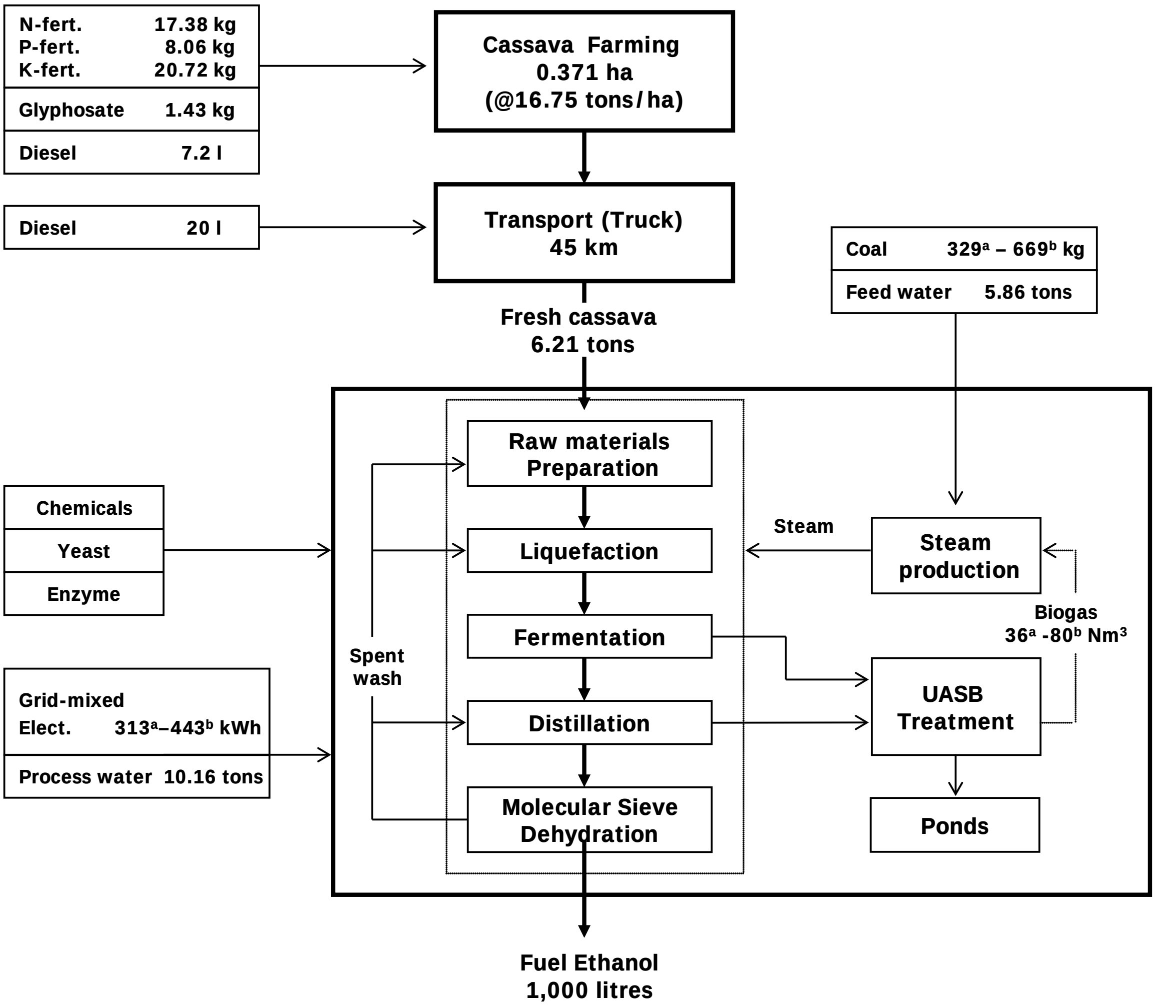
In this study, the NER and Renewability are obtained from the NEB calculations of a commercial cassava ethanol plant with a capacity of 130,000 L/day in Thailand. The analyses are divided into two scenarios i.e. Scenario I: current operation of the existing cassava ethanol plant and Scenario II: designed operation of the existing cassava ethanol plant. These two scenarios are considered because cassava ethanol production is a new industry in Thailand being promoted by the government; therefore, there is a high potential that current production will have lower efficiency than the design due to lack of adequate experience to control the plants. System boundary is “cradle to gate” of the cassava ethanol system consisting of four stages including (1) cassava cultivation and harvesting, (2) fresh cassava transport (3) cassava processing and (4) ethanol conversion. The details of each stage are described below:

a. Cassava cultivation and harvesting: This stage consists of land preparation, stem preparation, planting, treatment and harvesting. An average fresh cassava yield of about 16.75 tonnes fresh cassava/ha was used in the study. The amount of N-P-K fertilizers and fuel used for the cultivation and harvesting stages are shown in **Figure 5. 1**. The amount of fresh cassava consumed for producing 1000 L of ethanol (99.5% purity) is 6.12 tonnes. Manual planting is a common practice in Thailand. The total labor work of 442 Man-hours per hectare of cassava are accounted since land preparation to harvesting.

Even though there are many methods for evaluating the energy equivalent from human work inputs and many researchers have used different values range 0.62 – 12.1 MJ/person/hr, one of the most popular methods, "Total Food Consumed (TFC)", was applied in this analysis [8, 18, 38-39]. Regarding TFC method, the value of 2.3 MJ/h derived for human labor energy equivalent was obtained and used to convert hours of labor to energy.

b. Transport: The fresh cassava roots are transported directly from the main suppliers or local farmers to the ethanol plant by truck or pick-up car. In general, fresh cassava is transported to drying floors which are equipped with simple facilities in order to make the dry chips. The existing full scale plant on which this study is based uses fresh cassava as the main raw material, while dry cassava chips are reserved in case of fresh cassava shortage. Therefore, very less amount of dry cassava chips are supplied to this ethanol plant.

c. Ethanol conversion: The cassava-ethanol plant consists of four main sub-processes: milling, mixing and liquefaction, fermentation, distillation and molecular sieve dehydration. In this stage, environmental impacts related to several aspects, such as emissions from combustion of fuel in industrial boilers for steam production, emissions from electricity used in the plant and water emissions after treatment by the Upflow Anaerobic Sludge Blanket (UASB) system were accounted. From the UASB, biogas is a by-product that is used as fuel for steam production, CO_2 emissions from biogas combustion, being of biogenic origin, are considered net zero as also the bio-based CO_2 emissions during fermentation.



Remark: [a]Scenario I: Current Operation; [b]Scenario II: Designed Operation

Figure 5.1 Life cycle materials flow diagram of cassava based ethanol (Silalertruksa and Gheewala, 2009)

As seen in **Table 5.1**, an NER of about 0.82 of the current operation scenario indicates that producing cassava ethanol by the existing plant leads to a net energy loss. This result differs significantly from designed operation scenario where the plant should have NER = 1.19 and also has a significant difference when compared to another study of cassava ethanol assessment in Thailand which showed the NER = 1.93 (Nguyen et al., 2007). However, the study by Nguyen and colleagues used the estimated information from a pilot-scale study and scaled-up calculation. One of the reasons that NER in the previous study is higher than the existing cassava plant is the use of Simultaneous Saccharification and Fermentation (SSF) which can save energy and time when compared to the traditional fermentation which is currently in use. The energy analysis results show that the current operation consumes 17,287 MJ/1000 L of ethanol for steam production which is 1.75 times the design value. A key factor resulting in the high energy consumption is an inefficient steam production system. The detailed energy analysis of the existing plant showed an average boiler efficiency (η), defined as energy in produced steam divided by total energy input, of only 62 % efficiency while the designed efficiency ranges between 85-90%. A major cause of this inefficiency is the high hardness level of feed water resulting in problems with the boiler tubes. However, this problem is very site specific and should not occur if this and other new cassava ethanol plants have good practices for steam production.

Table 5.1 Energy balance (MJ) for production of 1000 L cassava based ethanol[a]

Items	Unit	Scenario I: Current operation Total energy	Scenario I: Current operation Fossil energy	Scenario II: Designed operation Total energy	Scenario II: Designed operation Fossil energy
1) Cassava farming/processing					
1a. Cassava farming					
NPK fertilizers	MJ	1,790	1,703	1,779	1,693
Herbicide	MJ	649	617	645	612
Diesel (farm machinery)	MJ	317	317	315	315
Labor	MJ	377		375	
1b. Cassava processing					
Diesel (chip processing)	MJ	-	-	761	761
2) Transport					
Fresh cassava	MJ	885	885	880	880
3) Ethanol conversion		-		-	
Coal (Steam production)	MJ	16,495	16,495	8,104	8,104
Energy recovered from biogas used for steam production)	MJ	792	-	1,760	-
Electricity	MJ	4,430	4,297	3,130	3,036
Net energy inputs	**MJ**	**25,735**	**24,314**	**17,749**	**15,401**
NEV[b]	**MJ**	**(-4,535)**		**3,827**	
NRnEV[c]	**MJ**		**(-3,114)**		**5,799**
Net Energy Ratio (NER)[d]		**0.82**		**1.19**	
Renewability[e]		**0.87**		**1.38**	

Source: (Silalertruksa and Gheewala, 2009)

[a]Energy content of ethanol = 21,200 MJ/1000 L ethanol.
[b]Net Energy Value (NEV) = Energy content of ethanol – Net energy inputs.
[c]NRnEV = Energy content of ethanol – Fossil energy inputs.
[d]Net Energy Ratio (NER) = Net energy outputs/Net energy inputs.

[e]Renewability = Net bioenergy outputs/Net fossil energy inputs.

5.1.2 Cane molasses ethanol

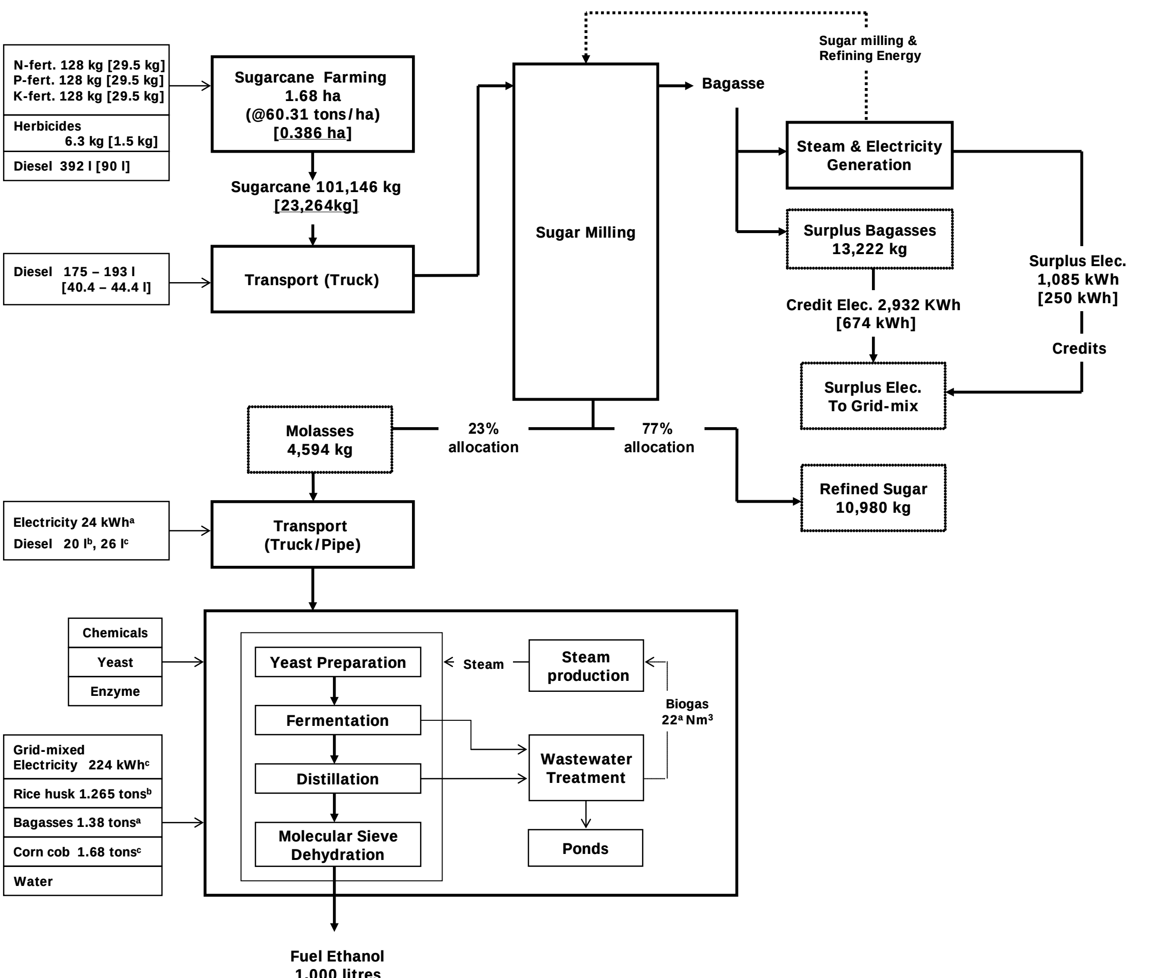
Cane molasses ethanol has been produced in Thailand for many years, three existing molasses ethanol plants in Thailand were assessed to evaluate the NER and renewability. The "cradle to gate" of molasses based ethanol system consists of four stages including (1) sugar cane farming and harvesting, (2) sugar milling (3) ethanol conversion and (4) transportation during each stage. The details of each stage are presented below:

a. Sugar cane farming and harvesting: Sugarcane farming includes field preparation, plant cane farming, treatment and harvesting. Sugar cane is initially grown from short sections of cane (plant cane). For the next three years the cane is cut and regrown (ratoon cane) before replanting with new cane stems. A cycle of sugarcane planting and harvesting is about 12 months. The average sugarcane yield from four cycles is 60.31 tonnes.ha^{-1}.yr^{-1} based on the decreasing rate of sugarcane yield. Fertilizers and diesel used for cultivation and harvesting of sugarcane are 487.5 kg.ha^{-1} and 223.6 L.ha^{-1} respectively. An average human labor of 466 man-hours per hectare of sugarcane is required for all farming activities since land preparation, planting, crop maintenance and harvesting.

b. Sugar milling: Sugar milling involves crushing cane to extract the juice. This juice is clarified to remove any impurities and concentrated into syrup by boiling off excess water, seeded with raw sugar crystals in a vacuum pan and boiled until sugar crystals have formed and grown. The crystals are separated from the syrup by centrifugal process before more crystals are grown in the syrup. Molasses is the syrup remaining after the sugar has passed through the centrifuge for the last time in a mill or refinery. Products and by-products of sugar milling include raw sugar, refined sugar, super refined sugar, molasses and bagasse. Bagasse is used to produce steam and electricity. The surplus electricity is sold to the national grid and can thus get the credits from avoided conventional electricity production. Molasses is an internationally traded commodity with total sugar content as the key quality criterion. The sugar in the molasses will be converted to ethanol in the fermentation process. Energy based allocation technique was applied to share the environmental burdens from sugarcane cultivation and sugar mill between the co-products, sugar and molasses. To determine the allocation factor, all kinds of sugar products have been assumed to have an average energy content (HV_{sugar}) = 16.33 MJ/kg and the energy content of molasses is ($HV_{molasses}$) = 11.43 MJ/kg. Allocation factor for molasses ($AF_{molasses}$) can be calculated from $AF_{molasses} = (M_{molasses} \times HV_{molasses})/(\Sigma M_{sugar,i} \times HV_{sugar} + M_{molasses} \times HV_{molasses})$, where $M_{sugar,i}$ is the mass of sugar product (i) and $M_{molasses}$ the mass of molasses per ton sugarcane. The above calculations yielded a factor of 0.23 which was used to determine the environmental burdens from molasses production.

c. Ethanol conversion: The process of making molasses based ethanol consists of yeast preparation, fermentation, distillation and dehydration. The generation of bio-based CO_2 from fermentation was not accounted for in the life cycle assessment.

d. Transport: The whole cycle of molasses ethanol production involves transportation of sugarcane to the sugar mill and transportation of molasses to the ethanol plant. Sugarcane is transported to the sugar mill by various types of trucks e.g. 15-t truck, 21-t truck, or trailer. The average distance (one-way trip) of 10 sugar mills in Thailand is 42.5 km. The most widely used truck for transporting sugarcane ranges between 18 to 25 tonnes per trip (average value used in the study is 21.50 tonnes per trip). Trucks are generally used for transporting molasses to the commercial ethanol manufacturers; however, some molasses ethanol plants receive molasses from the sugar mills through pipeline. This study assumes that 140 km (102-206 km) is the average road distance (from four molasses ethanol producers) for transporting molasses to the ethanol plant.



Remark: [ ] values in parentheses are the results after allocation to molasses. .

[a]Specific inputs for the MoE Plant-1

[b]Specific inputs for the MoE Plant-2

[c]Specific inputs for the MoE Plant-3

Figure 5.2 Life cycle materials flow diagram of molasses based ethanol (Silalertruksa and Gheewala, 2009)

As seen in **Table 5.2**, the net energy output from molasses ethanol includes energy content of ethanol and surplus electricity from sugar milling. Two of the molasses ethanol plants (MoE plant-1 and plant-2) have an NER slightly higher than 1 while the third one (MoE plant-3) loses energy. The poor performance of the third one is due to inadequate energy conservation practices especially for the steam production and utilization system e.g. less amount of condensate recovery, no biogas recovery and low efficiency of boiler due to lack of preventive maintenance. The result also shows that among all subsystems in the molasses ethanol cycle, ethanol conversion is the most energy-consuming stage, contributing two-thirds of the net energy input. Of special interest is the MoE plant-1 where due to the integration of sugar milling and ethanol production, molasses can be transported through pipes to the ethanol conversion plant resulting in reduced fossil energy use. Moreover, the MoE plant-1 also has the highest renewability of about 3.21 indicating that about 69% of the final fuel energy is obtained from renewable resources. It means that fuel ethanol produced from the MoE plant-1 can be considered renewable and the system approaches complete renewability (100%).

Table 5.2 Energy balance (MJ) for production of 1000 L molasses based ethanol (MoE)

	MoE Plant-1		MoE Plant-2		MoE Plant-3	
Items	**Total energy**	**Fossil energy**	**Total energy**	**Fossil energy**	**Total energy**	**Fossil energy**
1) Sugarcane farming						
NPK fertilizers	3,228	3,069	3,089	2,937	2,932	2,788
Herbicide	662	626	634	599	601	569
Diesel (farm machinery)	3,968	3,968	3,798	3,798	3,604	3,604

	MoE Plant-1		MoE Plant-2		MoE Plant-3	
Items	**Total energy**	**Fossil energy**	**Total energy**	**Fossil energy**	**Total energy**	**Fossil energy**
Labor	429		418		397	
2) Sugar Milling						
Surplus electricity during normal operation (to grid)	(-2,608)		(-2,496)		(-2,369)	
Surplus bagasse (converted to electricity to grid)	(-7,047)		(-6,745)		(-6,401)	
3) Ethanol conversion						
Steam & Electricity	17,378		16,412		23,491	2,173
4) Transport						
Sugarcane	1,955	1,955	1,871	1,871	1,775	1,775
Molasses	238		869	869	1,155	1,155
Net energy inputs	27,858	9,618	27,091	10,074	33,955	12,064
Net energy outputs (Ethanol & surplus electricity)	30,855		30,441		29,970	
NEV	2,997		3,350		(-3,985)	
NRnEV		21,237		20,367		17,906
Net Energy Ratio (NER)	1.11		1.12		0.88	
Renewability	3.21		3.02		2.48	

Source: (Silalertruksa and Gheewala, 2009)

Table 5.3 Comparison of NER and Renewability of existing bioethanol systems in Thailand

	NER	**Renewability**
Cassava ethanol	0.82 - 1.19	0.87 – 1.38
Cane molasses ethanol	0.88 – 1.12	2.48 – 3.21
Sugarcane ethanol*	n/a	n/a

*No results of the existing sugarcane ethanol production due to there is only 1 sugarcane ethanol in Thailand today and the plant just recently started operation in 2010.
Source: (Silalertruksa and Gheewala, 2009)

5.2 Change in total primary energy supply due to ethanol production in Thailand

Table 5.4 and **Figure 5.3** show the total primary energy supply by types of fuels and the trends of primary energy supply in Thailand, respectively. The statistics reveal that biofuels nowadays (year 2010) have a very low effect to the change in total primary energy supply of Thailand due their low overall contribution of only 0.7% of total primary energy supply or only 0.3% if considering only bioethanol. The average bioethanol production in 2010 was around 1.17 million litres and this value is still far from the target set by government at producing 3 million litres bioethanol production per day in 2011 and 9 million per day in 2022. Nevertheless, due to the several promotion policies, availability of feedstocks supply as cassava and also the new ethanol plants that are under construction and going to operate soon, bioethanol still has a high potential to help country in diversification of energy supply in the foreseeable years.

Table 5.4 Total primary energy supply by types (Unit: ktoe)

	2005	2006	2007	2008	2009	2010
COMMERCIAL ENERGY	**86,303**	**88,449**	**90,087**	**90,688**	**93,030**	**99,494**
	100%	**100%**	**100%**	**100%**	**100%**	**100%**
ANTHRACITE	360	411	230	180	484	312
	0.4%	0.5%	0.3%	0.2%	0.5%	0.3%
BITUMINOUS	3,879	3,557	4,749	4,557	4,411	3,908
	4.5%	4.0%	5.3%	5.0%	4.7%	3.9%
COKE	45	35	43	34	7	183
	0.1%	0.0%	0.0%	0.0%	0.0%	0.2%
LIGNITE	6,050	5,231	4,919	4,968	4,801	4,867
	7.0%	5.9%	5.5%	5.5%	5.2%	4.9%
BRIQUETTES & OTHER COAL	1,123	3,029	3,925	5,208	4,504	5,352
	1.3%	3.4%	4.4%	5.7%	4.8%	5.4%
CRUDE OIL	45,663	47,275	46,118	46,658	47,733	47,664
	52.9%	53.4%	51.2%	51.4%	51.3%	47.9%
CONDENSATE	2,817	3,072	3,095	3,449	4,932	5,090
	3.3%	3.5%	3.4%	3.8%	5.3%	5.1%
NATURAL GAS	28,770	29,615	31,418	33,230	34,819	40,217
	33.3%	33.5%	34.9%	36.6%	37.4%	40.4%
NATURAL GASOLINE	-143	-109	-104	-104	-109	-89
	-0.2%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
PETROLEUM PRODUCTS	-3,868	-5,844	-6,409	-9,205	-10,213	-9,755
	-4.5%	-6.6%	-7.1%	-10.2%	-11.0%	-9.8%
ELECTRICITY	1,607	2,177	2,103	1,713	1,661	1,745
	1.9%	2.5%	2.3%	1.9%	1.8%	1.8%
RENEWABLE ENERGY	**16,679**	**17,058**	**18,227**	**19,330**	**19,578**	**21,279**
	100%	**100%**	**100%**	**100%**	**100%**	**100%**
FUEL WOOD	11,722	10,276	11,369	11,770	11,328	12,722
	70%	60%	62%	61%	58%	60%
CHARCOAL	21	27	-6	35	37	47
	0%	0%	0%	0%	0%	0%
PADDY HUSK	1,594	1,555	1,646	1,814	1,939	1,533
	10%	9%	9%	9%	10%	7%
BAGASSE	3,332	2,863	3,218	3,486	3,623	3,864
	20%	17%	18%	18%	19%	18%
AGRICULTURAL WASTE	6	2,329	1,991	2,205	2,611	3,035
	0%	14%	11%	11%	13%	14%

GARBAGE	3	4	3	4	4	3
	0%	0%	0%	0%	0%	0%
BIOGAS	1	4	6	16	36	75
	0%	0%	0%	0%	0%	0%
BIOFUEL	**-**	**-**	**190**	**602**	**798**	**804**
	100%	**100%**	**100%**	**100%**	**100%**	**100%**
ETHANOL			130	253	335	329
			68%	42%	42%	41%
BIODIESEL			60	349	463	475
			32%	58%	58%	59%
OTHER ENERGY	**320**	**255**	**292**	**267**	**304**	**238**
	100%	**100%**	**100%**	**100%**	**100%**	**100%**
BLACK LIQUOR & RESIDUAL GAS	320	255	292	267	304	238
	100%	100%	100%	100%	100%	100%
TOTAL PRIMARY ENERGY SUPPLY	**103,302**	**105,762**	**108,796**	**110,887**	**113,710**	**121,815**
TOTAL (%)	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
COMMERCIAL ENERGY	83.5%	83.6%	82.8%	81.8%	81.8%	81.7%
RENEWABLE ENERGY	16.1%	16.1%	16.8%	17.4%	17.2%	17.5%
BIOFUEL	0.0%	0.0%	0.2%	0.5%	0.7%	0.7%
OTHER ENERGY	0.3%	0.2%	0.3%	0.2%	0.3%	0.2%

Source: DEDE, 2011

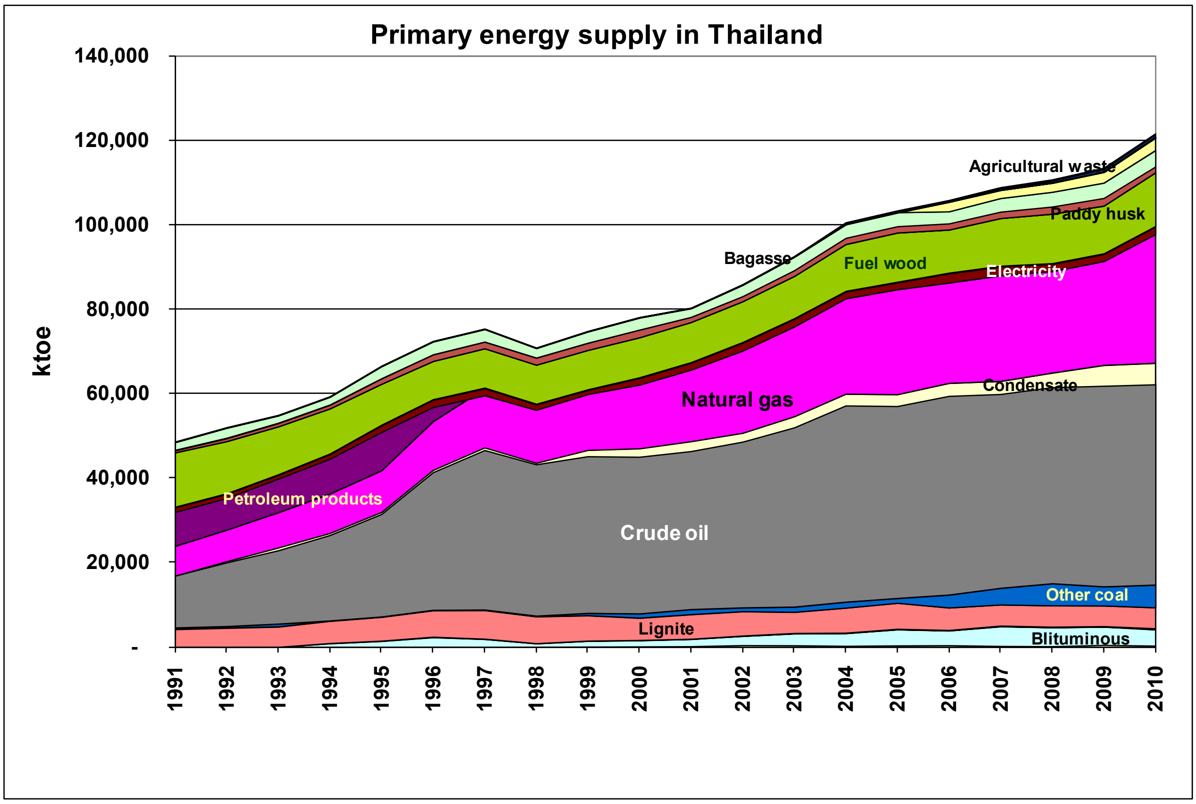


Figure 5.3 Trends of total primary energy supply of Thailand (year 1991-2010)

5.3 Change in the consumption of gasoline used for transport in Thailand

Relevant Indicator	I 20: Change in the consumption of fossil fuels and traditional use of biomass
Indicator descriptions (ID)	Substitution of fossil fuels with domestic bioenergy measured by energy content and in annual savings of convertible currency from reduced purchases of fossil fuels •Substitution of traditional use of biomass with modern domestic bioenergy measured by energy content

The promotion of bioethanol in Thailand has obviously changed the consumption pattern of people who use passenger cars and also motorcycles from gasoline to gasohol. Nowadays, there is a widespread replacement of gasoline with gasohol namely E10 (a 10% blend of ethanol with 90% gasoline). Moreover, E20 (a 20% blend of ethanol with 80% gasoline) and E85 (an 85% blend of ethanol with 15% gasoline), introduced in Thailand in 2008, are expected to attain significant market recognition and penetration along with the E10 blend. Table 5.5 shows the change in fuel consumptions for transport in Thailand in terms of kilo ton of oil equivalent (10^3 tons of oil equivalent).

Table 5.5 Energy consumption for Transport classified by Types (Unit: ktoe)

	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
LPG	295	267	245	263	353	535	667	904	778
Gasoline RON91	2,815	3,177	3,327	3,375	3,155	3,254	3,263	2,462	2,099
Gasoline RON95	2,223	2,213	2,286	2,197	1,653	1,086	817	244	129
Gasohol E10 RON91	2	-	-	-	21	72	182	688	1,044
Gasohol E10 RON95	2	1	2	45	481	883	1,132	1,817	2,210
Gasohol E20 RON95	-	-	-	-	-	-	-	22	61
Gasohol E85	-	-	-	-	-	-	-	-	-
Jet fuel	3,038	3,038	3,074	3,074	3,509	3,694	4,031	3,789	3,623
High Speed Diesel	9,459	9,958	10,810	10,810	12,654	11,709	11,202	7,579	6,722
Low Speed Diesel	78	83	70	70	60	47	26	7	-
Palm Diesel	1	1	1	1	4	3	3	2	1
High Speed Diesel (B5)	-	-	-	-	4	37	540	3,258	4,734
Fuel oil	716	839	1,096	1,096	1,543	1,579	1,539	1,593	1,466
Total	**18,629**	**19,577**	**20,911**	**20,931**	**23,437**	**22,899**	**23,402**	**22,365**	**22,867**

Source: DOEB, 2010; DEDE, 2009

5.4 Flex-fuel vehicles (FFVs) in Thailand

Relevant Indicator	I 23: Infrastructure and logistics for distribution of bioenergy;

Indicator descriptions (ID)	Number and capacity of routes for critical distribution systems, along with an assessment of the proportion of the bioenergy associated with each
Relevant Indicator	I 24: Capacity and flexibility of use of bioenergy;
Indicator descriptions (ID)	Ratio of capacity for using bioenergy compared with actual use for each significant utilization route • Ratio of flexible capacity which can use either bioenergy or other fuel sources to total capacity

The motor is continually replaced due to the aging of vehicles. Replacing the fleet with flex-fuel cars (FFV) is also one of the measures that the Thai government is using to promote biofuels production in the country. Even though the policy targets include primarily the E10 blends that can be used in the majority of post-1990 standard engines without modification, to achieve the ambitious targets of bioethanol production and use in medium and long term, a limited number of cars capable of handling the higher blends of ethanol are anticipated: According to policy goals, 318,000 cars that can use E20 and 1000 cars that can use E85 are expected in the year 2011. Economic measures such as subsidies for FFV buyers have been implemented in order to encourage use of FFV. However, in fact, the decision of consumers to buy these new vehicles capable of running on higher ethanol blends such as E20 and E85 should be influenced primarily by the subsidized fuel prices that can be attained from the switch. These customers will not be otherwise incentivized to purchase flex-fuel cars and will likely only purchase the vehicles as part of the standard aging and replacement process for motor vehicles (Bell et al., 2011).

Nowadays, most new passenger cars sold in Thailand can support E10 and an increasing number of models that can use E20. **Table 5.6** shows the existing four vehicle models that can be used for E85 and the rise in numbers of FFVs sold in Thailand during 2008-2010. As of July 2011, the accumulated number of FFVs used in Thailand is 5,548 vehicles accounting for 0.1% of total passenger cars available in Thailand (based on total numbers of passenger cars (size less than 7 people) which is around 4.8 million cars) (DLT, 2011). If compared to the total passenger cars sale in 2010 which is around 338,000 units (DLT, 2011), the FFV sale in 2010 shares about 0.7%.

Table 5.6 Total sales of FFVs in Thailand

	2008 (Nov-Dec)	**2009**	**2010**	**2011 (Jan-July)**	**Total**

1. Volvo S80 2.5FT	44	92	298	70	504
2. Volvo S80 Business line			182	77	259
3. Volvo C30 1.8F	2	2	3	-	7
4. Mitsubishi Lancer EX	-	1,014	1,852	1,604	4,470
5. Chevrolet Captiva				308	308
Total	**46**	**1,108**	**2,335**	**2,059**	**5,548**

Source: FFV Promotion project, 2011

6. Food security

Relevant Indicators	GBEP-I10: Price and supply of a national food basket
Indicator descriptions (ID)	Effects of bioenergy use and domestic production on the price and supply of a food basket, which is a nationally-defined collection of representative foodstuffs, including main staple crops, measured at the national, regional, and/or household level, taking into consideration: • changes in demand for foodstuffs for food, feed, and fibre; • changes in the import and export of foodstuffs; • changes in agricultural production due to weather conditions; • changes in agricultural costs from petroleum and other energy prices; and • the impact of price volatility and price inflation of foodstuffs on the national, regional, and/or household welfare level, as nationally-determined • influence of the feedstock (cassava and sugarcane) to food security, land use problems etc.

Thailand is known as an agro-industrial based country and one of the world's leaders in food exports. In 2007, the agricultural areas in Thailand were about 21.05 million hectares contributing 40% of the total area of Thailand (51.31 million hectares) (OAE, 2010a). Paddy rice is the country largest crop both in terms of cultivated area and economic output value, followed by natural rubber, cassava, sugarcane and maize, respectively (FAOSTAT, 2011). A variety of crops such as sugarcane, cassava, sweet sorghum and maize can possibly be used for bioethanol production in Thailand. However, cassava and sugarcane are the outstanding crops being promoted by the government due to their availability of supply. Statistics show that Thailand is the world's largest cassava producer and exporter contributing about 70% of the world market share (Sriroth et al., 2010) and is also ranked as the world's second leading sugar exporter after Brazil which is the outstanding sugarcane producer (OAE, 2008a). In addition, Thailand is one of the world's leaders in exporting of other agricultural products especially rice and natural rubber.

Thailand's policy framework for bioethanol development is underpinned by the 15-year Alternative Energy Development Plan (2008-2022) which sets an ambitious goal of producing 9.0 M.litres/day by 2022 (DEDE, 2008). This rapidly anticipated growth of bioethanol production in the foreseeable years leads to several concerns on its effects to food security (both national and global). For example, if the scarce and limited resources such as fertile land, water, fertilizers, etc. are diverted from food and feed production to be used for energy crop cultivation. Where the arable land competition exists and the bioenergy crop cultivation is an alternative land use, prices of agricultural inputs could rise leading to the rising prices of staple foods (FAO, 2008a; WBGU, 2010). The rapid rise in staple food prices would be a burden on the poor and consumers in developing countries, who spend roughly half of their household incomes on food.

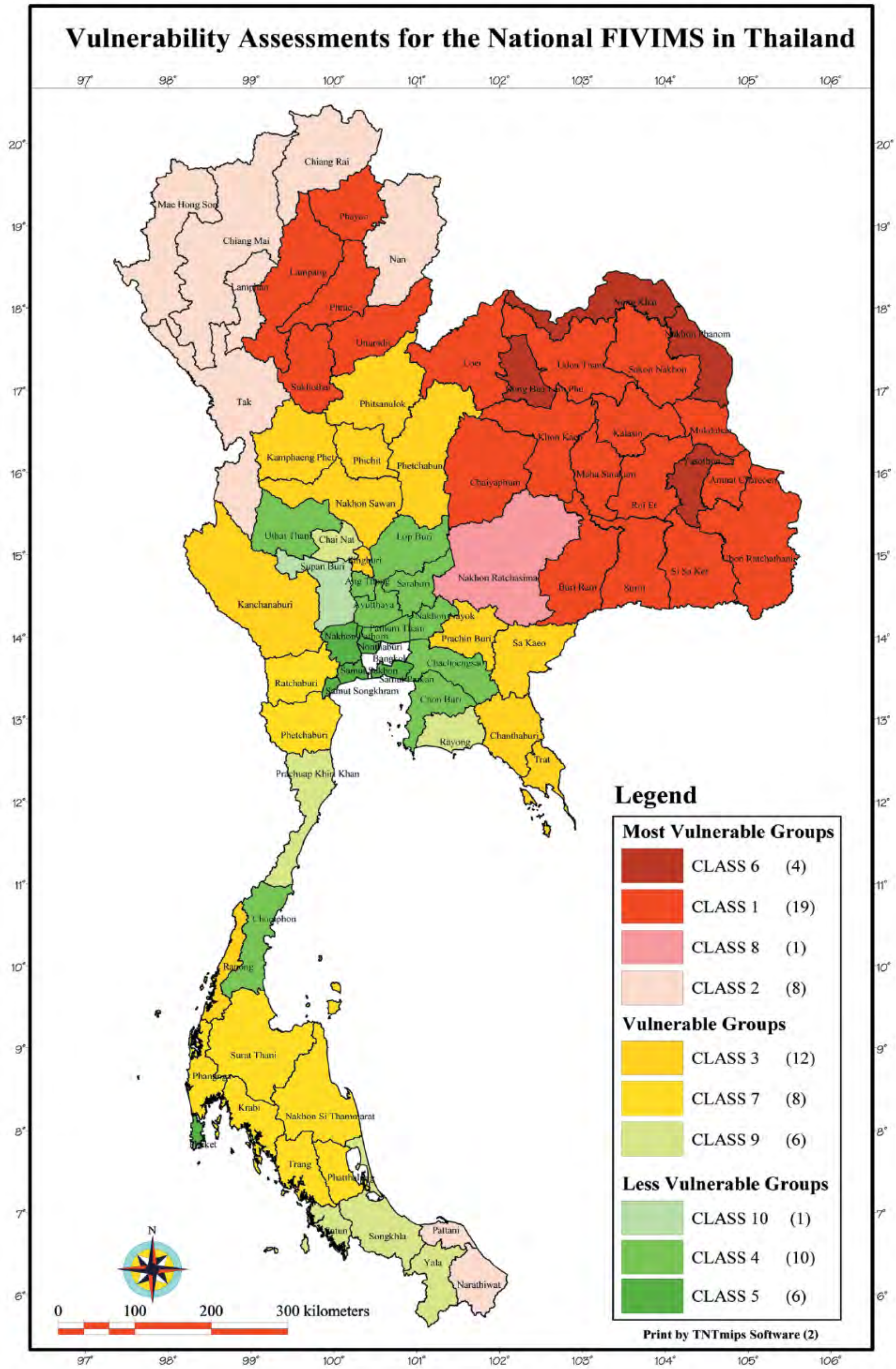
6.1 Food insecurity area in Thailand

For Thailand, the National Food Security Committee (NFC) was set up in May 2000 by supporting of FAO. The first Thailand's Food insecurity and vulnerability mapping system (FIVIMS) has also been conducted from this program. The results show that 23 of the 32 most vulnerable provinces or about 38.75% of total population indicated significant food insecurity as revealed by the negative health and nutrition conditions and high prevalence of malnutrition (FIVIMS, 2004). Moreover, those 32 provinces are mainly located in the Northeastern and the Northern region as shown in **Figure 6.1** and **Table 6.1**. The point to note is that the Northeastern region is also the main area of cassava and sugarcane cultivation in Thailand. The major vulnerability factors are (1) very low per capita/household income; (2) high percentage of inactive household members; (3) small farm holdings; and (4) cultivated land being "under mortgage" or rented under "share of produce" arrangement (FIVIMS, 2004). Therefore, the promotion of bioethanol industry in those vulnerable provinces on food insecurity would be a great opportunity to provide benefits to rural farmers by generating more and stable income from selling energy crops. This is because the surveys revealed that the average buying price of cassava (25% starch) by ethanol industry is higher than the buying prices of starch, animal feed and dried chip industries. In addition, high food prices would be an opportunity for the agricultural sector in the long run as it can help foster the development of infrastructure to support agricultural sector. Nevertheless, the impact of price volatility and price inflation of foodstuffs on the national, regional, and/or household welfare level need to be considered in terms of ability to access foodstuffs.

Table 6.1 Groups of food insecurity and vulnerability in Thailand (FIVIMS, 2004)

Group	**No.of provinces**	**% of to tal population**	**Regions**
A. The most vulnerable group	32	53.4%	Northeastern, Northern

B. Vulnerable Group	26	28.2%	Central, Southern
C. Less vulnerable group	17	18.4%	Central



Source: FIVIMS (2004)

Figure 6.1 Vulnerability mapping by province

6.2 Change in farmgate prices of crops

Figure 6. 2 shows the trend of main staple crop prices in Thailand. Based on the farm gate prices during 1990-2009 collected from FAOSTAT, the average annually rising rates of farm gate prices of rice, soybean, maize, sugar and cassava are 4%, 3%, 2%, 4% and 7%, respectively. The rises in farmgate price rates of cassava are higher than other crops but, of course, bioethanol alone could not be responsible for the price rise, or even most of it because there are various factors combined to increase the food prices e.g. increasing of food production costs due to the rising oil prices, production shortfalls because of the climatic events such as drought, changing of consumption patterns when the people have changed in incomes, the weak currency exchange, stock level and market volatility (Oxfam, 2008; Mitchell, 2008; Tyner, 2010; FAO, 2008a). In addition, cassava consumption for bioethanol production contributes a very small percentage as compared to cassava consumption in other industries. Nevertheless, in fact, it is obvious that bioethanol production result in the competition in sourcing of cassava in the area that ethanol plant located. The contract and price incentive from ethanol factories are generally given to farmers to ensure the availability of cassava supply.

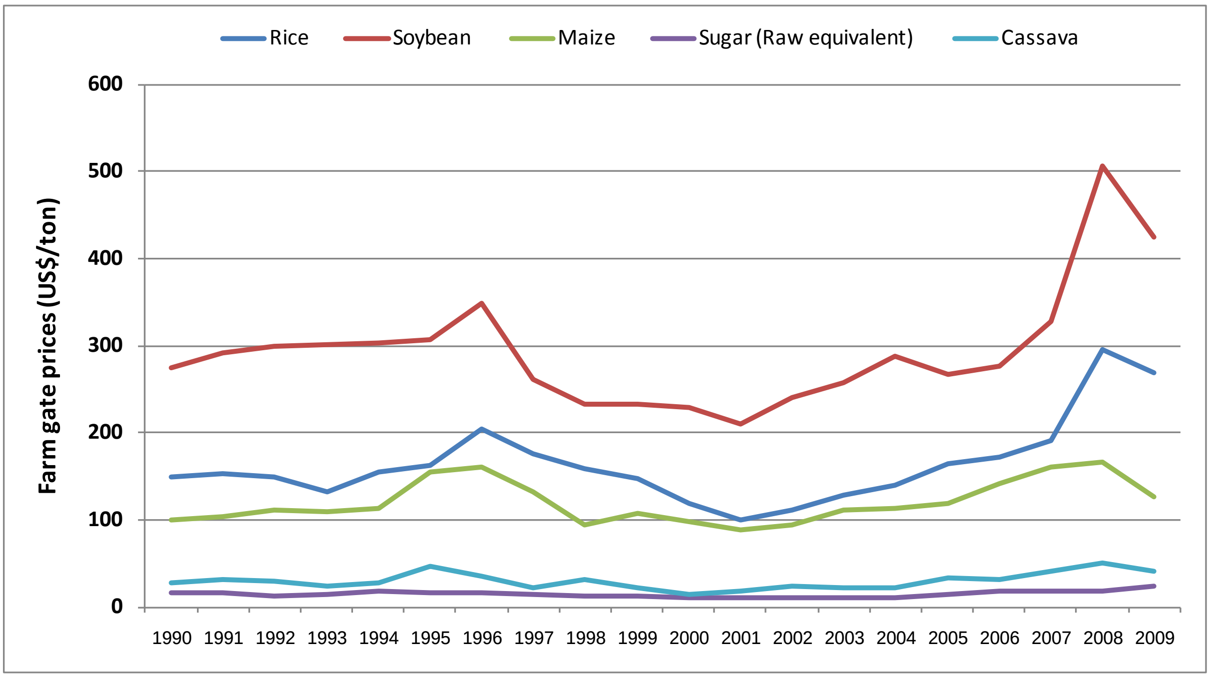


Figure 6.2 Farm gate prices of major staple crops in Thailand during 1990-2009 (AFSIS, 2011)

6.3 Impacts of price variation of biofuel crops on Thai households

Thailand Development Research Institute (TDRI) has recently conducted a microeconomic analysis to see the impacts of Thailand household income, consumption and poverty due to the movements in the price of agricultural commodities and biofuel crops (TDRI, 2009). The effects to household are divided into two parts i.e. (1) changes in food prices affecting the cost of living of people, particularly affecting the affordability for poor people and (2) changes in incomes of farmers who grow biofuel crops due to the increase in price of crops. The potential impacts of a price increase on farm income are shown in **Table 6.2**. Per percentage of increase in food price will result in a greater percentage in the increase in farm income. However, the results of TDRI also reveal that a rise in food price will also result in an increase of the incidence of poverty in all regions as shown in **Table 6.3**. Households growing only rice will suffer the most from the rising food prices as rice-only households in Thailand are generally closer to the food poverty line than the other household types (FAO, 2010a). These results indicate that the increase in income of farmers resulting from higher food prices may offset the change in the food poverty line and lead to benefits for some household types.

Table 6.2 Impacts of food price on farm income

Scenarios	Farm income increase (%)	
	Elasticity = 1.10	Elasticity = 1.25
Scenario 1 (S1): Food price increase 3%	3.30	3.75
Scenario 2 (S2): Food price increase 5%	5.50	6.25
Scenario 3 (S3): Food price increase 10%	11.00	12.50

Source: FAO, 2010a

Table 6.3 Changes in poverty incidence by household type

Household type	**Elasticity = 1.00**			**Elasticity = 1.25**		
	S1	**S2**	**S3**	**S1**	**S2**	**S3**
Non-agriculture	0.11	0.19	0.54	0.08	0.17	0.53
Agriculture - No rice	0.11	0.18	0.36	0.01	0.09	0.05
Agriculture – Rice only	0.31	0.58	1.14	0.23	0.43	0.66
Agriculture – Rice and other crop	0.17	0.16	0.46	0.04	-0.09	-0.31
Total	0.16	0.28	0.65	0.10	0.19	0.40

Source: FAO, 2010a

6.4 Change in exporting cassava and molasses

The assessment of security of feedstock supply for future bioethanol production in Thailand based on the bioethanol development plan (year 2008-2022) of the Royal Thai Government i.e. producing 3.0, 6.2 and 9.0 M.litres.day^{-1} ethanol by year 2011, 2016 and 2022, respectively has been performed by Silalertruksa and Gheewala (2010). The feedstock supply potentials as shown in **Table 6.4** are analyzed based on three scenarios varied by the possibilities of yields improvement. An expansion of cultivation area for growing cassava and sugarcane is not considered following the government policy aimed at maintaining the plantation areas of cassava and sugar cane as of year 2008 i.e. 7.75 M.rais for cassava and 6.59 M.rais for sugar cane [1 rai = 0.16 hectare]. The descriptions of the three scenarios are as follows:

Scenario 1: Low yields improvement: Crop yields are projected to continue growing as usual as if there is no policy on biofuels development. The annual growth rates of cassava and sugar cane yields are about 3% and 2%, respectively.

Scenario 2: Moderate yields improvement: Crop yields are anticipated to be improve as per the short-term government's policy targets as mentioned in the Thailand's 15-year renewable energy development plan i.e. increase yield of cassava from 3.46 (in 2008) to 5.4 tons roots/rai by 2013 and increase yield of sugar cane from 11.15 to 15 tons cane/rai by 2012. Linear growth rates in the crop yield are assumed;

Scenario 3: High yields improvement: Crop yields are projected to reach the genetic potential of cassava and sugar cane varieties. Based on genetic potentials of the current varieties of cassava and sugar cane, their yields could possibly reach 8 tons/rai and 20 tons/rai, respectively if they were cultivated in appropriate soil with good agricultural practices.

Table 6.4 Feedstock resource estimates for long-term bio-ethanol production

Surplus feedstocks		**2008**	**2009**	**2010**	**2011**	**2016**	**2022**
Scenario 1: Low yields improvement	Molasses (M.tons/year)	1.31	1.50	1.58	1.66	1.96	2.34
	Cassava (M.tons/year)	3.65	1.30	0.27	0.34	-3.94	-7.80
	Sugarcane (M.tons/year)	6.08	5.93	9.81	10.23	9.89	10.39
	Estimated molasses ethanol(M.litres/day)	0.90	1.03	1.08	1.14	1.35	1.61
	Estimated cassava ethanol (M.litres/day)	1.80	0.64	0.14	0.17		
	Estimated sugarcane ethanol (M.litres/day)	1.17	1.14	1.88	1.96	1.90	1.99
		3.87	**2.81**	**3.10**	**3.27**	**3.24**	**3.60**

	Total potential ethanol production (M.litres/day)						
Scenario 2: Moderate yields improvement	Molasses (M.tons/year)	1.31	1.77	2.06	2.36	2.54	2.44
	Cassava (M.tons/year)	3.65	1.99	3.02	5.14	2.11	-7.48
	Sugarcane (M.tons/year)	6.08	11.84	20.30	25.30	22.46	12.38
	Estimated molasses ethanol (M.litres/day)	0.90	1.21	1.41	1.61	1.74	1.67
	Estimated cassava ethanol (M.litres/day)	1.80	0.98	1.49	2.54	1.04	
	Estimated sugarcane ethanol (M.litres/day)	1.17	2.27	3.89	4.85	4.31	2.37
	Total potential ethanol production (M.litres/day)	**3.87**	**4.47**	**6.80**	**9.00**	**7.09**	**4.04**
Scenario 3: High yields improvement	Molasses (M.tons/year)	1.31	1.77	2.06	2.36	3.15	3.95
	Cassava (M.tons/year)	3.65	1.99	3.02	5.14	8.83	12.67
	Sugarcane (M.tons/year)	6.08	11.84	20.30	25.30	35.65	45.33
	Estimated molasses ethanol (M.litres/day)	0.90	1.21	1.41	1.61	2.16	2.71
	Estimated cassava ethanol (M.litres/day)	1.80	0.98	1.49	2.54	4.35	6.25
	Estimated sugarcane ethanol (M.litres/day)	1.17	2.27	3.89	4.85	6.84	8.69
	Total potential ethanol production (M.litres/day)	**3.87**	**4.47**	**6.80**	**9.00**	**13.35**	**17.65**

Source: (Silalertruksa and Gheewala, 2010)

To satisfy both the increase in demand for cassava and sugarcane by related industries (as shown in **Table 6.5**) and of the future ethanol production as shown in **Table 6.6**, the projections reveal that molasses is still enough to supply in the short- and medium-term. Nevertheless, for the long-term (year 2022), there will be a deficit of about 0.17 M.tons molasses. Therefore, increase of sugarcane yield to 15 tons/rai as per the current policy on biofuels development would help the country attain security of supply molasses. Otherwise, decreased export of molasses of around 16% in 2022 would be required to satisfy the bio-ethanol demand. For cassava, due to the continuously increasing demand for dried chips and starch especially for export to countries such as China and incorporating the rapidly growing domestic demand for cassava, the balances reveal that cassava is going to run short since year 2010, 2014 and 2016 for the low-, moderate- and high-yields improvement scenarios, respectively. Even though the deficits of cassava supply for bio-ethanol production in the future could possibly be fulfilled by decreasing export of cassava products, export reduction is an indicator of supply insecurity. It will affect not only the existing dried chips and starch industry in the country but also the lack of supply to global market bringing about the consequential impacts to global cropping systems and land-use change. This is because Thailand is known as the world's leading cassava exporter. For example, in case of moderate yield improvement, the deficit of cassava at about 6.95 and 20.63 M.tons in 2016 and 2022 could be compensated by decrease in the projected cassava export by about 24% and 55%, respectively. Therefore, the most appropriate approach is that cassava yields should be improved at least to 6.3 tons/rai by 2016 and 8.1 tons/rai by 2022.

On the other hand, sugarcane juice would play an important role as feedstock for the medium and long-term bio-ethanol production in Thailand because of its surplus availability and high net balances as compared to cassava and molasses. Nevertheless, increased diversion of sugarcane juice to ethanol in the simultaneous sugar-ethanol producers in the future would directly decrease the potential to export sugar in the future. Thus, policy makers need to consider proper management measures for balancing the use of sugarcane for producing both sugar and ethanol. Regularly monitoring is also required because feedstock prices can change rapidly by forcing of many factors in the market mechanism. In addition, the measures to guard against the future risks on feedstocks supply shortage need to be developed and promoted by the government.

Table 6.5 Feedstock requirements for other related industries (Unit: M.tons feedstocks)

Feedstocks used		**2008**	**2009**	**2010**	**2011**	**2016**	**2022**
Cassava	**Domestic uses**	***7.76***	***8.18***	***8.42***	***8.68***	***10.21***	***12.00***
	Chips/ pellets	2.31	2.52	2.63	2.73	3.44	4.26
	Flour/starch	5.45	5.66	5.78	5.94	6.76	7.74
	Exports	14.16	19.63	21.38	22.01	29.54	37.33
	Cassava chips	2.53	8.45	7.35	7.77	11.41	15.07
	Cassava pellets	3.29	0.70	3.36	3.15	3.15	3.15
	Cassva flour/starch	8.35	10.49	10.67	11.09	14.98	19.11
Sugarcane	**Domestic uses**	19.23	19.42	20.00	20.00	22.43	24.43
	Exports						
	Raw sugar	*28.82*	*22.67*	*22.75*	*23.16*	*25.18*	*27.62*
	Refined sugar	*19.38*	*25.91*	*23.14*	*24.08*	*28.78*	*34.42*
Molasses	**Domestic uses**						
	Animal feed & MSG	0.36	0.4	0.4	0.4	0.50	0.61
	Distillery	1.00	1.00	1.00	1.00	1.00	1.00
	Exports	0.71	0.5	0.5	0.5	0.5	0.5

Source: (Silalertruksa and Gheewala, 2010)

Table 6.6 Projections of feedstocks required for bioethanol production

	2008	2009	2010	2011	2016	2022
Bio-ethanol production targets						
(M.litres/day)	0.88	1.34	2.11	3.00	6.20	9.00
Projected bio-ethanol production classified by feedstock types						
Molasses ethanol (M.litres/day)	0.81	0.66	0.64	0.72	1.19	1.72
Cassava ethanol (M.litres/day)	0.07	0.38	1.17	1.95	4.47	6.48
Sugarcane ethanol (M.litres/day)		0.31	0.30	0.33	0.55	0.80
Estimated. feedstocks required						
Molasses (M.ton/year)	1.18	0.96	0.93	1.05	1.73	2.51
Cassava (M.ton/year)	0.15	0.76	2.38	3.95	9.06	13.15
Sugarcane (M.ton/year)		1.60	1.55	1.74	2.86	4.15

Source: (Silalertruksa and Gheewala, 2010)

6.5 Key findings and recommendations to enhance the future food security

(1) Biofuels demand can lead to increase in cassava and sugarcane prices which on one side can increase income to farmers but on the other will also increase the incidence of poverty in Thailand due to the increased food and agricultural prices.

(2) Cassava and sugarcane ethanol could help spurring the rural development and improve food security of the farmers in the Northeastern region which is the poorest region in Thailand through employment and income generation.

(3) Resolving the potential conflict between food and fuel crops by improving yields with existing feedstocks: Yield improvement would be another vital measure to enhance security of feedstocks supply with less environmental and social impacts as compared to expansion of cultivation areas. Due to the continual development of genetic technology, there are various high yield varieties of cassava and sugarcane nowadays that would nearly and possibly reach those yield targets under appropriate soil with good agricultural practices such as improved soil quality by using organic fertilizers, good practices in land preparation, plantation, harvesting and regularly weed control (Vichukij, 2007;

FCRI, 2005; FCRI, 2007). For example, the current varieties of cassava (e.g. Kasetsart 50, Rayong 5, Rayong 72 and Rayong 9) and sugarcane (e.g. K 84-200, U thong 3 and K 90-54) being recommended to Thai farmers have the potential to yield about 33.5 – 50 tons/hectare for cassava and 92 – 125 tons/hectare for sugarcane. Intensification of fertilizer use could be another way to quickly improve yields but it needs careful control because it may create adverse impact on ecosystem and GHG emissions.

(4) System for zoning crops should be developed in case expansion of cultivation areas is required: Due to the possibility to achieve the targeted yields of biofuel crops as scenarios are highly dependent on the suitability class of cultivated areas for that crops and water input conditions, the Land Development Department has analyzed the ratio of cultivated land under sugarcane and cassava in 2010 classified by land suitability class and irrigation as shown in **Table 6.6**. The results show that just a small percentage of the existing cultivated area for cassava and sugarcane is under the very suitable class or suitable class which can result in the higher yields. Therefore, suitable future land use planning for energy crops would be useful to maximize resource use and enhance food security due to the productivity improvement.

Table 6. 6 Ratio of cultivated land under sugarcane and cassava in 2010 classified by land suitability class and irrigation

	Sugarcane			**Cassava**		
Suitability class	**Irrigated**	**Rainfed**	**Total**	**Irrigated**	**Rainfed**	**Total**
Very suitable	0.6%	6.0%	6.6%	0.2%	9.2%	9.4%
Suitable	3.7%	32.2%	36.0%	0.1%	9.9%	10.1%
Moderately suitable	0.3%	13.0%	13.3%	0.5%	25.3%	25.8%
Marginally suitable	1.6%	42.6%	44.2%	0.2%	54.4%	54.7%
Total	**6.2%**	**93.8%**	**100.0%**	**1.1%**	**98.9%**	**100.0%**

Source: FAO, 2010a

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