UNEP

Application of the Sustainability Assessment of Technologies Methodology: Guidance Manual

United Nations Environment Programme

Preface / Foreword

There has been a significant development of the paradigm of sustainability through various global deliberations and conferences over the past years. However, the dominant system of decision making in technology selection for development has focused on economic considerations and tends to disassociate social and environmental factors. Policy makers and stakeholders increasingly recognized that there is a need to take environmental and social concerns into account on decision making for investments. This led to the promotion of Environmentally Sound Technologies (ESTs) in the context of sustainability. Highlighted within the Agenda 21 at the United Nations Conference on Environment and Development (UNCED) in 1992, many initiatives have developed. ESTs include technologies for cleaner production processes, pollution prevention, end-of-pipe and monitoring technologies. ESTs function as total 'systems' that include knowledge and skills, as well as organizational and managerial procedures.

The world has also witnessed the rapid development of the Technology Assessment (TA) framework. TA is a process of assessing and evaluating environmental technologies to facilitate identification and selection of the best technology option.

The International Environmental Technology Centre (IETC) of the United Nations Environment Programme (UNEP) accordingly initiated the development of a methodology for the Environmental Technology Assessment (EnTA). EnTA is a systematic procedure whereby a proposed technology intervention is described and appraised in terms of its potential influence on the environment, implications for sustainable development and the likely cultural and socio-economic consequences.

Later, IETC transformed the EnTA methodology into a Sustainability Assessment of Technologies (SAT), with further improvements, including a focus on process and outcome and more attention to informed and participatory decision making. It was developed through an elaborate process of research and consultations with experts. This methodology has been used extensively in the field and the present guidance manual was developed based on feedback from various stakeholders, including policy makers and practitioners. The guidance manual also includes detailed case studies that show applications of the SAT methodology in different sectors and at different levels of decision making.

The SAT methodology is expected to be used by a diverse group of stakeholders in different situations and at various levels for strategic decision making. The methodology can also be applied at the operational level – primarily by the technical/engineering staff, designers, and consultants – to assess alternate technology systems.

This manual incorporates the SAT methodology for both strategic and operational level assessments while enabling it to be applied in any or all scenarios in the context of sustainable socio-economic development. SAT methodology can be adapted to the specific parameters and constraints of each country. Integration of economic, social and environmental considerations ensures resource efficiency and social acceptability. Hence, for policy makers, Governments and financial institutions, the methodology can be used with the objective of strategic planning and policy making, and assessing projects for funding. For operating communities and enterprises, it can be used for assessment and comparison of collective alternative technologies.

This manual may also be of interest to interested parties/organizations supporting decision-makers on applying SAT methodology. These application areas may include:

- Environment and health related programs;
- Provision of basic infrastructure such as roads, power, water etc.
- Bio-diversity management;
- Land remediation/reclamation;
- End-of pipe water and waste management;
- Water and waste recycling programs;
- Process technology modernization at shop floors and at industrial clusters.

There were many steps involved to produce this guidance manual. Much effort went in to produce the SAT methodology through collaboration with internal and external partners. IETC, with the Environmental Management Centre (EMC) of India led by Dr. Prasad Modak, finalized the methodology through intensive expert-reviewed workshops. Later, IETC used the SAT methodology in its projects in water management and waste management sectors, involving various local and national partners such as Governments, academia, technical institutes and private sectors. Some of these projects were used as case studies for preparing this guidance. IETC also developed training materials on the SAT methodology and provided intensive training to partners and stakeholders. Based on the training feedback, this guidance manual was developed to accelerate the capacity building progress on SAT methodology.

This manual is intended to serve as a living document. Practitioners and policy makers are encouraged to provide feedback, which will be incorporated into the next edition. The coming edition will also have case studies from the beneficiaries of this manual. Therefore, we ask all policy makers and practitioners to actively send us case studies involving technology selection based on SAT methodology.

Application of the Sustainability Assessment of Technologies Methodology: Guidance Manual

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List of Abbreviations

%	Percent
3Rs	Reduce, reuse and recycle
AHP	Analytic hierarchy process
Amp	Amperes
BDT	Bangladesh taka
BIMA	Biogas induced mixing arrangement
C/B ratio	Cost to benefit ratio
CDM	Clean Development Mechanism
CDMA	Chennai Metropolitan Development Authority
CERs	Certified emission reductions
CH4	Methane
CLRI	Central Leather Research Institute
cm	Centimeters
CO	Carbon monoxide
CO2	Carbon dioxide
DS	District Secretariat
EnTA	Environmental Technology Assessment
EST	Environmentally Sound Technology
ft	Feet
GEC	Global Environment Centre Foundation
GI	Galvanized iron
H	Height
H2	Hydrogen
H_2S	Hydrogen sulphide
ha/h	Hectares per hour
HP	Horsepower
IETC	International Environmental Technology Centre
IOOI	Input-Output-Outcome-Impact
IRR	Internal rate of return
IWMS	Integrated waste management schemes
Kcal	Kilocalories
Kg	Kilograms
kg/ha	Kilograms per hectare
kg/hr-m^2	Kilograms per hour per square metre
kW	Kilowatt
kWe	Kilowatt electrical
kwh/d	Kilowatt hours per day
kWth	Kilowatt thermal
L	Liter
L	Length
l/day	Liters per day
LPG	Liquefied petroleum gas
m	Meters
m^3	Cubic meters
MEAs	Multilateral Environmental Agreements
min	Minutes
mm	Millimeters
MNRE	Ministry of New Renewable Energy Sources
MS	Mild steel

MTM	Madhyapur Thimi Municipality
N2	Nitrogen
no.	Number(s)
NPK	Nitrogen, phosphorus and potassium content
NPV	Net present value
Ø	Diameter
^{o}C	Degrees centigrade
ODS	Ozone depleting substances
RECAST	Research Centre for Applied Science and Technology
Rp	Indonesian rupiah
rpm	Revolutions per minute
Rs.	Indian rupees
SAT	Sustainability Assessment of Technology
SEED	Society for Environment and Economic Development
t	Tons
t/m^3	Tons per cubic meter
TNEB	Tamil Nadu Electricity Board
TOC	Total organic carbon
TPD	Tons per day
UASB	Upflow Anaerobic Sludge Blanket
UNEP	United Nations Environment Programme
V	Volts
v/v	Volume by volume
VAT	Value added tax
W	Width
W/W	Weight-weight
WAB	Waste agricultural biomass
TA	Technology assessment

PART I

UNDERSTANDING SAT

What Will You Learn Here?

- Background
- Overview of SAT
- Key Elements of SAT Methodology
- Applying the SAT Methodology
- Conclusion

1.0 UNDERSTANDING SAT

1.1 BACKGROUND

The paradigm of sustainability has evolved through various global deliberations and conferences over the past few years, most notably the Rio Earth Summit of 1992/Agenda 21 and the World Summit on Sustainable Development in Johannesburg in 2002. The concept of sustainability emphasizes the integration of economic, environmental and social interests and concerns.

When it comes to making decisions on investments, economic aspects often govern. Decisions that imply the least costs are thus preferred without explicitly factoring in environmental or social aspects. Thus, environmental and social concerns have invariably taken a backseat, and this in turn has led to unsustainable decisions and investments.

To close this gap, in the early 1990s the need to promote Environmentally Sound Technologies (ESTs) in the context of sustainability came to be recognized. In particular, at the United Nations Conference on Environment and Development (UNCED) in 1992, the need to promote ESTs was highlighted within Agenda 21. Chapter 34 of Agenda 21 defines ESTs as those technologies that "protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products and handle residual wastes in a more sustainable manner than the technologies for which they are substitutes." ESTs include a variety of cleaner production processes and pollution prevention technologies, as well as end-of-pipe and monitoring technologies. ESTs extend beyond just individual technologies to total systems that may include knowledge and skills transfer, operating procedures, goods, services and equipment as well as organizational and managerial procedures[1]. Many initiatives have been developed in relation to the promotion of ESTs in developing countries and countries with economies in transition.

In parallel to the promotion of ESTs, there has been a need to develop a Technology Assessment (TA) framework to assess and evaluate

[1] DTIE-UNEP. EST Assessment Methodology and Implementation - Training Kit prepared for the support of the project on Environmental Management of the Iraqi Marshlands. Funded by International Environmental Technology Centre (IETC) DTIE, UNEP.

environmental technologies to facilitate identification and selection of the 'best possible technology option.' Accordingly, the International Environmental Technology Centre of the United Nations Environment Program (IETC-UNEP) initiated the development of a methodology for Environmental Technology Assessment (EnTA). EnTA is defined as a systematic procedure whereby a proposed technology intervention is described and appraised in terms of its potential influence on the environment, the implications for sustainable development and the likely cultural and socio-economic consequences. The scope of EnTA has been outlined with a focus on identifying the specific and broader environmental impacts of technologies. EnTA is primarily qualitative and comparative and it looks at broader processes over the entire life cycle of a technology.

More recently, further improvements have been introduced to the approach in TA under the concept of sustainability and a new methodology known as Sustainability Assessment of Technologies (SAT), which has received international commendation, has been developed[2]. This methodology focuses on both the process and the outcome, with an interest towards informed and participatory decision making. Part 1 of this Manual explains the SAT Methodology.

1.1.1 Development of the SAT Methodology

The SAT methodology was developed through an elaborate process of research and expert consultations. Figure 1.1 illustrates the key steps that were followed.

Based on the steps outlined in Figure 1.1, the SAT methodology lays down generic criteria and indicators, which can be customized for sector-specific applications. The four target sectors covered are drinking water and sanitation, wastewater treatment, solid waste management and application of phyto-technologies.

[2] Chandak, S.P. (2009). Sustainablity Assessment of Technologies: Making the Right Choices. IETC-UNEP. Presented at the 1st Stakeholder Consultative Workshop/Training Program of the Project on Converting Waste Agricultural Biomass to Fuel/Resources in Moneragala District, Sri Lanka funded by UNEP and coordinated by the National Cleaner Production Centre, 21 August 2009.

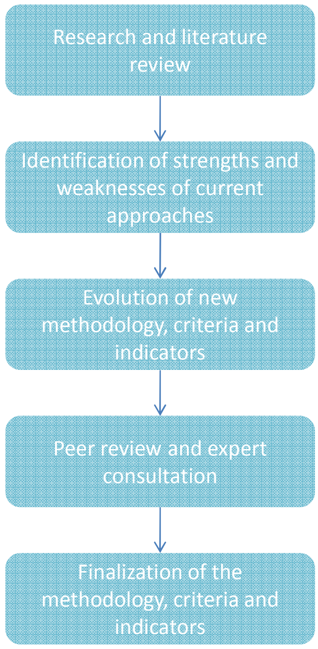


Figure 1.1: Development Process of SAT Methodology

1.2 OVERVIEW OF SAT

1.2.1 Who Can Use the SAT Methodology?

The SAT methodology is expected to be used by a broad spectrum of stakeholders in different situations and at different levels of decision making (see Figure 1.2).

At the policy/government level, SAT can be applied to strategic decision-making. These strategic-level decisions are often made by planners, civic body officials and mayors or other elected representatives.

Once decisions are taken at the strategic level, SAT can be applied at the financing institution level. Target users may also include developmental as well as commercial financing institutions that often play a key role in the funding of projects and programmes utilizing various technologies.

The methodology is also applicable at the operational level – primarily by the technical/engineering staff, designers and consultants – to assess alternate technology systems.

Communities and industrial clusters can use the SAT methodology as well, for instance when they are building a centralized water or wastewater treatment system, or a recycling facility.

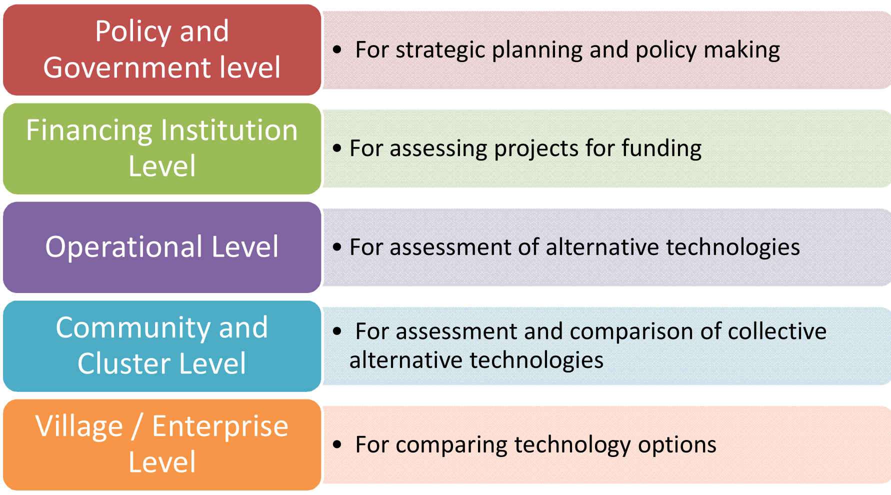


Figure 1.2: Proposed Levels of Use for the SAT Methodology

Last but not least, individual hamlets/villages and enterprises can also use the SAT methodology for comparing a number of available options for sanitation, water supply, waste treatment or manufacturing technologies.

The SAT methodology can be applied to a variety of situations – wastewater management, biodiversity management, recycling programs, land reclamation and so on.

1.2.2 Potential Areas of Application of the SAT Methodology

The above-mentioned stakeholder groups could apply the SAT methodology towards the selection of suitable technology systems in a variety of situations. These situations and interests might include:

- End-of-pipe or waste management technologies;
- Programs related to environmental health;
- Provision of basic services and infrastructure such as roads, power, water etc.;
- Biodiversity management;

- Remediation/land reclamation;
- Process technology modernization (on shop floors/in industrial clusters);
- Recycling programs and so on.

In short, the SAT methodology can be applied in any or all scenarios such as those listed above for technology interventions in the context of sustainable socio-economic development.

1.2.3 Key Features of SAT

The SAT methodology has a specific focus on the following features. Each of these features is explained below in detail.

1. Addressing strategic as well as operational levels;

2. Addressing sustainability (integration of environmental soundness, social/ cultural acceptability, and technical and economic feasibility) through a specially designed methodology and criteria;

3. Employing a progressive assessment procedure, through tiers addressing screening, scoping and detailed assessment, thereby allowing entry points for a diversity of stakeholders and optimizing information requirements;

4. Employing quantitative procedures that allow more objective assessment, sensitivity analyses and incorporation of scenarios;

5. Ensuring application to technology "systems" as opposed to individual technologies; and

6. Placing importance on information expertise and stakeholder participation.

Each of these key features is discussed in detail below.

1. Addressing Strategic as well as Operational Levels

While the SAT methodology incorporates both strategic level and operational level assessments, it is flexible enough to allow users to directly commence with operational level assessment if desired. This is likely to be needed in situations where strategic assessment is either not relevant or not feasible to undertake.

2. Addressing Sustainability through Specially Designed Methodology and Criteria

The criteria and indicators are probably the most important components of the SAT methodology. In order to develop more robust sets of criteria and indicators, the following aspects were considered during the development of the SAT methodology:

1. Criteria and indicators proposed under EnTA;

2. The need to consider the life cycle perspective, keeping in mind parallel approaches like the World Bank's Input-Output-Outcome-Impact (IOOI) framework[3];

3. Risks and restrictions associated with technology choices (see Box 1.1); and

4. Other important considerations, such as the availability of skills and local capacity (supply, operation, maintenance and repairs), which are often overlooked, but provide important pointers for the development of situation-specific criteria and indicators.

Box 1.1: Addressing Risks and Restrictions Associated with Technology Choices

In any decision-making process, special attention needs to be given to the risks and restrictions associated with each choice, since these become crucial factors in many instances. Typically, risks and restrictions that need to be considered in making the technology choice include:

- Stability or resilience
- Flexibility
- Size/scale of operation
- Adaptability

[3] Further information on the IOOI framework can be found within Frameworks for Organizing Indicators at http://www.communitiescommittee.org/fsitool/AppendixB.html. Scroll down to entry B.5.

- Hazardous effects
- Other pre-requisites (availability of space etc.).
- Skill levels needed

Considering all the above-mentioned aspects, the SAT methodology offers a set of generic criteria and indicators under the following broad categories:

- Technological suitability;
- Environmental considerations (in terms of resources and emissions, risks etc.);
- Economic/ financial concerns; and
- Socio-cultural considerations.

A list of generic criteria and indicators has been presented in Annex 1.1. It should be noted however that these generic criteria are indicative and that it is also possible (and indeed even recommended) to develop customized criteria and indicators in accordance with specific situations. This is best done through consultative meetings in the presence of a moderator and with the support of relevant stakeholders, as well as domain/sector specific experts.

The erstwhile EnTA methodology has been designed for application at the enterprise level and can be used for the assessment of individual technologies, such as for a particular unit operation. However, real-life applications require the consideration of "technology systems," in which a system may comprise a number of individual technologies.

3. Employing a Progressive Assessment Procedure through Tiers

A tiered approach is both effective and efficient, as it does not require exhaustive data collection for all technology systems under consideration. Users can eliminate the clearly non-feasible options at an early stage (screening) and then focus on select qualified technology systems. In this way, detailed information collection becomes essential only for short-listed technology systems, thereby saving substantial time and effort.

Briefly, arriving at the final choice from a number of available options can be done through the following steps or tiers. Additional information on tiered assessment is provided in Section 1.4 of Part 1.

Tier 1 - Screening: Firstly, technology systems are screened against logical operators (i.e. 'Yes/No' type) for EST criteria. This is essentially the Screening Tier.

Tier 2 - Scoping: The ESTs that pass through the screening stage are then subjected to a second round of elimination through the scoping tier. Scoping uses select criteria that require more of qualitative or readily available quantitative information. Through the scoping process, a number of less competitive options are likely to be discarded, thus leaving stakeholders with a more limited yet relevant number of technology system options.

Tier 3 – Detailed Assessment: Technology systems shortlisted from the scoping tier are then subjected to a more rigorous evaluation, using additional criteria, specially drafted for the purpose, and demand a greater extent of quantitative information. This is the Detailed Assessment Tier. Upon completing the detailed assessment, the stakeholders would understand which technology systems are the most sustainable for their situation, in an order of ranking.

4. Employing Quantitative Procedures that Allow More Objective Assessment, Sensitivity Analyses and Incorporation of Scenarios

During the drafting of the SAT methodology, a quantification and aggregation framework was proposed to facilitate objective decision-making, and at the same time overcome the limitations of qualitative assessment. The key elements here are:

- Weights to be assigned to a criteria; and
- Scores to be assigned to indicators.

Depending on the complexity and sensitivity of the decision to be made, as well as the competence and the capability of stakeholder groups, a range of aggregation techniques can be applied. As seen in Box 1.2, these range from a simple Weighted Sum Method to more sophisticated approaches such as the Analytic Hierarchy Process (AHP).

Box 1.2: Risks and Restrictions

The following commonly applied quantification and aggregation methods may be used. They are listed in increasing order of complexity:

- Weighted Sum Matrix or Decision Matrix;
- Sequential Elimination by Lexicography;
- Sequential Elimination by Conjunctive Constraints;
- Goal Programming;
- Delphi Method for Consensus Building; and
- Analytic Hierarchy Process (AHP).

Additionally, advanced methods such as Expert Systems and Neural Networks have also been known to be applied for decision making and evaluation. However, for the purposes of this manual, only the more commonly applied methods are considered and discussed in Annex 1.2.

5. Ensuring Application to Technology "Systems" as Opposed to Individual Technologies

The erstwhile EnTA methodology of UNEP was designed for application at the enterprise level and can be used for the assessment of individual technologies, such as for a particular unit operation. However, real-life applications require the consideration of technology "systems," with a system typically comprising a number of individual technologies.

For instance, a wastewater treatment technology in reality comprises a number of technologies/unit operations, each of which is dependent on the others for the treatment process to be effective. While individual technologies can be assessed objectively, in most situations, they behave differently when used in combination with other technologies as part of a system. The SAT methodology recognizes the interdependencies among technology units and places emphasis on the "system" rather than on individual technologies.

6. Placing Importance on Information Expertise and Stakeholder Participation

The SAT methodology relies on a number of tools and techniques to facilitate the assessment process. These tools include information driven benchmarking, expert opinions and participatory assessment by relevant stakeholders. Depending on the level of assessment, the SAT methodology uses these tools in combination with each other and to different degrees.

1.3 Applying the SAT Methodology

The SAT methodology is shown in Figure 1.4. The methodology follows the typical Plan-Do-Check-Act cycle of continuous improvement as recommended by systems like Quality/Environmental Management Systems (ISO[4] 9000/ 14000).

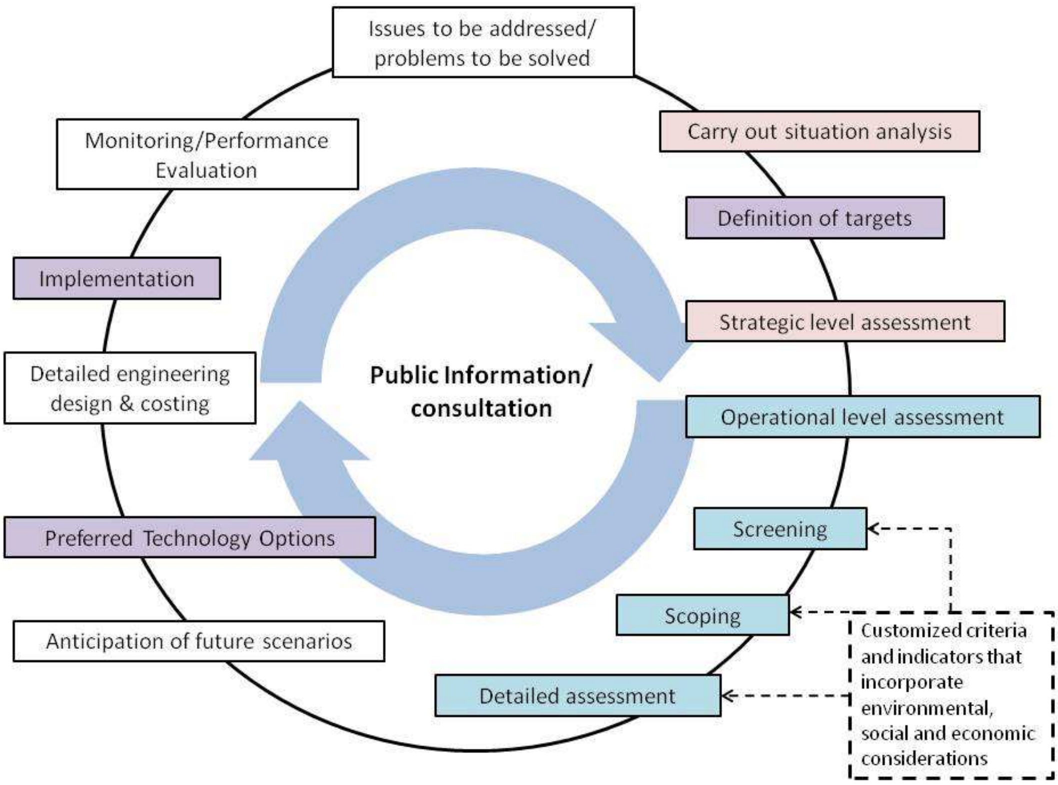


Figure 1.4: The SAT Methodology

A brief explanation of the various steps follows.

[4] ISO stands for the International Organization for Standardization.

1.3.1 Conducting the Situation Analysis and Defining Targets

Technological intervention addresses various problems, such as managing solid waste in a city or establishing a centralized wastewater treatment plant in an industrial cluster. Once the problem is defined, it is essential to undertake a situation analysis. The situation analysis will include baseline data collection, stakeholder consultation, mapping and analyses as necessary. A situation analysis helps to identify issues and assess their significance. It also utilizes experience concerning what has worked and what has not. It moreover contributes to scenario building. Finally, situation analysis leads to the setting of realistic targets to be achieved through the proposed technology intervention.

1.3.2 Conducting Strategic Level Assessment

During the strategic level assessment, planners and decision-makers including mayors or elected representatives brainstorm and study various options at the policy and planning levels. The outcomes of the strategic level assessment are very important for the following reasons.

- The decision at the strategic level is a critical factor in the subsequent identification of technology system options. These technology elements are then combined to create appropriate situation-specific technology systems. These system options will later undergo assessment at the operational level.

- Strategic decisions may help in the development of customized criteria and indicators (possibly with weights across criteria) from a generic list, enabling decisions to be taken at the operation level. The objectives and targets of the technology system intervention must also be considered when developing new customized criteria and indicators.

- The outcomes of the strategic level assessment can also provide leads for possible future scenario building, which in turn can influence the decision regarding the technology chosen. These future scenarios may include for instance future population growth, changes in waste composition, increases in the stringency of legal requirements requiring higher efficiency in waste treatment, or changes in production requirements at the enterprise level due to specific quality or capacity requirements for products requiring the technology upgrade.

1.3.3 Operational Level Assessment

Once the macro-level or strategic level options are finalized, the process moves on to the operational level, in which engineers, technical staff etc. assess the available EST systems. In cases in which the SAT methodology is to be applied only at a community or enterprise level, stakeholders can start with the operational level SAT as the first step, skipping the earlier stage of strategic assessment. It is worthwhile to note that this is the level requiring the highest degrees of expert opinion and technology information.

At this stage, a basket of potential technology systems is finalized based on the problem definition, the situation analysis and the outcomes of the strategic level assessment. The potential technology systems in this basket are then subjected to further rigorous three-tiered assessment. This exercise must be done with the help of expert opinion.

Depending upon the specific situation and needs, the stakeholder group may choose to adopt the proposed set of generic and/or sector specific criteria and indicators without any changes (outlined in Annex 1.1). As noted earlier, in some situation-specific cases, it may be essential to revisit the generic set of criteria-cum-indicators and modify or add specific criteria. The criteria and indicators are then finalized through stakeholder consultation.

1.3.4 Screening Tier (Tier 1)

At this stage, the short-listed system options first undergo screening using the finalized criteria and indicators. Tier 1 criteria yield only objective yes/no type answers. Hence, any options that do not qualify under one or more mandated conditions are automatically eliminated from consideration.

For example, one of the criteria in Tier 1 relates to a very fundamental requirement – legal compliance. Any technology system unable to ensure legal compliance would get eliminated at this point.

Tier 1 assessment can be done by a suitable stakeholder group with or without the help of expert opinion.

1.3.5 Scoping Tier (Tier 2)

Short-listed system options from Tier 1 then go through the comprehensive scoping assessment (Tier 2), which is more quantitative in nature. During this stage of SAT, stakeholders must assess the various technology system options vis-à-vis customized criteria-cum-indicators, using any of the listed computational methods (see Box 1.2 for a listing and Annex 1.2 for additional details) by following the steps described below.

It is important to note that the scoping exercise lends an advantage in narrowing the decision range of scores, for a particular criterion in the detailed assessment level. For instance, if 'low/medium/high' scores are assigned on a basis of a scale of 0-10, then evaluation as 'medium' would scope the scores between perhaps 4 and 6. This system allows a narrowing of trajectories, better congruence of opinions and thus reduced subjectivity.

1.3.6 Detailed Assessment Tier (Tier 3)

Through the scoping exercise, a number of non-feasible or unqualified EST options come to be eliminated and the options with the best overall ratings are selected for further feasibility studies that assess environmental, socio-cultural, technical and economic aspects in detail. As this level of assessment is rather situation-specific, the suggested criteria at this stage demand much more detailed and quantitative information to facilitate decision making.

Using the information, the stakeholder group once again prepares a new weighted sum matrix or revises the existing one. In some instances, the ratings of the technology systems may change due to new scoring based on available information.

As noted earlier, as an outcome of this exercise, the group will emerge with a number of technology system options ranked in the order of their scores – or in other words, their performance vis-à-vis the principles of sustainability.

1.3.7 Anticipating Future Scenarios

When a stakeholder group undertakes the systematic application of the SAT methodology, it arrives at a set of technology systems based on the current situation analysis. However, the selected "best" technology system choice made with the existing set of information may be inadequate or inappropriate in the future. This may happen due to changes in the situation, revisions to local requirements or legislation, or even new developments in technology.

It is therefore recommended that once the group has completed one cycle of SAT, before making a final decision, they apply the same methodology to simulate possible future scenarios in order to ensure that the outcome of the current exercise is sufficiently robust and to confirm that the suggested technology system can stand the test of time. It follows naturally that when assessing these new scenarios, the criteria, weights and scores may differ enough ultimately to alter the technology system choice to be adopted.

The Tier 3 level of assessment is rather situation-specific and the suggested criteria at this stage demand much more detailed and quantitative information to facilitate decision making.

1.3.8 Decision-making on Preferred Technology Options

After conducting the three-tiered detailed SAT, a final decision on the technology choice must be reached. At the outset, the option with the highest score may be likely to be viewed as the best candidate. However, some caution needs to be exercised before finalizing the choice. One reason for this has already been explained in the last sub-section, namely that even though a particular technology system may score the highest in the current context, the same option may not qualify as the best option under other possible scenarios.

On the other hand, an option that does not initially yield high-end scores under the current circumstances may in fact top the list if there are appropriate technology transfer/adaptation or capacity building efforts. This important point should be kept in mind before low-scoring options are discarded. It highlights the value of a careful scrutiny of the options that goes beyond the result apparently indicated by the initial numbers.

1.3.9 Detailed Design and Implementation

Once the decision to adopt a particular technology system has been made, it forms a foundation for further steps such as detailed engineering design, tendering, actual construction and commissioning.

Even though one particular technology system may score the highest in the current context, the same option may not qualify as the best option under other possible scenarios.

1.3.10 Monitoring and Performance Evaluation

It is also important to monitor and evaluate the technology system continuously during its operational phase to ensure that it is meeting the desired objectives vis-à-vis the various criteria considered during the application of the SAT methodology. The outcomes of the monitoring and evaluation should be reported to the stakeholder group – especially government agencies, planners and other decision makers. This feedback can help in future decisions at both the strategic as well as the operational level.

Such information forms a basis for situation analysis for similar future projects, and hence can enable better informed decisions. For instance, negative experiences with a technology system can lead to its disqualification under similar situations in the future. At the same time, the experiences of implementation and monitoring may make it essential to include new criteria within future decision making on technology choices.

1.4 Conclusion

The concept and methodology of SAT as elaborated in Part I are demonstrated through a case study in the next part, Part II. It provides a guideline on the application of the SAT methodology. A case study has been presented as part of the guideline.

PART II

GUIDELINES FOR APPLICATION OF SAT

What Will You Learn Here?

- Introduction to the Case Study
- Solved Case Study Example
- Scoring and Ranking Based on Technical, Financial, Social and Environmental Feasibility Criteria
- Graphical Representation of Scoring Results Based on Criteria
- Verifying Continuing Suitability of Ranked Technologies

2.0 GUIDELINES FOR APPLICATION OF SAT

2.1 INTRODUCTION TO THE CASE STUDY

Part 2 presents guidelines for applying the SAT methodology with the help of a case study. Every step of the SAT methodology is elaborated and the case study is presented as a fully solved example. This case study relates to the identification, assessment and selection of ESTs for converting waste agricultural biomass (WAB) to an energy and/or material resource for two locations in Sri Lanka - District Secretariat (DS) divisions Moneragala and Buttala.

The solution for the case study will proceed in the manner depicted in Figure 1.4, which is reproduced here as Figure 2.1 for the reader's convenience.

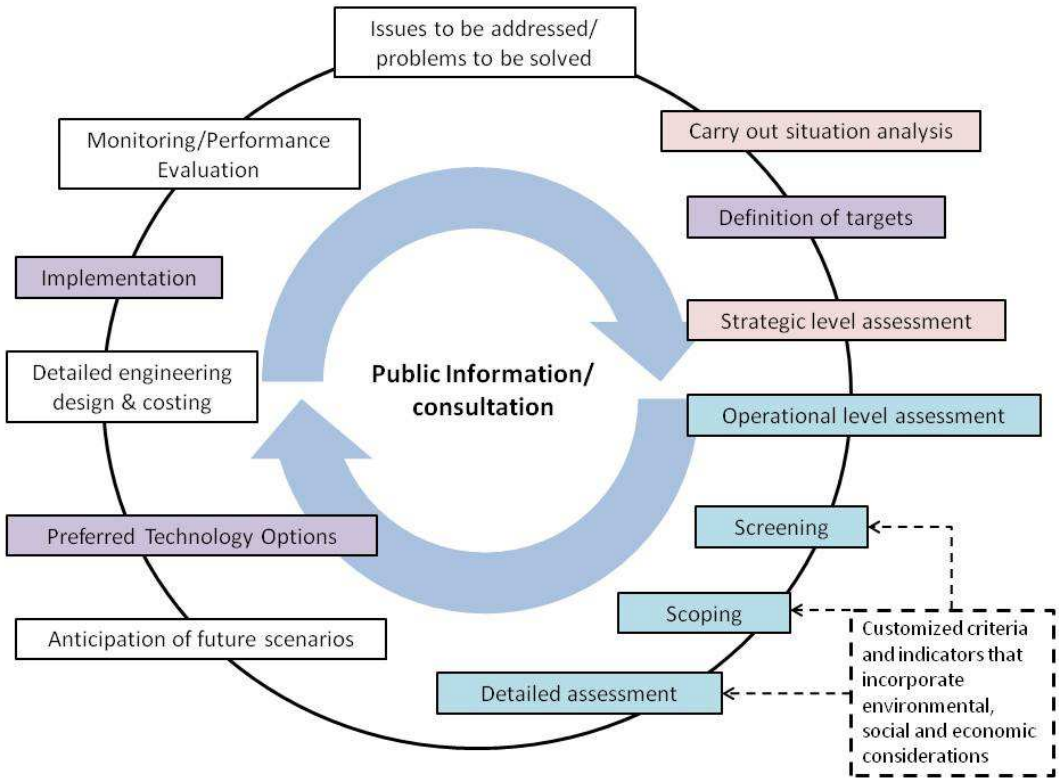


Figure 2.1: Steps for Arriving at a Solution to the Case Study

2.2 CONDUCTING THE SITUATION ANALYSIS

As explained in Part I, technological intervention serves to address a defined problem or set of related problems. Once the problem is defined, it is essential to undertake a situation analysis. The situation analysis should include the following activities:

- Baseline data collection;
- Stakeholder consultation; and
- Mapping, analysis and the setting of targets.

2.2.1 Defining Problems/Issues

2.2.2.1 Background to the Case Study

The project "Converting Waste Agricultural Biomass to Fuel/Resources" implemented in the Districts of Sri Lanka noted above was initiated with the final objective of developing a pilot project based on a selected resource-technology combination as a means of managing waste. Given the inherent properties of WAB, it is prudent to treat it as a resource rather than dispose of it in an unsustainable manner. The project was therefore intended to explore the most appropriate ways of converting these resources into value added products or materials, thereby minimizing the environmental and social issues which have traditionally arisen due to improper management practices. In doing so, every effort will be made to explore and enable the generation of additional income to the local community.

How to define problems/issues

Guidance

The process of defining problems and issues requires a focused approach. Perhaps the most common problem in this case is the failure to identify the real problems/issues. As a result, one often ends up solving the "wrong problem" or merely addressing a symptom while the original problem/issue remains unsolved. To avoid such pitfalls, some useful diagnostic questions to ask are noted below[1].

- Explicitly state the problem. Is the matter indeed a "problem"? Is it important? What would happen if the problem were left as is? Could attempts to solve the problem result in unintended consequences?
- Why is it a problem? Is there a gap between the actual performance and

[1] Questions adapted from *Teaching and Learning with Technology: Tips for Solving Case Problems* by Pennsylvania State University. URL: http://tlt.its.psu.edu/suggestions/cases/studenttips/define.html

desired performance? For whom is it a problem and why?

- Is this problem masking a deeper systematic problem?
- Is there deviation from relevant standards?
- What is the current situation? What are the ideal outcomes?
- How do key people or stakeholders feel about the problem and current outcomes?
- How urgent is the problem? How important is the problem relative to other problems?
- How high are the stakes? Factors include costs and benefits, as well as environmental and social concerns.
- What information is lacking?

These questions are best answered by a team of qualified personnel or stakeholders intimately involved with the problem. In this case, the stakeholders could be local governments, NGOs, waste generators, waste users, technology suppliers and other relevant institutions and experts.

Case Study

The issues concerning waste agricultural residues in Moneragala and Buttala have been defined as the following.

- Lack of waste management practices could lead to health and environmental, and perhaps even social problems
- Disposal of such wastes could also be considered as a loss of useful resources
- The inability to utilize generated waste agricultural residues for useful applications (as an energy source, for materials recycling or for reuse) puts a strain on the already overburdened solid waste management system

2.2.2 Baseline Data Collection

What is Baseline Data and How to Collect It

Guidance

Baseline data is defined as the initial collection of data which serves as both a starting point for project analysis and a basis for comparison with subsequently acquired data. Baseline data therefore helps in assessing the impact of any actions taken for a project (in this case, the implementation of a technology).

At this stage of the process, the stakeholder team must concentrate on collecting baseline data relevant to the defined problem. Baseline data should be robust enough to assist in the analysis and interpretation of data in the context of the problem. For the case being examined in this chapter, a brief overview of the baseline data collected by the stakeholders and its analysis is given below.

Case Study

Baseline data on types, generation and availability of WAB was collected. The analysis was restricted to the two divisions of Moneragala and Buttala, since accurate numbers were available for these divisions only. A summary of the situation appears in Figures 2.2 and 2.3. The waste materials considered include agricultural residues as well as other waste types having significant generation potential within the area. These are paddy straw, paddy husks, sawdust, market waste, banana waste, and wild guinea grass.

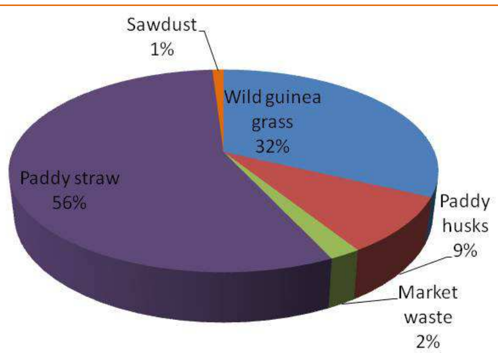


Figure 2.2: Availability of WAB in Moneragala DS Division

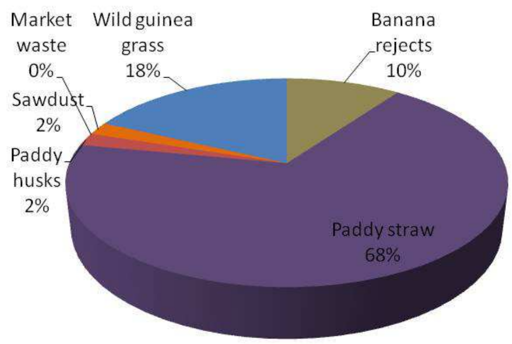


Figure 2.3: Availability of WAB in Buttala DS Division

2.2.3 Stakeholder Consultation

About Stakeholder Consultation Workshops

Guidance

At this juncture, a Stakeholders' Consultation Workshop needs to be organized. As stated earlier, stakeholders could be local governments, NGOs, waste generators, waste users, technology suppliers and other relevant institutions and experts.

The Workshop is essentially a means to discuss with the stakeholders defined problems and their possible solutions, draw out a roadmap for the technology assessment process, and obtain their opinions. For this reason, adequate preparation must be made before holding such a Workshop. This preparation includes but is not limited to detailing the Workshop agenda, preparing a list of invitees and speakers, and providing reference reading material if required. The minutes or proceedings of the workshop should be available for future reference and actions. The consultation with stakeholders conducted in this particular case is overviewed below.

Case Study

A Stakeholder Consultation Workshop was conducted to receive feedback on the data collected and planned activities, and also to identify stakeholder needs and technologies worth exploring. Key points discussed during the Workshop are noted below.

- There were concerns about the year-round sustainable supply and availability of paddy husks;
- Paddy straw was noted as being the most abundantly available waste in both DS divisions and therefore was thought to hold good potential for the project;
- A number of technology options at the commercial level were available for processing sawdust and market waste;
- Improved technology options were available for paddy husk applications already in use, particularly brick making and tobacco processing;
- There was a need to analyze the availability, enforcement and impact of regulations and economic tools for various technology applications;
- Analyzing the efficiency and effectiveness of collection, treatment, usage and disposal technologies and associated infrastructure was important; and
- It was important to understand the role of various stakeholders at different levels of the waste management chain.

2.2.4 Mapping, Analysis and Setting Targets

Guidance

About Targets

It is now important to set targets for each problem/issue, based on the data collected and feedback received during the Stakeholders'

Consultation Workshop.

In the context of this manual, these targets specify the mitigation of a defined problem/issue. For example, one defined issue could involve the increase in amounts of WAB of a particular type expected to be generated in the future. In this case, the target would be to identify and implement a technology that can be easily duplicated or scaled up in order to be able to tackle increasing WAB quantities in the future.

Case Study

Issue-specific targets for the said case are given in Annex 2.1, an excerpt of which is provided below.

Excerpt from Annex 2.1: Setting Targets

Waste: Paddy straw

Issues	Targets
Present policies cause the dumping of waste generated in fields, resulting in adverse effects on the environment and loss of a potential resource	Use of relevant technologies to convert waste to energy or ensure material reuse/recycling, together with policy level interventions
Increase in amounts of waste expected to be generated in the future	Implementation of technologies that can easily be duplicated or that which can easily be scaled up
Lack of appropriate technologies and local expertise	Introduction of technologies suited to local resources and expertise
Low bulk density, which decreases the waste's value as raw material (e.g. fuel value)	Use of relevant technologies (e.g. bailing, briquetting, pelletizing, pressing) to upgrade the waste's value as a raw material

2.3 STRATEGIC LEVEL ASSESSMENT

As the next step, planners, decision-makers, mayors or other elected representatives should brainstorm and study various options at the policy and planning levels. One must consider the local context when choosing an appropriate methodology for carrying out a strategic assessment.

Guidance

How to Conduct a Strategic Level Assessment

The following steps are suggested for carrying out a strategic level assessment:

- Conducting a techno-economic feasibility study;
- Obtaining and reviewing feedback from operational level experts (note that technology fact sheets would provide useful operational level information); and
- Using planning tools such as Logical Framework Analysis, Participatory Project Planning with vision mapping, and the like.

2.3.1 Overview of Available Technology Options

As part of the techno-economic feasibility study, an overview of available technology options and a description of the technologies therein must be prepared. It should include aspects such as:

- Maturity of the technology [research stage (R), pilot plant stage (P) or commercial stage (C)];
- Its applicability within the given case;
- Its capacity/range;
- Its efficiency;
- Its limitations;
- Resource requirements imposed by the technology, etc.

Case Study

An overview of possible technology options prepared for this particular case is given in Annex 2.2. An excerpt of this Annex is provided on the following page.

References

To find out more about Logical Framework Analysis, refer to comprehensive guidance notes on the topic at http://www.gdrc.org/ngo/logical-fa.pdf and http://www.adb.org/Documents/Guidelines/Logical_Framework/default.asp.

Excerpt from Annex 2.2: Overview of Possible Technology Options

Residue	Application	Process/ Technology	Equipment	Capacity Range	Selection			Remarks	Additional Comments (If Any)
					R	P	C		
Paddy husks	Value addition to the residue as a fuel for process heat generation in industry	Densification/ briquette making	Screw type briquetting machine	Typical capacity range: 100 – 250 kg/hr Selected capacity: 200 kg/hr			X	Briquette density = 0.8 – 1.2 t/m^3. Energy requirement = 150 – 225 kWh/t.	Increase in density and change in physical form can diversify applications and increase fuel value (Example: Application – tea industry, fuel value > 15 Rs/kg). Although the technology is not considered low-end, local manufacture/fabrication is possible.
	Value addition to the residue as a fuel for small scale heat generation	Carbonization/ charcoal making	Small scale charcoal kiln	Typical capacity: Input - 6 kg/load; Output - 2 kg/load			X	Low environment performances; need hand operated extruder type briquetting machine for densification.	Small scale technology; applicable at the domestic level alone.

2.4 OPERATIONAL LEVEL ASSESSMENT

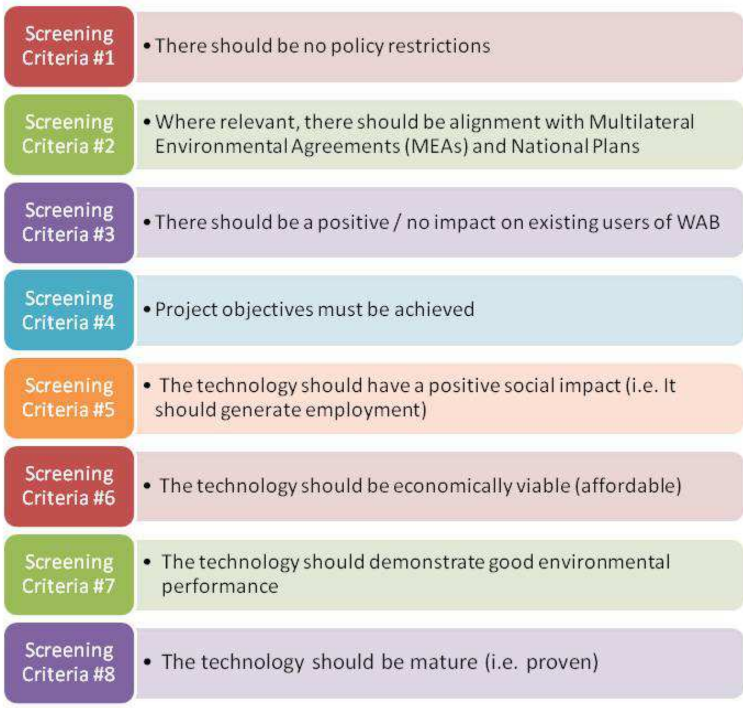
As explained in Part 1, once the macro-level or strategic level options are finalized, the methodology moves on to a more operational level where engineers, technical staff etc. take over to assess available technology systems. The need for expert opinion and technology information are the highest at this step.

> **Important**
>
> *As mentioned in Part 1, cases in which the SAT methodology is applied only at a community or enterprise level, stakeholders can start with the operational level SAT as the first step, skipping the earlier stage of strategic assessment.*

2.4.1 Screening (Tier 1)

At this stage, the short-listed system options first undergo screening using criteria in Tier 1. The criteria applied to these technology systems in Tier 1 are shown in Figure 2.4.

Figure 2.4: Screening Criteria (Tier 1) Used for the Case Study



Tier 1 Assessment: How to Screen Technologies

Guidance

Once the criteria for screening have been finalized, technologies should be assessed at Tier 1 in the following manner:

- Consider an example in which the technology to be screened is one for briquette making using paddy husks. The first screening criterion to be tested against is whether this approach would be restricted at the policy level ("Are there any policy restrictions?"; see Excerpt from Annex 2.3 on the following page). In this case, there are no such restrictions and hence the said technology passes the test for screening criteria #1, as it would be allowed. Accordingly, the stakeholders make the entry "No" for the column for screening criterion #1.

- Now, one must test whether the technology passes the test for screening criteria #2, namely whether the said technology using paddy husks is aligned with MEAs and/or National Plans. In this case, such an alignment exists, and so the technology passes the test for screening criteria #2. Accordingly, the stakeholders make the entry "Yes" for the column for screening criterion #2 ("Is there alignment with MEAs/National Plans?"; see Excerpt from Annex 2.3 on the following page).

- This process continues by checking the technology against the remaining screening criteria, with the stakeholders entering either "Yes" or "No" against that technology in the relevant column.

- The favorable outcome for a particular criterion has been listed in the second row of the Excerpt from Annex 2.3. For the purposes of this case, a particular technology is said to pass the screening provided it scores a favorable outcome for at least seven of the listed screening criteria. In the case of the technology chosen in this example – briquette making using paddy husks – the technology scores a favourable outcome for all eight screening criteria. Hence, the technology advances to further consideration in Tier 2 – scoping analysis.

Case Study

Detailed results from the screening of technologies are given in Annex 2.3, an excerpt of which is provided on the following page. Based on the results of the Tier 1 screening analysis, the technology and associated equipment options selected for the Tier 2 scoping analysis are finalized in Table 2.1.

Excerpt from Annex 2.3: Screening of Technologies

Residue	Technology	Are there policy restrictions?	Is there alignment with MEAs and National Plans?	Are there positive/zero impacts on existing users of WAB?	Are project objectives achieved?	Is the technology economically viable?	Does the technology exhibit good environmental performance?	Is there a positive social impact (employment/ income generation)?	Is the technology proven?	Outcome
Favorable outcome for the criterion		No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	--
Paddy husks	Briquette making	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Selected

Table 2.1: Technologies Selected for Scoping (Tier 2) Analysis

Application	Technology (and identifier in brackets)	Equipment
Waste: Paddy Husks[2]		
Value addition to residue as a fuel	(A) Briquette making	Briquetting machine
Domestic cooking	(B) Direct combustion	Paddy husk cook stove
	(C) Gasification	Paddy husk gas stove
Process heat for lime smoking	(D) Direct combustion/direct heating	Paddy husk stove cum cabinet dryer
Process heat for vegetable/fruit drying	(E) Direct combustion/indirect heating	Paddy husk stove cum tray dryer
Process heat for tobacco curing	(F) Direct combustion/indirect heating	Tobacco barn
Conversion to cement extender	(G) Carbonization	Basket burner
Waste: Sawdust		
Value addition to residue as a fuel	(H) Briquette making	Briquetting machine
Domestic cooking	(I) Direct combustion for cooking	Improved sawdust cook stove with multi-fuel capability
Manufacture of particle boards	(J) Pressing	Multiple types of equipment including chipper/ press
Manufacture of medium density fiber board (MDF)	(K) Pressing	Multiple types of equipment including chipper, boiler, press, etc.
Waste: Market Waste		
Cooking and lighting	(L) Biogas generation	Biogas digester– Continuous type
Fertilizer	(M) Composting	Hand tools (for handling waste)
Waste: Banana Rejects[3]		
Off-grid electricity generation	(N) Biogas generation	Biogas digester– Continuous type and IC Engine

[2] Paddy husks generated in Buttala DS Division are used by brick kilns in the area. Therefore the paddy husks considered in the above matrix is for Moneragala DS Division only.
[3] This is applicable in Buttala DS Division only, as the banana plantation is located in this area.

2.4.2 Scoping Analysis (Tier 2)

Now, we need to develop and select appropriate criteria for the scoping analysis. We must also apply a suitable assessment method from the available alternatives, and then rank the technologies based on the assessment results.

How to Proceed with the Scoping Analysis

Guidance

Criteria may be assigned for different categories – technical, financial, social and environmental. Essentially, the weight assigned to each criterion within a category is based on the importance given to it by the stakeholders undertaking the assessment. The number or rating assigned to the technology reflects how well the technology complies with each defined criterion, according to the stakeholders' judgement. The ratings within each category are then added up to arrive a score for that category. Users of this manual are encouraged to view the sample calculations for the scoping analysis in Annex 2.4.

Case Study

For the given case study, Table 2.2 shows the scoping analysis criteria that are to be applied to the technology systems, reflecting the results of stakeholder consultations. There are four categories (technical, financial, social and environmental), with 11 technical criteria (TC), 7 financial criteria (FC), 5 social criteria (SC), and 6 environmental criteria (EC).

Table 2.2: Criteria Selected for Scoping Analysis

Category	Criterion	Notation
Technical	Suitability for characteristics of waste stream	TC1
	Availability of adequate amount of waste	TC2
	Compliance with prevailing local environmental laws, regulations and standards	TC3
	Accessibility of technologies	TC4
	Availability of local expertise/capacity building requirement for design, operation and maintenance	TC5
	Level of use of local materials and resources for fabrication and operation	TC6
	Availability of in-country technical assistance during commission and operation	TC7
	Level of similar usage and performance records in	TC8

Category	Criterion	Notation
	Sri Lanka	
	Adaptability - Ability to fit into local (project area) conditions	TC9
	Adaptability to future situations (scaling up/expansions)	TC10
	Ability to replicate	TC11
Financial	Capital investment	FC1
	Operational and maintenance costs	FC2
	Payback period	FC3
	Value addition to WAB	FC4
	Investor attractiveness	FC5
	Availability of co-financing	FC6
	Co-benefits	FC7
Social	Job creation	SC1
	Acceptability within the local culture	SC2
	Improvement of quality of life	SC3
	Occupational safety and health conditions	SC4
	Improvement of local technical skills and knowledge base	SC5
Environ-mental	Additional support services/utilities (water/energy)	EC1
	Environmental emissions	EC2
	Noise, vibration and odor	EC3
	Space and infrastructure requirements	EC4
	Contribution to WAB management	EC5
	Net carbon emissions	EC6

Annex 2.4 gives detailed results of the scoping analysis using the weighted score method. An excerpt appears on the following page.

Excerpt from Annex 2.4: Scoping Analysis Using Weighted Sum Matrix

Criteria	Weight	Max. Wt. Score	Technology																											
			A		B		C		D		E		F		G		H		I		J		K		L		M		N	
			Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score
Technical Criteria																														
TC1	8	24	2	16	2	16	2	16	2	16	2	16	2	16	2	16	2	16	2	16	2	16	1	8	1	8	2	16	3	24
TC2	10	30	2	20	3	30	3	30	3	30	3	30	3	30	1	10	1	10	2	20	1	10	0	0	2	20	3	30	3	30
TC3	9	27	3	27	2	18	3	27	2	18	2	18	2	18	2	18	3	27	2	18	2	18	2	18	3	27	2	18	3	27
TC4	9	27	1	9	3	27	1	9	2	18	2	18	1	9	1	9	2	18	3	27	1	9	2	18	3	27	3	27	3	27
TC5	8	24	1	8	3	24	1	8	3	24	3	24	2	16	1	8	2	16	3	24	1	8	2	16	3	24	3	24	3	24
TC6	6	18	2	12	3	18	3	18	3	18	3	18	3	18	3	18	2	12	3	18	2	12	1	6	3	18	3	18	3	18
TC7	6	18	1	6	3	18	2	12	3	18	3	18	2	12	1	6	2	12	3	18	2	12	1	6	3	18	3	18	3	18
TC8	7	21	0	0	2	14	1	7	2	14	3	21	3	21	1	7	2	14	3	21	1	7	1	7	2	14	2	14	2	14
TC9	9	27	2	18	1	9	2	18	3	27	3	27	2	18	1	9	2	18	2	18	1	9	1	9	2	18	2	18	3	27
TC10	5	15	1	5	1	5	0	0	2	10	2	10	2	10	1	5	1	5	1	5	2	10	2	10	3	15	3	15	3	15
TC11	8	24	2	16	3	24	2	16	3	24	3	24	2	16	1	8	2	16	2	16	2	16	1	8	3	24	3	24	1	8
Total Score - TC		255		137		203		161		217		224		184		114		164		201		127		106		213		222		232

The resulting ranking of technologies based on the scoping analysis is given in Table 2.3.

Table 2.3: Ranking of Technology Options

Rank	Technology - (Identifier)	Equipment	Application	Residue
1	Biogas generation - (N)	Biogas digester– continuous type and IC Engine	Off-grid electricity generation	Banana rejects
2	Direct combustion/ indirect heating - (E)	Paddy husk stove cum tray dryer	Process heat for vegetable/fruit drying	Paddy husks
3	Direct combustion/ direct heating - (D)	Paddy husk stove cum cabinet dryer	Process heat for lime smoking	Paddy husks
4	Biogas generation - (L)	Biogas digester– continuous type	Cooking and lighting	Market waste
5	Composting - (M)	Hand tools	Fertilizer	Market waste
6	Direct combustion/ indirect heating - (F)	Tobacco barn	Process heat for tobacco curing	Paddy husks
7	Gasification - (C)	Paddy husk gas stove	Domestic cooking	Paddy husks
8	Briquette making – (H)	Briquetting machine	Value addition to residue as a fuel	Sawdust
9	Direct combustion – (B)	Paddy husk cook stove	Domestic Cooking	Paddy husks
10	Direct combustion for cooking – (I)	Improved sawdust cook stove with multi-fuel capability	Domestic cooking	Sawdust
11	Briquette making – (A)	Briquetting machine	Value addition to residue as a fuel	Paddy husks
12	Pressing – (J)	Multiple types of equipment including chipper/press	Manufacture of particle boards	Sawdust
13	Carbonization	Basket burner	Conversion to cement	Paddy husks

Rank	Technology - (Identifier)	Equipment	Application	Residue
	– (G)		extender	
14	Pressing – (K)	Multiple types of equipment including chipper, boiler, press, etc.	Manufacture of medium density fiber board (MDF)	Sawdust

2.5 DETAILED ASSESSMENT TIER (TIER 3)

As explained in Part 1, a number of unfeasible or unqualified EST options are eliminated through the scoping analysis. Options with the best overall ratings advance to further detailed analysis (Tier 3) – technical, financial, social and environmental feasibility. Remember, the Tier 3 level of assessment is rather situation-specific and the suggested criteria at this stage demand a lot more detailed and quantitative information to facilitate decision making.

Important

In some instances, it is possible that the rating of the technology systems may change due to new scoring based on available information. Using the information, the stakeholder group should once again prepare a new weighted sum matrix or revise the existing one

Using all the information available up to this point, the stakeholder group should once again prepare a new weighted sum matrix or revise the existing one. In some instances, it is possible that the rating of technology systems may change due to new scoring based on available information. The logic and calculations for this more detailed assessment are similar to those used in the scoping analysis.

Case Study

In the example being considered, a check was performed to determine whether the ratings of the technology systems change or stay the same. A scenario analysis for scoring through a Tier 3 assessment was completed for:

- Ranks of technological options based on equal weights for criteria (as seen in Table 1 of Annex 2.5)
- Ranks of technological options based on simultaneous comparison of criteria (as seen in Table 3 of Annex 2.5)
- Ranks of technological options based on total scores of all criteria (produced below as Table 2.4)

Important

In all cases, the technologies ranking the highest remain at the same standing. No changes emerged in the rankings of eight technologies (including the top six). In other words, the results of all the scenario analysis shown in Annex 2.5 indicate the robustness of the rankings. As a result, it can be concluded that the top ranking technologies basically have higher scores in all categories. This facilitates decision making on the final technology selection vis-à-vis the principles of sustainability.

Table 2.4: Ranks of Technology Options Based on Total Scores of All Criteria

Rank	Technology Identifier	Technology Name [WAB]	Sub-total Score of Criterion				Total Score
			Technical	Financial	Social	Environmental	
1	N	Biogas generation [Banana rejects]	232	109	65	102	508
2	E	Direct combustion (indirect heating) [Paddy husks]	224	84	74	95	477
3	D	Direct combustion/ direct heating [Paddy husks]	217	84	74	95	470
4	L	Biogas generation [Market waste]	213	90	64	95	462
5	M	Composting [Market waste]	222	87	66	66	441
6	F	Direct combustion/indirect heating [Paddy husks]	184	78	52	78	392
7	B	Direct combustion [Paddy husks]	203	76	19	72	370
8	I	Direct combustion for cooking [Sawdust]	201	76	19	72	368
9	C	Gasification [Paddy husks]	161	67	45	90	363
10	H	Briquette making [Sawdust]	164	56	54	74	348
11	J	Pressing [Sawdust]	127	79	53	66	325
12	A	Briquette making [Paddy husks]	137	56	47	74	314
13	G	Carbonization [Paddy husks]	114	77	39	71	301
14	K	Pressing [Sawdust]	106	44	54	63	267

2.5.1 Graphical Representation of Scoring Results

Numerical results given in tabular form are usually not very effective when one needs to investigate more closely the reasons for the relative ranking of different technologies or identify critical or important criteria requiring more consideration. A graphical representation of the results using what is known as a star diagram is one method for enhancing users' ability to grasp and utilize scoring results.

What are Star Diagrams?

Guidance

Star diagrams are diagrams that condense and organize data about multiple traits, facts, or attributes associated with a single topic. For the purposes of the SAT methodology, the various criteria under the chosen categories (technical, financial, social and environmental) translate into these multiple traits.

How Are Star Diagrams Drawn?

Draw a circle and divide it into sectors. The number of sectors depends on the number of criteria that need to be reflected in the star diagram. For example, in order to draw the star diagram showing scores for composite criteria for the first four top-ranking technologies (see Figure 2.5), the circle would need to be divided to reflect 29 criteria in all - 11 TC, 7 FC, 5 SC, and 6 EC. Assign a name to each line – one line for one criterion – until all the lines have been named.

Next, draw concentric circles within the main circle to reflect a scale for the scores assigned to the criteria. Now, as seen in Figure 2.5, against each criterion, mark off the point on the line corresponding to the score received by each technology in question. Once this has been done for all criteria belonging to the same technology, join the points representing that single technology using straight lines. In this case, there will be four different sets of lines, one for each technology – the technology ranked 1st (technology N), the technology ranked 2nd (E), and then those ranked 3rd (D) and 4th (L). Using a different color for each technology represented on the graph will demarcate them more clearly. These four different sets of lines represent the composite star diagram for the first four top ranking technologies.

Case Study

Scores for composite criteria for the first four top-ranking technologies are presented in the star diagram seen in Figure 2.5. In terms of performance, the results primarily indicate weightiness in technical aspects. The weakest area is that of social aspects. Some environmental aspects and financial aspects also show poor scores. In order to optimize the benefits of these technological interventions, more detailed analyses are required, firstly to identify the root causes of these weaknesses, and secondly to develop remedial measures to tackle them. Otherwise, technological implementation may not be able to achieve the project's overall objectives or expected outcomes. These technologies are, in the order of ranking:

1. Biogas generation from banana rejects to generate off-grid electricity (N);
2. Process heat generation from paddy husks for the indirect drying of vegetables/fruit (E);
3. Process heat generation from paddy husks for the direct smoking of lime (D); and
4. Biogas generation from market waste for cooking and lighting applications (L).

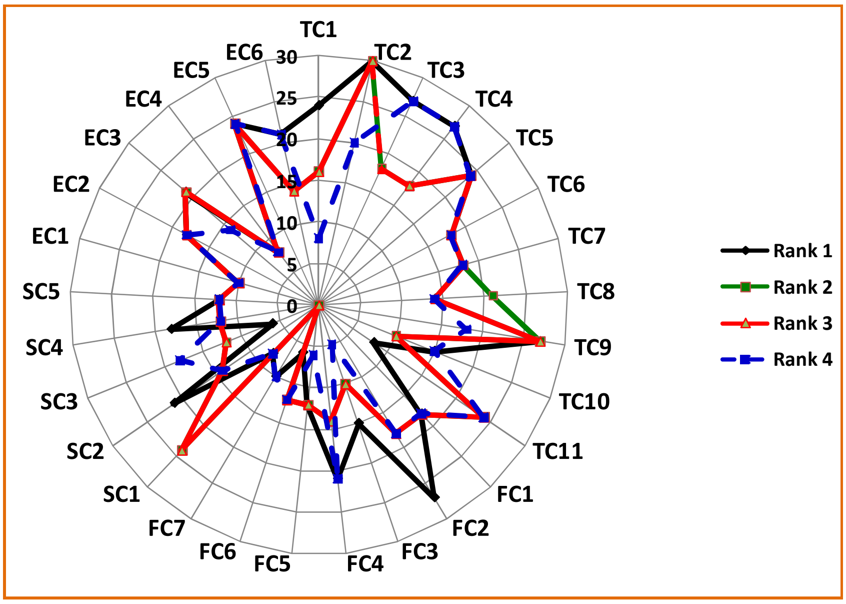


Figure 2.5: Star Diagram Showing Scores for Composite Criteria for the First Four Top-Ranking Technologies

Detailed descriptions of star diagrams arising out of Tier 3 assessment for environmental, financial, technical and social aspects have been given in Annex 2.5.

2.6 VERIFYING CONTINUED SUITABILITY OF RANKED TECHNOLOGIES

Important

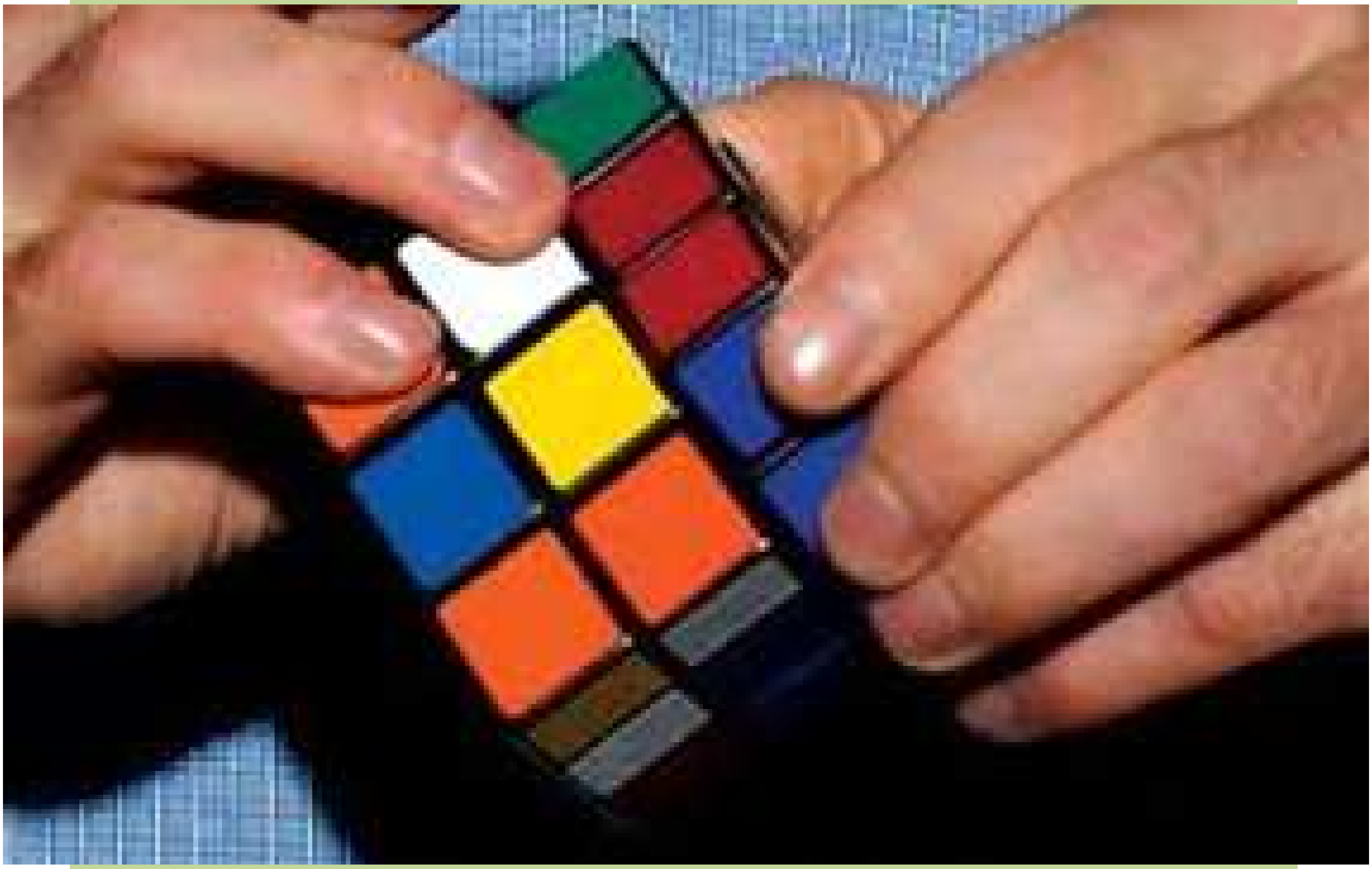
As explained in Part 1, after conducting the three-tiered detailed SAT, one needs to make the final decision about the technology choice to be implemented. At the outset, the option with the highest score may be likely to be viewed as the best candidate. However, some caution needs to be exercised before finalizing that choice for the reasons enumerated in Part 1.

Additionally, it is important to monitor and evaluate the technology system continually during its operational phase to ensure that it continues to meet the desired objectives in terms of the various criteria considered during the SAT process.

Finally, outcomes of the monitoring and evaluation should be reported to the stakeholder group – especially government agencies, planners and other decision makers – in order to help in situational analysis for similar future projects, and thereby enable better informed decisions.

PART III

APPLYING THE SAT METHODOLOGY: A PRACTICE EXAMPLE



What Will You Find Here?

- Background
- Literature Review of Technology Options
- Technology Factsheets
- Activities for Participants (Worksheets for Screening, Scoping and Detailed Assessment)

3.0 SOLVING A DEFINED PROBLEM

3.1 PREAMBLE

This part of the manual introduces a problem faced by a municipality in selecting an appropriate EST for converting WAB into a reusable material and/or an energy resource. This manual first defines the problem and then provides all the supporting information and worksheets for users of the manual. One solution to this problem is provided in the next part (Part IV) of this manual.

3.2 BACKGROUND OF THE PROBLEM

The Society for Environment and Economic Development (SEED) Nepal, in collaboration of Madhyapur Thimi Municipality (MTM), has taken up a project for the conversion of WAB into a material and/or an energy resource[1]. The project area falls under the jurisdiction of MTM. A survey has been conducted in the project area for the collection of baseline information on the availability of WAB, its quantification and categorization, and also on the present waste management system. In August 2009, a Capacity Enhancement Training Workshop was conducted for partners of the project implementers and stakeholders, including MTM.

A talk on the topic of the SAT methodology was also organized for the professionals in SEED Nepal. Consultations were carried out to identify issues of concern. Technology searches were conducted and series of meetings were held for review, along with discussions with the stakeholders on the choice and implementation of the technology.

One of the main outcomes of this project is to establish and operate a pilot demonstration project on the chosen EST using the SAT methodology outlined in Part 1 of this manual.

3.2.1 Availability of WAB and Its Present Disposal/Use

The baseline study carried out in the MTM has shown that WAB materials being generated in the municipality are rice straw, wheat straw, maize stalks and waste vegetables from farms; rice husk from rice mills and beaten rice mills; and waste vegetables from market facilities. The quantity of WAB is given in Table 3.1.

[1] Interested readers may view the link at http://www.seednepal.org/project-wab.php

Table 3.1: WAB Generation in MTM

No.	Type of WAB	Quantity in Metric Tons (MT)
i	Rice straw	861.994
ii	Wheat straw	147.982
iii	Maize stalks	4.385
iv	Waste vegetables (other than those from commercial facilities)	2,021.639
v	Waste vegetables from commercial facilities	153.0
vi	Rice husks from processing units	744.0
	Total	3,932.965

Out of these WAB, rice straw, wheat straw, and rice husks are all used or sold, as they have sale value. Maize stalks are used to some extent but are also openly burnt in the fields before new crops are planted. Only waste vegetables are dumped for composting in the field. Waste vegetables from commercial facilities (in this case, vegetable markets) are transported and dumped along with the municipal solid waste. Taken together, the total availability of waste vegetables is 2,174 MT per annum – a sizable quantity (about 55%) of the total amount of WAB. Therefore, in this project, careful consideration is being given to the possibility of targeting vegetable wastes as a potential reusable material/energy source.

3.2.2 Identified Stakeholders and Findings of the Consultation Workshop

The various stakeholders as identified by MTM are:

- The municipality office;
- Representatives of political parties in the All Party Committee (seven in total);
- Representatives of three women's groups;
- The Community Development Group;
- Representative of the Youth Farmer Group;
- District Development Committee, Bhaktapur;
- District Agriculture Office, Bhaktapur;
- Bhaktapur Chambers of Commerce and Industry;
- Bhaktapur Cottage and Small Industry Association;
- Nepal Ceramic Cooperative;
- Office of Cottage and Small Industry, Bhaktapur;
- Madhyapur Organic Farmer Group;
- Former mayor; and
- Social workers (five in total).

The Stakeholder Consultation Workshop identified the following issues of concern regarding the technology to be installed for converting the WAB into a resource:

- The technology selected must not be polluting; it must be environmentally friendly;
- It should be financially profitable;
- It should be able to utilize agro-waste from domestic sources;
- If possible, it should also utilize wastes from forests;
- The technology should occupy minimal space, as the price of land is escalating;
- The operation of the technology must be simple enough not to require highly trained or skilled operators for implementation.

3.3 ACTIVITIES FOR PARTICIPANTS (INCLUDING WORKSHEETS)

Activities for participants will follow the steps outlined in Figure 3.1. The steps indicated in the Figure with the Worksheet icon (WS #) need to be completed by the participants.

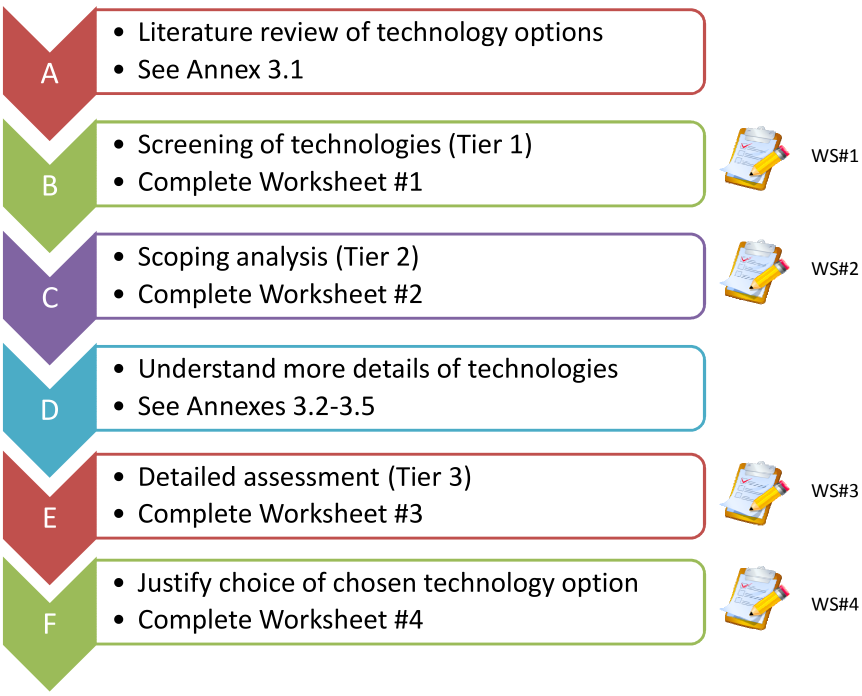


Figure 3.1: Activities for Participants (Including Worksheet Completion)

The following pages provide the Worksheets as well as the guidance to complete them.

WORKSHEET #1: SCREENING OF TECHNOLOGIES (TIER 1)

Guidance for Completing Worksheet #1

- This assessment can be done by a suitable stakeholder group with or without assistance from expert opinions.
- The criteria to be considered at this stage would ideally be taken from the outcomes of the Stakeholder Consultation Workshop.
- A literature review was carried out on technologies for the conversion of WAB into energy/material resources. It has been provided as Annex 3.1 for reference purposes. Participants are advised to examine this review in order to understand the technology/application/equipment options for the case at hand.
- Participants may attach additional sheets if required.

The completed Worksheet must show which technologies have been selected for the next stage of the SAT process.

TABLE FOR WORKSHEET #1: SCREENING TECHNOLOGIES (TIER 1)

Residue	Application	Technology	Equipment	Criteria for Screening							Outcome (Selected/Not selected)
				Criteria #1	Criteria #2	Criteria #3	Criteria #4	Criteria #5	Criteria #6	Criteria #7	

WORKSHEET #2: SCOPING ANALYSIS (TIER 2)

Guidance for Completing Worksheet #2

- This assessment is intended to be done by a suitable stakeholder group with assistance from expert opinion(s).
- Short-listed system options from the Tier 1 should now go through the comprehensive scoping assessment (Tier 2).
- During this stage of SAT, the stakeholders are required to assess the various technology system options vis-à-vis the generic and customized criteria and indicators using any of the listed computational methods (preferably the Simple Weighted Sum Method) by using Worksheet #2.
- Develop and select appropriate criteria – technical, environmental, social, and financial.
- Scores can be assigned on the basis of a pre-decided scale. Actual information on a particular criterion could be qualitative or quantitative and will have to be converted to a score on the basis of the scale assumed. It is critical here to decide a consistent descriptor definition for the scores; whether a higher or lower score is better and desirable for quantification.
- Participants may attach additional sheets if required.

The completed Worksheet must show a preliminary ranking of suitable ESTs based on the scoping analysis.

TABLE FOR WORKSHEET #2: SCOPING ANALYSIS WITH WEIGHTED SUM METHOD (TIER 2)

Criteria	Weight	Maximum Weighted Score	Tech System 1		Tech System 2		Tech System 3		Tech System 4		Tech System 5	
			Score	Weight x Score	Score	Weight x Score	Score	Weight x Score	Score	Weight x Score	Score	Weight x Score
TOTAL												

WORKSHEET #3: DETAILED ASSESSMENT (TIER 3)

Guidance for Completing Worksheet #3

- This assessment is intended to be done by a suitable stakeholder group with assistance from expert opinion(s). This is because this level of assessment is rather situation-specific and demands much more detailed and quantitative information in order to arrive at a good assessment.

- Overall, the better rated options that emerge through the Tier 2 analysis will be carried over to Tier 3 for a more detailed assessment.

- During this stage of SAT, the stakeholder group should once again prepare a new weighted sum matrix or revise the existing one. In some instances, it is possible that the ratings of the technology systems may change due to new scoring based on available information. In this case, use the information provided as technology factsheets for Annexes 3.2 to 3.5.

- Ranks of technology options are to be assessed using the weighted score method[2].

- It would be beneficial to use a graphical presentation such as a star diagram to investigate more closely the reasons for the relative rankings of different technologies and also to identify critical or important criteria that may need more extensive consideration.

- Participants may attach additional sheets if required.

The completed Worksheet must indicate the EST chosen after the detailed assessment.

[2] Note that for more complex cases (unlike this one), these ranks would also be assessed for equal weights for technical, environmental, social and financial criteria, simultaneous comparison of criteria, and total scores of all criteria (as done in Annex 2.4).

TABLE FOR WORKSHEET #3: DETAILED ASSESSMENT (TIER 3)

Criteria	Weight	Maximum Weighted Score	Tech System A		Tech System B		Tech System C	
			Score	Weight x Score	Score	Weight x Score	Score	Weight x Score
TOTAL								

WORKSHEET #4: JUSTIFY CHOICE OF CHOSEN TECHNOLOGY OPTION

Guidance for Completing Worksheet #4

- This assessment is intended to be done by a suitable stakeholder group with assistance from expert opinion(s).
- At the outset, the option with the highest score resulting from the weighted sum matrix may be likely to be viewed as the best candidate. However, some caution needs to be exercised before finalizing that choice, for the various reasons mentioned in Part 1 of the accompanying manual.
- Participants may also make use of star diagrams to underscore the extent to which the chosen technology would meet all the criteria laid down by them.
- Participants may attach additional sheets if required.

The completed Worksheet must enumerate the reasons for the participants justifying their choice of EST after the Tier 3/detailed assessment.

TABLE FOR WORKSHEET #4: JUSTIFY CHOICE OF EST MADE AFTER DETAILED (TIER 3) ASSESSMENT

PART IV

SOLUTION TO THE GIVEN EXAMPLE

What Will You Find Here?

- Solution to the Worksheets Provided in Part III of this Manual

4.0 SOLUTION TO THE GIVEN EXAMPLE

4.1 INTRODUCTION

The solution to the problem given in Part III of this manual is provided here. The solution has been provided as per the Worksheets in Part III.

4.2 NOTES FOR TRAINERS

The trainer/instructor should share the solutions from different working groups on a tier-by-tier basis. This is mainly due to the nature of the SAT methodology – Tier 1 outcomes impact Tier 2 solutions and Tier 2 solutions in turn influence Tier 3 outcomes.

4.3 SOLUTION FOR SCREENING OF TECHNOLOGIES (TIER 1) – WORKSHEET #1

Remember, there may not be a "right" or "wrong" solution, given that the SAT methodology caters to situation-specific issues. However, a particular solution may be "appropriate" or "inappropriate" in the given context and the trainer/ instructor should ensure that inappropriate solutions are detected.

The outcomes of the Stakeholder Consultation Workshop identified certain issues of concern regarding the technology to be installed for converting the WAB into resources. Accordingly, these issues have been converted into screening criteria for the given problem.

Additionally, Annex 3.1 provided a literature review on technologies for conversion of WAB into energy/material resources. The review provides some information about technology/application/equipment options for the case at hand. Table 4.1 shows how these criteria have been applied against the reviewed technologies.

The following technologies were short-listed for Tier 2 assessment:

- Briquetting
- Gasification to produce syngas
- Biogas-cum-fertilizer generation (biomethanation)

Table 4.1: Solution for Worksheet #1: Screening Technologies (Tier 1)*

Technology	Criteria for Screening							Outcome (Selected/Not selected)
	Simple technology	Flexibility in accepting various WAB types	Uses minimal land area	Imparts economic value	Non-polluting/ environmentally friendly	-	-	
Briquetting	✓	✓	✓	✓	✓			Selected
Sizing, mixing and densification (for use as animal fodder)	✓	✓	×	×	✓			Not selected
Off-grid electricity generation using boiler with steam turbine	×	×	×	✓	✓			Not selected
Gasification to produce syngas	✓	✓	✓	✓	✓			Selected
Ethanol production using bio-refinery system	×	×	✓	✓	✓			Not selected
Biogas-cum-fertilizer generation (biomethanation)	✓	✓	✓	✓	✓			Selected
Strawboard manufacture using waste straw and extruding equipment	✓	×	×	✓	✓			Not selected

*: The defined problem in Part III is much less complex than the solved problem in Part II of this Manual. Therefore the columns "Application" and "Equipment" have been grouped together under "Technology".

4.4 SOLUTION FOR SCOPING ANALYSIS (TIER 2 ASSESSMENT) – WORKSHEET #2

In order to illustrate the solution, the following criteria have been applied within a scoping analysis of the three screened technologies. The weighted score method has been used for the ranking of these technologies. The scoring of the technologies may be seen in Table 4.2, while the end result (ranking) may be viewed in Table 4.3.

Table 4.2: Solution for Worksheet #2 - Scoping Analysis with Weighted Sum Method (Tier 2)

Criteria	Weight	Briquetting		Gasification		Biomethanation	
		Score	Weight x Score	Score	Weight x Score	Score	Weight x Score
Low on air pollution	10	3	30	8	80	10	100
Low on odor	20	8	160	9	180	5	100
Proven technology	10	8	80	7	70	7	70
Can use all types of WAB	10	5	50	5	50	8	80
Provides additional economic benefits	20	5	100	5	100	8	160
Social acceptance is high	20	3	60	5	100	6	120
Additional processing needed	10	4	40	6	60	8	80
TOTAL	100	-	520	-	640	-	710

Note: Scoring is done on a scale of 1 - 10

Table 4.3: Ranking of Technologies (After Scoping Analysis – Tier 2)

Ranking	Score	Technology
1	710	Biomethanation
2	640	Gasification
3	520	Briquetting

4.5 SOLUTION FOR DETAILED ANALYSIS (TIER 3 ASSESSMENT) – WORKSHEET #3

The detailed information about technologies obtained through the provided quotations/ factsheets should be analyzed. Based on this additional information (provided in Annexes 3.2 to 3.5) the top three ranked technologies have been subjected once more to the weighted score method. The results of this analysis are given in Table 4.4 and Table 4.5.

Table 4.4: Solution for Worksheet #3 –
Detailed Assessment with Weighted Sum Method (Tier 3)

Criteria	Weight	Briquetting		Gasification		Biomethanation	
		Score	Weight x Score	Score	Weight x Score	Score	Weight x Score
Low on air pollution	10	7	70	8	80	9	90
Low on odor	20	8	160	8	160	5	100
Proven technology	10	9	90	7	70	7	70
Can use all types of WAB	10	5	50	5	50	8	80
Provides additional economic benefits	20	5	100	5	100	8	160
Social acceptance is high	20	6	120	5	100	6	120
Additional processing needed	10	5	50	6	60	8	80
TOTAL	100	-	640	-	620	-	700

Note: Scoring is done on a scale of 1 - 10

Table 4.5: Final Ranking of Technologies
(After Detailed Assessment – Tier 3)

Ranking	Score	Technology
1	710	Biomethanation
2	640	Briquetting
3	620	Gasification

4.6 SOLUTION FOR JUSTIFICATION OF CHOSEN TECHNOLOGY OPTION – WORKSHEET #4

It may be noted that scoring as well as ranking for biomethanation remains robust and unchanged between Tiers 2 and 3 (see Tables 4.3 and 4.5), while that for briquetting and gasification trades places. As a result, after a detailed assessment has been completed, biomethanation appears to the best choice for the given.

Let us now review if and how biomethanation can be justified as the chosen technology option with respect to consideration of future scenarios.

SOLUTION FOR WORKSHEET #4: JUSTIFY CHOICE OF EST MADE AFTER DETAILED (TIER 3) ASSESSMENT

Urbanization is on the increase in MTM; the agricultural area is decreasing and residential area is expanding at a rapid pace. The area's population has also recorded a consistent increase since the last decade. As a result, it would not be illogical to assume that WAB generated from farming activities will decrease over time. Therefore, WAB to be used for gasification and/or briquetting is also likely to decrease. However, WAB from commercial markets and households would increase exponentially at the same time. Therefore, WAB generated for biogas production, especially through the use of waste vegetables, will increase with time. As a result, biogas from waste vegetables will continue to remain the first preference for the demonstration project for the conversion of WAB into a resource in MTM.

Additionally, biomethanation will provide tremendous environmental benefits, most notably a reduction in greenhouse gas (methane) emissions, the promotion of organic fertilizer, and improved sanitation and health conditions due to proper management of the waste vegetables in the municipality. On the social front, there will be benefits as it will improve the habit of waste segregation and promote cleanliness. The municipality will also save on the considerable resources presently being spent on WAB management.

Annex 1.1: Sample Generic Criteria and Indicator System

Group Heading	Criteria	Indicators	Guidance Notes/Verification Requirements
Tier 1: Screening Criteria			
Compliance	Compliance with local environmental laws	Yes/no	This is a very fundamental requirement and a rather simple check. The proposed technology system must be in compliance with local as well as national legislation. Supporting information to make this decision can be found using technology fact sheets as well as expert opinions and information from vendors when necessary.
Compliance	Compliance with national environmental laws	Yes/no	
Compliance	Compliance with Multilateral Environmental Agreements (MEAs)	Yes/no	Check if the proposed technology system results in violation of MEAs. For instance, the use of ozone depleting substances (ODS) can result in such a violation and hence must be avoided. It is necessary to rely on expert opinion for this, since this is rather a specialized area requiring careful scrutiny.
Other requirements	Meeting objectives (e.g. 3Rs, remediation, rehabilitation etc.)	Yes/no	In view of the outcome of the strategic assessment, at times the objective of the technological intervention may not merely be legal compliance, but could be something more, such as recycling or remediation. It is essential to ensure that the proposed technology meets this objective. Decisions concerning this criterion can be made using information such as technology fact sheets, expert opinions and information from vendors.
Tier 2: Scoping Criteria			
Technical suitability	Compatibility with local natural conditions (geographical, climate, topographical)	Low/medium/ high	To ensure optimal performance of the technology system, it is necessary to check the compatibility with local natural conditions (e.g. Is the proposed technology system suitable for geographical, climatic and topographical conditions? Will it result in any secondary impacts such as groundwater contamination?). To make this decision, refer to technology fact sheets, expert opinions and information from

Group Heading	Criteria	Indicators	Guidance Notes/Verification Requirements
			vendors.
Technical suitability	Extent of local materials usage	Low/medium/ High	Technology intervention should give preference to the use of local materials in light of both cost and social considerations. Reference to vendor information and technology fact sheets may assist in making this decision.
Technical suitability	Availability of local expertise	Low/medium/ high	Local expertise is necessary for commissioning a new technology system as well as for operating and managing it. A rating of low, medium or high is given in accordance with the expertise requirements vis-à-vis availability. Use vendor information and technology fact sheets vis-à-vis available local expertise to make the decision on this criterion.
Technical suitability	Performance-related track record	Low/medium/ high/not available	Before making a decision about any technology system option, it is essential to check the track record of both the technology and the vendor. Technology fact sheets, market intelligence, and site visits to similar installations all assist in assigning a rating to this aspect.
Technical suitability	Compatibility with existing situation (technology, management systems)	Low/medium/ high	A new technology system may in some cases build upon an existing system. Therefore, the new system must be compatible with existing infrastructure/technology systems as well as the organization's management systems. It is possible to make this decision with the help of expert opinions supplemented by technology fact sheets and vendor information.
Technical suitability	Adaptability to future situations	Low/medium/ high	In order to get the maximum benefit from the technology intervention, it is essential to check the technology system's flexibility or adaptability to future scenarios. This may, for instance, include the possibility of a scaling-up/expansion or an upgrade in the technology that improves efficiency in order to meet changing needs. Ratings can be assigned for this criterion by referring to technology fact sheets and expert opinions. It may also be essential to revisit the situation analysis and undertake some simulation or scenario building exercises to be able to decide on this aspect.
Technical suitability	Process stability	Low/medium/ high	The stability of the proposed technology system during its operation phase is a very important consideration in bringing about the desired results. The technology system must perform in a stable manner under a variety of scenarios/situations

Group Heading	Criteria	Indicators	Guidance Notes/Verification Requirements
			during the operation phase, such as shock loads or sudden variations in process parameters. When assessing the stability, it is essential to rely on expert opinions while also referring to technology fact sheets, past similar case studies and vendor information.
Technical suitability	Level of automation/ sophistication	Low/medium/ high	The level of automation and the sophistication of the proposed technology system can be assessed by referring to vendor information, technology fact sheets and expert opinions.
Environment, health and safety risks	Risk levels for workers	Low/medium/ high	Before making the decision on the proposed technology system, it is essential to assess the potential environmental, health and safety risks to the workers and to communities/beneficiaries as well as to the environment/biodiversity. Depending on the scale and sensitivity of the proposed technological interventions, a full-fledged risk assessment exercise may be necessary in some instances, while in other others, this decision can simply be made by referring to expert opinions supported by technology fact sheets and vendor information. It is important to note that in assessing this aspect, higher scores are assigned for lower risks, with scores to be assigned using a weighted sum matrix. This is different from many other criteria, in which high ratings correspond to high scores.
Environment, health and safety risks	Risk levels for communities/ beneficiaries	Low/medium/ high	
Environment, health and safety risks	Risk to the environment, e.g. to biodiversity	Low/medium/ high	
Environment: Resources and emissions	Resource usage		
Environment: Resources and	Space requirement	Low/medium/	Various aspects related to resource usage can be assessed by referring to vendor

Group Heading	Criteria	Indicators	Guidance Notes/Verification Requirements
emissions		high	information, technology fact sheets and expert opinions. It is important to note that in assessing this aspect, higher scores should be assigned for lower resource required such as space/land requirements and energy, water and raw material consumption, with scores to be assigned using a weighted sum matrix. This is different from many other criteria, in which high ratings correspond to high scores.
Environment: Resources and emissions	Energy consumption per unit	Low/medium/ high	
Environment: Resources and emissions	Extent of use of renewable energy	Low/medium/ high	
Environment: Resources and emissions	Extent of use of waste materials as input	Low/medium/ high	
Environment: Resources and emissions	Water consumption	Low/medium/ high	
Environment: Resources and emissions	Raw material consumption	Low/medium/ high	
Environment: Resources and emissions	Resource augmentation capabilities	Low/medium/ high	The proposed technology intervention may result in the remediation or recovery/augmentation of resources as a side effect/additional benefit and must be considered when deciding on a technology system. For this decision, one can rely on expert opinions while also referring to technology fact sheets, past similar case studies as well as vendor information.
Environment: Resources and emissions	Emissions	Low/medium/ high	Various aspects related to emissions, odor and usage of hazardous materials can be assessed by referring to vendor information, technology fact sheets and expert opinions. It is important to note that in assessing this aspect, higher scores should be assigned for lower emissions, odour etc., with scores to be assigned using a

Group Heading	Criteria	Indicators	Guidance Notes/Verification Requirements
			weighted sum matrix.
Environment: Resources and emissions	Odor	Low/medium/ high	
Environment: Resources and emissions	Extent of use of hazardous materials	Low/medium/ high	
Economic/ financial aspects	Capital investment	Low/medium/ high	Various aspects related to costs and benefits can be assessed primarily by referring primarily to vendor information and technology fact sheets as well as to expert opinions in certain cases. It is important to note that higher scores should be assigned for lower costs (and higher benefits), with scores to be assigned using a weighted sum matrix. This is different from many other criteria, in which high ratings correspond to high scores.
Economic/ financial aspects	Operation and maintenance costs	Low/medium/ high	
Economic/ financial aspects	Benefits (energy, fertilizer, reclaimed land, enhanced biodiversity)	Low/medium/ high	
Social/cultural aspects	Acceptability	Low/medium/ high	Criteria related to social aspects can be assessed by using information collated through relevant socio-economic surveys, census data etc. In addition, reference to vendor information and expert opinions may be critical. It is important to note that higher scores should be assigned for a lower extent of resettlement required, with scores to be assigned using a weighted sum matrix. This is different from many other criteria, in which high ratings correspond to high scores.
Social/cultural aspects	Extent of necessary resettlement and	Low/medium/ high	

Group Heading	Criteria	Indicators	Guidance Notes/Verification Requirements
	rehabilitation of people		
Social/cultural aspects	Income generation potential	Low/medium/ high	
Tier 3: Detailed Assessment Criteria			
Environment: Resources and emissions	Land/space requirements	Area of land required for installation of the technology (including surrounding buffer margins) vis-à-vis availability	In this tier of assessment, detailed information is collected for the listed criteria for this assessment level using information from vendors and technology fact sheets. Expert opinion is essential in studying and analyzing the collected information and in assigning the ratings for each criterion accordingly.
Environment: Resources and emissions	Energy consumption		
Environment: Resources and emissions	Fuel	Type of fuel; quantity per unit operating hours or unit output	
Environment: Resources and emissions	Electricity	Quantity per unit operating hours or unit output	
Environment: Resources and	Steam	Quantity per unit operating	

Group Heading	Criteria	Indicators	Guidance Notes/Verification Requirements
emissions		hours or unit output	
Environment: Resources and emissions	Raw materials consumption	Quantity per unit output or production	
Environment: Resources and emissions	Water consumption	Quantity per unit output or production	
Environment: Resources and emissions	Emissions	Quantity per unit output or production	
Environment: Resources and emissions	Noise and vibrations: Noise levels near installation during operation	Intensity in decibels	
Economic/ financial aspects	Capital costs		
Economic/ financial aspects	Operation and maintenance costs		
Economic/ financial aspects	Benefits (energy, fertilizer, reclaimed land, enhanced biodiversity, carbon credits)	Economic returns	
Economic/ financial aspects	Economic viability	NPV, IRR, C/B ratio, payback	

Group Heading	Criteria	Indicators	Guidance Notes/Verification Requirements
		period	

Annex 1.2: Techniques for Assessing Alternatives

1.0 TECHNIQUES FOR ASSESSING ALTERNATIVES

There are three steps in decision making:

Step 1: Problem Identification - This involves identifying the problem, determining which decisions need to be made and collecting all available information.

Step 2: Design - This involves creating a list of possible alternatives, assigning risk/advantage values to each alternative and decision, and determining success criteria.

Step 3: Choice - This involves processing the alternatives and then ranking them.

The following commonly applied methods for resolving the multiple criteria (advantages/disadvantages) characterizing different options are given in increasing order of complexity:

i. Weighting method or Weighted Sum Matrix or Decision Matrix;

ii. Sequential Elimination by Lexicography;

iii. Sequential Elimination by Conjunctive Constraints;

iv. Goal Programming;

v. Delphi Method for Consensus Building; and

vi. Analytic Hierarchy Process (AHP).

Additionally, advanced methods such as Expert Systems and Neural Networks are applied during decision making and evaluation. This report considers and discusses only the commonly applied methods.

1.1 Weighting Method or Weighted Sum Matrix or Decision Matrix

A decision matrix evaluates and prioritizes a list of options. The team first establishes a list of weighted criteria and then evaluates each option against those criteria. The following steps indicate the procedure for using a decision matrix.

- Brainstorm the evaluation criteria appropriate to the situation.
- Discuss and refine the list of criteria. Identify any criteria that must be included as well as any that must be excluded. Reduce the list of criteria to those that the team believes are most important.
- Assign a relative weight to each criterion based on how important that criterion is to the situation. For each criterion the weight is selected from 1 (minimum) to 10 (maximum). This assignment can be done through discussion and consensus. Alternately, each member can assign weights, then the numbers for each criterion are averaged for a composite team weighting.
- Draw an L-shaped matrix. Write the criteria and their weights as labels along one edge and the list of options along the other edge. Usually, whichever group has fewer items occupies the vertical edge.
- Evaluate each item in the list of options against the criteria.

1.2 Sequential Elimination by Lexicography

The steps followed in Sequential Elimination by Lexicography are:

- Each attribute is given a ranking from most important (1) to least important (e.g. 5).
- Alternatives are given scores for each attribute (1 to 10).
- The attributes and alternatives are sorted according to the rankings assigned.
- Alternatives are gradually eliminated according to scores.

1.3 Sequential Elimination by Conjunctive Constraints

The steps followed in Sequential Elimination by Conjunctive Constraints are:

- Each attribute is given a constraint (e.g. "must be greater than," "must be less than").
- Each alternative is rated under the given constraints.

- If there is more than one "survivor," tighten the constraints.
- If there are no survivors, slacken the constraints.

1.4 Goal Programming

This method is similar to Linear Programming. The attributes are converted to mathematical variables and incorporated into equations. These equations are then resolved to find the optimal solution.

1.5 Delphi Method for Consensus Building

The Delphi Method works through multiple cycles of discussion and argument, managed by a facilitator who controls the process and manages the flow and consolidation of information. The steps for consensus building under the Delphi Method are:

i. Clearly define the problem to be solved (in the case of SAT, assign weights to the criteria);

ii. Appoint a facilitator or chairperson with the skills and integrity needed to manage the process properly and impartially. This facilitator or chairperson then conducts steps iii through vii below.

iii. Select a panel of stakeholders having depth and breadth of knowledge and proven good judgment as needed for effective analysis of the problem;

iv. Have individual panel members brainstorm about the problem from their point of view and provide anonymous feedback to the facilitator;

v. Consolidate the individual responses and submit these to the panel;

vi. Resubmit this summary information to the panel to elicit new responses. Some individuals may change their minds and decide to go with the majority. In other cases, some people not siding with the majority may provide new information which may influence the group decision in the next round.

vii. This process continues until a consensus or a high degree of agreement has been reached on the options being considered. (For instance, 70% of the participants ultimately agree that social acceptability is the most important criteria and should be assigned a weight of 7 on a scale of 0-10.)

1.6 Analytic Hierarchy Process

This method is applied when there are complex relationships between criteria. It requires decision makers to make judgements regarding the importance of criteria. The alternatives are compared in pairs to one another. This method is described in detail in section 2 below.

2.0 ANALYTICAL HIERARCHY PROCESS (AHP)

2.1 Introduction to AHP

The **Analytic Hierarchy Process (AHP)** is a structured technique for dealing with complex decisions. Rather than prescribing a "correct" decision, the AHP helps the decision makers find the one that best suits their needs and their understanding of the problem.

First developed by Thomas L. Saaty in the 1970s, this process has been studied and refined extensively since then. The AHP provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals and for evaluating alternative solutions. It is used worldwide in a wide variety of decision situations in government, business, industry, healthcare, education, and many other fields.

Users of the AHP first decompose their decision problem into a hierarchy of more easily addressed sub-problems, each of which can be analyzed independently. The elements of the hierarchy can relate to any aspect of the decision problem—tangible or intangible, carefully measured or roughly estimated, well or poorly understood—anything at all that applies to the decision at hand.

Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to one another two at a time. In making the comparisons, the decision makers can use concrete data about the elements, or they can use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgment, and not just the underlying information *per se*, can be used in performing the evaluations.

The AHP converts these evaluations to numerical values that can be processed and compared across the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision making techniques.

In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision goal, thereby allowing a straightforward consideration of the various courses of action.

2.2 Applications of AHP

The Analytic Hierarchy Process (AHP) is most useful where teams of people are working on complex problems, especially problems where much is at stake, that involve human perceptions and judgments and whose resolutions have long-term repercussions. It has unique advantages when important elements of the decision are difficult to quantify or compare or when communication among team members is impeded by their different specializations, terminologies, or perspectives.

Decision situations to which the AHP can be applied include:

- Choice - The selection of one alternative from a given set of alternatives, usually where there are multiple decision criteria involved.
- Ranking - Ordering a set of alternatives from most to least desirable.
- Prioritization - Determining the relative merit of members of a set of alternatives, as opposed to selecting a single alternative or merely ranking them.
- Resource allocation - Apportioning resources among a set of alternatives.
- Benchmarking - Comparing the processes in one's own organization with processes used by ‘best-of-breed’ organizations.
- Quality management - Dealing with the multidimensional aspects of quality and quality improvement.

2.3 Using the Analytic Hierarchy Process

The AHP mathematically synthesizes numerous judgments about the decision problem at hand. It is not uncommon for these judgments to number in the dozens or even the hundreds. While the math can be done by hand or with a calculator, it is far more common to use one of several computerized methods for entering and synthesizing the judgments. The simplest of these involve standard spreadsheet software, while the most complex use custom software, often augmented by special devices for acquiring the judgments of decision makers gathered in a meeting room.

The procedure for using the AHP can be summarized as:

Step 1: Model the problem as a hierarchy containing the decision goal, the alternatives for reaching it, and the criteria for evaluating the alternatives.

Step 2: Establish priorities among the elements of the hierarchy by making a series of judgments based on pair-wise comparisons of the elements. For example, when comparing potential real-estate purchases, the investors might say they prefer location over price and price over timing.

Step 3: Synthesize these judgments to yield a set of overall priorities for the hierarchy. This would combine the investors' judgments about location, price and timing for properties A, B, C and D into overall priorities for each property.

Step 4: Check the consistency of the judgments.

Step-5: Come to a final decision based on the results of this process.

Annex 2.1: Setting Targets

Waste: Paddy Straw 	
Issues	Targets
Present policies result in dumping of all the waste generated in fields, resulting in adverse effects on the environment as well as the loss of a potential resource	Use of relevant technologies to convert waste to energy or ensure material reuse/recycling, together with policy level interventions
Increase in amount of waste expected to be generated in the future	Implementation of technologies that can be easily duplicated or scaled up
Lack of appropriate technologies and local expertise	Introduction of technologies suited to local resources and expertise
Low bulk density, which decreases the waste's value as a raw material (e.g. fuel value)	Use of relevant technologies (e.g. bailing, briquetting, pelletizing, pressing) to upgrade the waste's value as a raw material
Waste: Paddy Husks 	
Issues	Targets
Present policies result in indiscriminate dumping of generated waste, resulting in adverse effects on the environment as well as the loss of a potential resource	Use of relevant technologies to convert waste to energy (e.g. process heat)
Improper collection practices that adversely affect the environment and	Incorporation of appropriate design features to revamp the present

human health	collection system, in accordance with national regulatory standards
Lack of land for waste disposal	Use of relevant technologies to convert waste to energy
Use of conventional technologies for conversion of waste to energy (e.g. brick making, drying) results in low quality products, higher energy costs, waste of resources, and higher levels of pollution	Introduction of improved technologies and/or process modification to increase energy efficiency and produce better product quality
Lack of appropriate technologies and local expertise	Introduction of technologies suited to local resources and expertise
Waste characterized by low bulk density, which decreases the waste's fuel value	Use of relevant technologies (e.g. briquetting) to upgrade the fuel value
Increase in amount of waste expected to be generated in the future	Implementation of technologies that can be easily duplicated or scaled up
Public protests due to open dumping/open burning	Introduction of appropriate technologies to convert waste to energy, thereby reducing the need for disposal

Waste: Sawdust

Issues	Targets
Present policies result in indiscriminate dumping of generated waste, resulting in adverse effects on the environment as well as the loss of a potential resource	Use of relevant technologies to convert waste to energy (e.g. process heat)
Waste characterized by low bulk density, which decreases its fuel value	Introduction of appropriate technologies (e.g. briquetting, pelletizing etc.) to improve the waste's fuel value
Improper collection practices that result in contamination of sand	Incorporation of appropriate design features for the present collection system
Lack of appropriate technologies and local expertise	Introduction of technologies suited to local resources and expertise
Lack of land for waste disposal	Use of relevant technologies to convert waste to energy
Public protests against open dumping/open burning	Introduction of appropriate technologies to convert waste to energy, thereby reducing the need for disposal

Waste: Market Waste

Issues	Targets
Present policies result in the indiscriminate dumping of generated waste, resulting in adverse effects on the environment as well as the loss of a potential resource	Use of relevant technologies to convert waste to energy (e.g. biogas generation for process heat)
Lack of land for waste disposal	Use of relevant technologies to convert waste to energy
Lack of appropriate technologies and local expertise	Introduction of technologies suited to local resources and expertise
Increase in amount of waste expected to be generated in the future	Implementation of technologies that can be easily duplicated or scaled up
Public protests against open dumping	Introduction of appropriate technologies to convert waste to energy, thereby reducing the need for disposal

Waste: Wild Guinea Grass

Issues	Targets
Extensive growth as a weed, adversely affecting agriculture and useful land	Use of relevant technologies to convert waste to energy or material for reuse
Lack of appropriate technologies and local expertise	Introduction of technologies suited to local requirements and expertise
Difficulty in harvesting/cutting	Incorporation of appropriate design features for the harvesting system
Waste characterized by low bulk density, which decreases its fuel value	Introduction of appropriate technologies (e.g. baling, briquetting, pelletizing etc.) to improve the fuel value
Waste characterized by high moisture content, causing rapid decomposition and lowering the fuel value	Incorporation of appropriate pre-treatment process (i.e. drying)

Waste: Banana Rejects

Issues	Targets
Inappropriate waste dumping that adversely affects the environment and human health	Use of relevant technologies to convert waste to energy (e.g. biogas generation)
Lack of land for waste disposal	Use of relevant technologies to convert waste to energy
Lack of appropriate technologies and local expertise	Introduction of technologies suited to local resources and expertise
Waste characterized by high moisture content, causing rapid decomposition and lowering the fuel value	Introduction of technologies not sensitive to high moisture content

Annex 2.2: Overview of Possible Technology Options*

*Note: For the column titled "Selection," R stands for research stage, P for piloting stage and C for commercially proven.

Residue	Application	Process/ Technology	Equipment	Capacity Range	Selection			Remarks	Additional Comments
					R	P	C		
Paddy husks	Value addition to the residue as fuel for process heat generation in industry	Densification/ briquette making	Screw type briquetting machine	Typical capacity range: 100 – 250 kg/hr Selected capacity: 200 kg/hr			X	Briquette density = 0.8 – 1.2 t/m^3. Energy requirement = 150 – 225 kWh/t.	Increase in density and change in physical form can diversify applications and increase fuel value (Example: Application – tea industry, fuel value > 15 Rs/kg). Although the technology is not considered low-end, local manufacture/fabrication is possible.
	Value addition to the residue as fuel for small scale heat generation	Carbonization/ charcoal making	Small scale charcoal kiln	Typical capacity: Input - 6 kg/load; Output - 2 kg/load			X	Low environment performances; need hand operated extruder type briquetting machine for densification	Small scale technology; applicable at the domestic level alone.

Residue	Application	Process/ Technology	Equipment	Capacity Range	Selection			Remarks	Additional Comments
Paddy husks	Domestic cooking	Direct combustion	Paddy husk cook stove	Heat generated: 4.0 kWth Fuel input = 1.0 kg/load			X	Overall efficiency - 20% Combustion efficiency - 80% Fuel input rate = 1.3 kg/hr	At present, as fuel wood for cooking is abundant in the area, usage of this technology is likely to be unviable. This is a small scale application involving simple technology. ESTs are available at local as well as regional levels.
		Gasification	Paddy husk gas stove	Heat generated: 5.5 kWth Fuel input = 1.3 kg/load			X	Overall efficiency - 15% Combustion efficiency - 80% Fuel input rate = 1.75 kg/hr	-
		Carbonization	Charcoal making cook stove	Heat generated: 3.0 kWth Fuel input = 2.2 kg/load		X		Overall efficiency - 10% Charcoal output = 0.6 kg/load Fuel input rate = 1.8 kg/hr	-
	Process heat generation for lime drying/ smoking	Direct combustion/ direct heating	Paddy husk stove cum cabinet dryer	Product input = 200 kg/batch Heat generated: 5.0 kWth			X	Efficiency of drying = 60% Efficiency of stove = 65%	-

Residue	Application	Process/ Technology	Equipment	Capacity Range	Selection			Remarks	Additional Comments
				Fuel input = 72 kg/load				Fuel input rate = 2 kg/hr	
Paddy Husks	Process heat generation for vegetable/ fruit drying	Direct combustion/ indirect heating	Paddy husk stove cum tray dryer	Product input = 100 kg/batch Heat generated: 8.0 kWth Fuel input = 54 kg/load			X	Efficiency of drying = 40% Efficiency of stove = 65% Fuel input rate = 3 kg/hr	Available, but the technology is conventional. It is very relevant to the local community and could contribute to the development of local industry/agriculture. Local/regional level ESTs are available and complete local design/fabrication is possible.
	Process heat generation for brick making	Direct combustion/ direct heating	Improved brick kiln	Estimated capacity >100 kWth		X		Further research needed to develop the technology	Available, but the technology is conventional. There is a need as well as potential for the introduction of an appropriate EST.
	Process heat generation for tobacco curing	Direct combustion/ indirect heating	Tobacco barn	Selected capacity ~ 5.0 kWth		X		Requires modifications to existing technology; can be implemented on a commercial basis	Available, but the technology is conventional. Some technology interventions have been attempted but require further development.

Residue	Application	Process/ Technology	Equipment	Capacity Range	Selection			Remarks	Additional Comments
Paddy husks	Grid electricity generation	Direct combustion and external combustion/ steam cycle	Boiler and steam turbine	> 500 kWe			X	Overall efficiency – 25%; implementation under this project may not be viable due to limitations in resources and time	The increasing interest in large-scale biomass-based electricity generation could make this a very viable solution in the future. This is a large-scale operation and the technology should be acquired from a regional country. However, development of a pilot plant may not be viable under the present project.
	Off-grid electricity generation	Gasification/ four stroke spark ignition	Gasifier cum internal combustion engine	< 30 kWe		X		Overall efficiency – 15%; Commercially proven technologies not available; operational issues with gasifier	This technology is becoming popular under rural electrification programs using fuel-wood as the source, and could also be adapted for paddy husks (at least co-firing with fuel wood). However, donor funding is required to implement it because of high initial costs. Although some parts can be manufactured locally, the technology needs to be imported.
	Conversion to cement extender	Carbonization	Basket burner	Input - 20 kg paddy husks Output – 4 kg			X	Considerable energy loss unless a	Presently the technology is not available locally. It must be coupled with an energy

Residue	Application	Process/ Technology	Equipment	Capacity Range	Selection			Remarks	Additional Comments
				ash/batch				recovery system is used; limited market locally	application to recover the thermal energy loss.
	Fuel extraction (ethanol)	Fermentation and distillation (with or without husks)	Bio-refinery system	> 100 t/day of feed stoke > 30,000 L/day of ethanol (commercial systems)		X		1 t biomass mix yields about 300 L of ethanol and 150 kg of silica/sodium oxide	This is an emerging technology not available locally at present. It is a relatively complex process, but the value addition is quite high. It would probably be viable at a large scale in the future.
Paddy straw	Value addition as a raw material for variety of applications	Baling/ densification	Straw baler	Wide range; Selected capacity: Field capacity - 0.25 ha/h Rate – 100 bales/hr			X	Limited viability for small scale operations. Bale size (d×w)- 80×45 cm. Bale weight – 20 kg Need to create local market.	This technology is more suited to large fields using a mechanization process. Potential markets should be identified (e.g. heat/electricity generation plants).
	Manufacture of straw boards	Series of processes including baling, classifying, drying, blending,	Multiple types of equipment including press or extruder	Wide range; selected capacity – 2 t/day of material input Output – 60 no. of panels of size 0.8 m × 2.5 m × 5 cm			X	Density of straw panel – 0.7t/m^3	-

Residue	Application	Process/ Technology	Equipment	Capacity Range	Selection			Remarks	Additional Comments
		densification, sanding, etc							
	Paper making	Paper pulping	Hand tools and utensils	Small scale			X	Low-end technology but high social impacts in rural areas	Non-energy application with higher value addition. Technology does exist but needs wider dissemination.
Paddy straw	Cooking/ lighting	Anaerobic digestion/ biogas generation	Biogas digester– continuous type	Typical capacity range: 2 – 100 kg/day of waste Tank volume 1 – 15 m^3 Selected capacity: 40 kg/day of waste Tank volume 5 m^3			X	Biogas yield – 3.8 m^3/day; suitable for cooking and lighting for a family of 5 members	Existing application practiced at domestic/small farm level, and the technology is available locally. It can also be mixed with other waste types.
	Off-grid electricity generation	Anaerobic digestion/ four stroke spark ignition	Biogas digester and internal combustion engine	Typical capacity range: > 200 kg/day of waste Selected capacity: 500 kg/day of waste Plant capacity - 2.2 kWe		X		Biogas yield – 47 m^3/day; could generate about 50 kWh/day. Energy conversion efficiency: Digester – 13.5%. Engine – 20%.	Same remarks as in paddy husks entry.

Residue	Application	Process/ Technology	Equipment	Capacity Range	Selection			Remarks	Additional Comments
Paddy straw	Fertilizer	Composting	Hand tools (for handling waste)	No specific capacity range			X	Low level technology; other materials required	Highly relevant to the local community practicing agriculture. Can also be mixed with other waste types.
	As animal fodder	Sizing/mixing and densification	Densified TMR block making plant with TMR mixer	Typical capacity: 65 – 75 blocks per hr 12 – 15 kg/block Bale size: 40×50×15 cm Rated power 15 kWe			X	Densified Total Mixed Ration (DTMR) block is made with straw, concentrates and mineral blends	
	Fuel extraction (ethanol)	Fermentation and distillation (with/without husks)	Bio refinery system	> 100 t/day of feed stoke > 30,000 L/day of ethanol (commercial systems)		X		1 t biomass mix yields about 300 L of ethanol and 150 kg of silica/sodium oxide	Same remarks as in paddy husks entry.
Sawdust	Value addition to the residue as fuel for process heat generation in industry	Densification/ briquette making	Screw type briquetting machine	Typical capacity range: 100 – 250 kg/hr Selected capacity: 200 kg/hr			X	Briquette density: 0.8–1.2 t/m^3 Energy requirement: 150 – 225 kWh/t	The increase in density and change in physical form diversify the applications and increase fuel value. Although the technology is not at the low-end, local manufacture/fabrication is possible.

Residue	Application	Process/ Technology	Equipment	Capacity Range	Selection			Remarks	Additional Comments
Sawdust		Densification/ pelletizing	Pelletizing machine (roller and die press)	Typical capacity range: 1 – 30 t/hr Selected Capacity: 1 t/hr			X	Pellet size: 5 – 15 mm diameter, 30 mm length Energy requirement: 50 – 200 kWh/t Supply of waste is less reliable; market response is uncertain	Same as entry above.
	Domestic cooking	Direct combustion for cooking	Improved saw dust cook stove with multi-fuel capability	Heat generated: 3.5 kWth Fuel input = 1.0 kg/load			X	Dissemination will enhance options for managing agro-waste	At present, fuel wood for cooking is abundant in the area. This is a small scale application. Local as well as regional level ESTs are available.

Residue	Application	Process/ Technology	Equipment	Capacity Range	Selection			Remarks	Additional Comments
Sawdsust	Manufacture of particle boards	Series of processes including size reduction, screening, drum chipping, resin blending, drying, mat formation, pressing, cooling, sanding, etc.	Multiple types of equipment including chipper and press	Typical capacity range: > 40 m^3/day output			X	Density of particle board– 0.45 t/m^3	Relatively complex process, but the value addition is quite high.
	Manufacture of medium density fiber board (MDF)	Series of processes including size reduction, cooking, grinding, resin blending, drying, mat formation, hot pressing and curing, sizing and	Multiple types of equipment including chipper, boiler, grinder, blender and press	Typical capacity range: 120 to 1000 m^3/day output			X	Density of MDF – 0.75t/m^3.	Same as entry above.

Residue	Application	Process/ Technology	Equipment	Capacity Range	Selection			Remarks	Additional Comments
		sanding							
Market waste	Cooking and lighting	Anaerobic digestion/ biogas generation	Biogas digester–continuous type	Selected capacity: 500 kg/day of waste Tank volume 60 m^3			X	Biogas yield – 47 m^3/day, sufficient for cooking and lighting for 15 families Energy conversion efficiency: Digester – 13.5%	Existing application practiced at community/municipality level, and the technology is available locally. Local manufacture/fabrication is possible.
	Off-grid electricity generation	Anaerobic digestion/ four stroke spark ignition	Biogas digester and internal combustion engine	Selected capacity: 1 t/day of waste Plant capacity – 4 kWe		X		Biogas yield – 95 m^3/day; could generate about 100 kWh/day Energy conversion efficiency: Digester – 13.5% Engine – 20% Supply of waste is less reliable	This technology is becoming popular under rural electrification programs using fuel wood as the source, and could also be adapted for biogas. However, donor funding is required because of high initial costs. Although some parts can be manufactured locally, the technology needs to be imported.
	Fertilizer	Composting	Hand tools (for handling waste)	No specific capacity range Selected capacity:			X	Low level technology. Need proper	Highly relevant to the local community practicing agriculture. Can also be mixed

Residue	Application	Process/ Technology	Equipment	Capacity Range	Selection			Remarks	Additional Comments
				1 t/day of waste				operations.	with other waste types.
Banana rejects	Off-grid electricity generation	Biogas generation for off-grid electricity	Biogas digester and internal combustion engine	Selected capacity: 1 t/day of waste input Plant capacity – 4 kWe Biogas yield – 95 m^3/day			X	Could generate about 125 kWh/day. Energy conversion efficiency - Digester – 13.5%. Engine – 20%. Supply of waste is reliable.	The existing application is practiced at the community/municipality level, and the technology is available locally. Local manufacture/fabrication is possible.
	Grid electricity generation	Biogas generation for grid electricity (net metering)	Biogas digester and internal combustion engine	Selected capacity: 15 t/day of waste Plant capacity – 75 kWe Biogas yield–1500 m^3/day		X		Could generate about 2MWh/day; high potential for energy generation; company provides finance and project carries out technology transfer	High volumes of waste could be managed though this technology. The increasing interest in large-scale waste to energy (electricity) projects could make this a very viable solution. While development of a pilot plant may not be viable under the present project due to its scale, industry may implement it using its own resources if the appropriate technology is introduced.
	Value addition to the residue	Baling/ densification	Straw baler	Wide range; Selected capacity:		X		While this waste has potential as	Same remarks as in the paddy straw entry. Small scale

Residue	Application	Process/ Technology	Equipment	Capacity Range	Selection			Remarks	Additional Comments
	as fuel for process heat generation in industry			Field capacity - 0.4 ha/h Rate – 200 bales/hr				a resource, further research and development of technologies for collection, transportation, processing and conversion are needed	operation may not be viable.
Banana Rejects		Densification/ briquette making	Screw type briquetting machine	Typical capacity range: 100 – 250 kg/hr Selected capacity: 200 kg/hr		X			Same remarks as in the paddy husks entry.
		Densification/ pelletizing	Pelletizing machine (roller and die press)	Typical capacity range: 1 – 30 t/hr Selected capacity: 1 t/hr		X			-
Wild guinea grass	Value addition as animal fodder	Sizing/mixing and densification	Densified TMR block making plant	Typical capacity: Refer to entry for paddy straw			X		Currently, this technology is employed at a large-scale industrial level. It is also possible to adapt it to a small scale.
	Fuel extraction (ethanol)	Fermentation and distillation	Bio-refinery system	> 100 t/day of feed stoke > 30,000 L/day of ethanol (commercial systems for other biomass residues)	X				-

Annex 2.3: Screening of Technologies*

*Refer also to Figure 2.4 in Part 2 to for the complete wording of the screening criteria. N/A stands for not applicable.

The favorable outcome for a particular criterion has been listed in the second row of the table. In this case, a particular technology is said to pass the screening provided it scores a favorable outcome for at least 7 of the listed screening criteria.

Residue	Application	Technology	Equipment	Are there policy restrictions?	Is there alignment with MEAs and National Plans?	Are there positive/zero impacts on existing users of WAB?	Are project objectives achieved?	Is the technology economically viable?	Does the technology exhibit good environmental performance?	Is there a positive social impact (employment/income generation)?	Is the technology proven?	Outcome
			Favorable outcome for the criterion	***No***	***Yes***	***Yes***	***Yes***	***Yes***	***Yes***	***Yes***	***Yes***	--
Paddy husks[1]	Value addition to residue as a fuel	Briquette making	Briquetting machine	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Selected
		Charcoal making	Charcoal kiln	No	N/A	Yes	Yes	Yes	No	Yes	Yes	Not selected
	Domestic cooking	Direct combustion	Paddy husk cook stove	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Selected

[1] Paddy husks generated in Buttala D.S. Division are used by brick kilns in the area. Therefore the paddy husks considered in the above matrix are for Monaragala D.S. Division only.

Residue	Application	Technology	Equipment	Are there policy restrictions?	Is there alignment with MEAs and National Plans?	Are there positive/zero impacts on existing users of WAB?	Are project objectives achieved?	Is the technology economically viable?	Does the technology exhibit good environmental performance?	Is there a positive social impact (employment/income generation)?	Is the technology proven?	Outcome
		Gasification	Paddy husk gas stove	No	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Selected
		Carbonization	Charcoal making cook stove	No	N/A	Yes	Yes	Yes	No	Yes	No	Not selected
	Process heat for lime drying/smoking	Direct combustion/ direct heating	Paddy husk stove cum cabinet dryer	No	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Selected
	Process heat for vegetable/fruit drying	Direct combustion/ indirect heating	Paddy husk stove cum tray dryer	No	N/A	Yes	Yes	Yes	Yes	Yes	No	Not selected
	Process heat for brick making	Direct combustion/ direct heating	Improved brick kiln	No	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Selected
	Process heat for tobacco curing	Direct combustion/ indirect	Tobacco barn	No	N/A	Yes	Yes	Yes	Yes	Yes	No	Not selected

Residue	Application	Technology	Equipment	Are there policy restrictions?	Is there alignment with MEAs and National Plans?	Are there positive/zero impacts on existing users of WAB?	Are project objectives achieved?	Is the technology economically viable?	Does the technology exhibit good environmental performance?	Is there a positive social impact (employment/income generation)?	Is the technology proven?	Outcome
		heating										
	Grid electricity generation	Direct combustion/ steam cycle	Boiler and steam turbine	No	N/A	Yes	Yes	Yes	Yes	Yes	No	Not selected
	Off-grid electricity generation	Gasification/ four stroke spark ignition	Gasifier cum internal combustion engine	No	N/A	No	Yes	Yes	Yes	Yes	Yes	Not selected
	Conversion to cement extender	Carbonization	Basket burner	No	Yes	Yes	No	Yes	Yes	Yes	No	Not selected
	Fuel extraction (ethanol)	Fermentation and distillation (with or without husks)	Bio-refinery system	No	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Selected
Paddy straw	Value addition as a raw material	Baling/ densification	Straw baler	Yes	N/A	Yes	Yes	No	Yes	Yes	Yes	Not selected

Residue	Application	Technology	Equipment	Are there policy restrictions?	Is there alignment with MEAs and National Plans?	Are there positive/zero impacts on existing users of WAB?	Are project objectives achieved?	Is the technology economically viable?	Does the technology exhibit good environmental performance?	Is there a positive social impact (employment/income generation)?	Is the technology proven?	Outcome
	Manufacture of straw boards	Series of conversion processes	Multiple types of equipment including press or extruder	Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Not selected
	Paper making	Paper pulping	Hand tools and utensils	Yes	N/A	Yes	Yes	Yes	No	Yes	Yes	Not selected
	Cooking/lighting	Anaerobic digestion/ biogas generation	Biogas digester–continuous type	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Not selected
	Off-grid electricity generation	Anaerobic digestion/ four stroke spark ignition	Biogas digester and internal combustion engine	Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Not selected
	Fertilizer	Composting	Hand tools (for handling waste)	No	Yes	Yes	No	No	Yes	Yes	No	Not selected

Residue	Application	Technology	Equipment	Are there policy restrictions?	Is there alignment with MEAs and National Plans?	Are there positive/zero impacts on existing users of WAB?	Are project objectives achieved?	Is the technology economically viable?	Does the technology exhibit good environmental performance?	Is there a positive social impact (employment/income generation)?	Is the technology proven?	Outcome
	Value addition as animal fodder (Total Mixed Ration - TMR)	Sizing/mixing and densification	Densified TMR block making plant	Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Not selected
	Fuel extraction (ethanol)	Fermentation and distillation (with/without husk)	Bio refinery system	Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Not selected
Sawdust	Value addition to residue as a fuel	Briquette making	Briquetting machine	No	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Selected
		Pelletizing	Pelletizing machine	No	N/A	Yes	Yes	No	Yes	Yes	Yes	Not selected
	Domestic cooking	Direct combustion for cooking	Improved saw dust cook stove	No	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Selected
	Manufacture of Particle boards	Series of conversion	Multiple types of equipment including	No	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Selected

Residue	Application	Technology	Equipment	Are there policy restrictions?	Is there alignment with MEAs and National Plans?	Are there positive/zero impacts on existing users of WAB?	Are project objectives achieved?	Is the technology economically viable?	Does the technology exhibit good environmental performance?	Is there a positive social impact (employment/income generation)?	Is the technology proven?	Outcome
		processes	chipper/press									
	Manufacture of medium density fibre board (MDF)	Series of conversion processes	Multiple types of equipment including chipper, boiler, press, etc.	No	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Selected
Market waste	Cooking and lighting	Anaerobic digestion/ biogas generation	Biogas digester– continuous type	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Not selected
	Off-grid electricity generation	Anaerobic digestion/ four stroke spark ignition	Biogas digester and internal combustion engine	No	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Selected
	Fertilizer	Composting	Hand tools (for handling waste)	No	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Selected

Residue	Application	Technology	Equipment	Are there policy restrictions?	Is there alignment with MEAs and National Plans?	Are there positive/zero impacts on existing users of WAB?	Are project objectives achieved?	Is the technology economically viable?	Does the technology exhibit good environmental performance?	Is there a positive social impact (employment/income generation)?	Is the technology proven?	Outcome
Banana rejects	Off-grid electricity generation											
	Grid electricity generation	Biogas generation for grid electricity (net metering)	Biogas digester and internal combustion engine	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Not selected
Wild guinea grass	Value addition to the residue as a fuel for process heat generation in industry	Baling/ densification	Straw baler	No	Yes	Yes	No	No	Yes	No	No	Not selected
		Densification/ briquette making	Screw type briquetting machine	No	Yes	Yes	No	No	Yes	No	No	Not selected
		Densification/ pelletizing	Pelletizing machine (roller and die press)	No	Yes	Yes	No	No	Yes	No	No	Not selected

Residue	Application	Technology	Equipment	Are there policy restrictions?	Is there alignment with MEAs and National Plans?	Are there positive/zero impacts on existing users of WAB?	Are project objectives achieved?	Is the technology economically viable?	Does the technology exhibit good environmental performance?	Is there a positive social impact (employment/income generation)?	Is the technology proven?	Outcome
	Value addition as animal fodder	Sizing/mixing and densification	Densified TMR block making plant	No [2]	N/A	Yes	Yes	No	Yes	Yes	Yes	Not selected
	Fuel extraction (ethanol)	Fermentation and distillation	Bio-refinery system	No	Yes	Yes	No	No	Yes	Yes	No	Not selected

[2] The removal of this grass from certain areas may be restricted.

Annex 2.4: Results of Scoping Analysis

Table 1: Conducting the Scoping Analysis for Technologies A – N Using the Weighted Sum Matrix*

*Note: Refer to Table 2.3 of Part 2 for the technologies to be assessed (A to N) and Table 2.4 of Part 2 for the criteria (TC_n, FC_n, SC_n and EC_n).

Criteria	Weight	Max. Wt. Score	Technology																											
			A		B		C		D		E		F		G		H		I		J		K		L		M		N	
			Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score
Technical Criteria																														
TC1	8	24	2	16	2	16	2	16	2	16	2	16	2	16	2	16	2	16	2	16	2	16	1	8	1	8	2	16	3	24
TC2	10	30	2	20	3	30	3	30	3	30	3	30	3	30	1	10	1	10	2	20	1	10	0	0	2	20	3	30	3	30
TC3	9	27	3	27	2	18	3	27	2	18	2	18	2	18	2	18	3	27	2	18	2	18	2	18	3	27	2	18	3	27
TC4	9	27	1	9	3	27	1	9	2	18	2	18	1	9	1	9	2	18	3	27	1	9	2	18	3	27	3	27	3	27
TC5	8	24	1	8	3	24	1	8	3	24	3	24	2	16	1	8	2	16	3	24	1	8	2	16	3	24	3	24	3	24
TC6	6	18	2	12	3	18	3	18	3	18	3	18	3	18	3	18	2	12	3	18	2	12	1	6	3	18	3	18	3	18
TC7	6	18	1	6	3	18	2	12	3	18	3	18	2	12	1	6	2	12	3	18	2	12	1	6	3	18	3	18	3	18
TC8	7	21	0	0	2	14	1	7	2	14	3	21	3	21	1	7	2	14	3	21	1	7	1	7	2	14	2	14	2	14
TC9	9	27	2	18	1	9	2	18	3	27	3	27	2	18	1	9	2	18	2	18	1	9	1	9	2	18	2	18	3	27
TC10	5	15	1	5	1	5	0	0	2	10	2	10	2	10	1	5	1	5	1	5	2	10	2	10	3	15	3	15	3	15
TC11	8	24	2	16	3	24	2	16	3	24	3	24	2	16	1	8	2	16	2	16	2	16	1	8	3	24	3	24	1	8

Criteria	Weight	Max. Wt. Score	Technology																											
			A		B		C		D		E		F		G		H		I		J		K		L		M		N	
			Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score
Total Score - TC		**255**		**137**		**203**		**161**		**217**		**224**		**184**		**114**		**164**		**201**		**127**		**106**		**213**		**222**		**232**
Financial Criteria																														
FC1	9	27	1	9	3	27	2	18	2	18	2	18	2	18	2	18	1	9	3	27	2	18	1	9	2	18	3	27	2	18
FC2	9	27	1	9	3	27	2	18	2	18	2	18	2	18	2	18	1	9	3	27	2	18	1	9	2	18	2	18	3	27
FC3	5	15	1	5	3	15	1	5	2	10	2	10	2	10	2	10	1	5	3	15	2	10	1	5	1	5	2	10	3	15
FC4	7	21	3	21	1	7	2	14	2	14	2	14	2	14	2	14	3	21	1	7	3	21	3	21	3	21	2	14	3	21
FC5	6	18	1	6	0	0	1	6	2	12	2	12	2	12	1	6	1	6	0	0	1	6	0	0	1	6	1	6	2	12
FC6	6	18	1	6	0	0	1	6	2	12	2	12	1	6	1	6	1	6	0	0	1	6	0	0	2	12	2	12	1	6
FC7	5	15	0	0	0	0	0	0	0	0	0	0	0	0	1	5	0	0	0	0	0	0	0	0	2	10	0	0	2	10
Total Score - FC		**141**		**56**		**76**		**67**		**84**		**84**		**78**		**77**		**56**		**76**		**79**		**44**		**90**		**87**		**109**
Social Criteria																														
SC1	8	24	2	16	0	0	1	8	3	24	3	24	1	8	1	8	2	16	0	0	2	16	2	16	1	8	2	16	1	8
SC2	7	21	1	7	1	7	1	7	2	14	2	14	2	14	1	7	2	14	1	7	1	7	2	14	2	14	2	14	3	21
SC3	6	18	2	12	1	6	2	12	2	12	2	12	2	12	1	6	2	12	1	6	2	12	1	6	3	18	3	18	1	6
SC4	6	18	1	6	1	6	2	12	2	12	2	12	2	12	1	6	1	6	1	6	1	6	1	6	2	12	1	6	3	18
SC5	6	18	1	6	0	0	1	6	2	12	2	12	1	6	2	12	1	6	0	0	2	12	2	12	2	12	2	12	2	12

Criteria	Weight	Max. Wt. Score	Technology																											
			A		B		C		D		E		F		G		H		I		J		K		L		M		N	
			Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score	Score	Wt Score
Total Score - SC		**99**	**7**	**47**	**3**	**19**	**7**	**45**	**11**	**74**	**11**	**74**	**8**	**52**	**6**	**39**	**8**	**54**	**3**	**19**	**8**	**53**	**8**	**54**	**10**	**64**	**10**	**66**	**10**	**65**
Environmental Criteria																														
EC1	5	15	1	5	3	15	2	10	2	10	2	10	2	10	2	10	1	5	3	15	1	5	1	5	2	10	3	15	2	10
EC2	9	27	1	9	1	9	2	18	2	18	2	18	1	9	1	9	1	9	1	9	1	9	1	9	2	18	1	9	2	18
EC3	7	21	2	14	2	14	3	21	3	21	3	21	3	21	2	14	2	14	2	14	2	14	2	14	2	14	1	7	3	21
EC4	4	12	2	8	3	12	3	12	2	8	2	8	2	8	2	8	2	8	3	12	2	8	1	4	2	8	1	4	2	8
EC5	8	24	3	24	1	8	1	8	3	24	3	24	2	16	2	16	3	24	1	8	2	16	3	24	3	24	3	24	3	24
EC6	7	21	2	14	2	14	3	21	2	14	2	14	2	14	2	14	2	14	2	14	2	14	1	7	3	21	1	7	3	21
Total Score - EC		**120**	**11**	**74**	**12**	**72**	**14**	**90**	**14**	**95**	**14**	**95**	**12**	**78**	**11**	**71**	**11**	**74**	**12**	**72**	**10**	**66**	**9**	**63**	**14**	**95**	**10**	**66**	**15**	**102**

Sample Calculation for Row #1 of Table 1

Technology = A

Criteria = TC1

Weight assigned = 8

Score assigned = 2

This gives a weighted score (calculated) as follows:
= 8 * 2
= 16

The weighted scores for TC2 to TC11 are calculated in the same manner.

To calculate the Total Score – TC for technology A, add all the weighted score values for that technology from TC1 to TC11.

So, Total Score – TC for technology A
= 16+20+27+9+8+12+6+0+18+5+16
= 137

Explanation

Altogether there are 29 criteria used in the above analysis (11 under technical, 7 under financial, 5 under social and 6 under environment).

Important

Typically in the scoping analysis, only a few important criteria are selected and the competing technologies are ranked against these criteria and top scorer gets the first rank. Based on the outcome of scoping, top 3 to 5 technologies are selected for detailed assessment to assign the final ranking. However, in the present analysis, a more detailed analysis is being carried out at the scoping level. This is because it is felt that most of the technologies selected are important and difficult to differentiate through a simple assessment.

It is important to highlight here that the weight assigned to each criteria is a common value for all stakeholders, and therefore different sections of the spectrum of stakeholder opinions are captured in the data. However, additional calculations for each criterion may be necessary in order to arrive at a consolidated ranking that takes into account all the aspects of all criteria at the scoping stage. These calculations will generate what are referred to as "priority values."

References

To find out more about how to calculate priority values, users of this manual may refer to:

- *A tutorial on AHP at* http://people.revoledu.com/kardi/tutorial/AHP/Priority%20Vector.htm
- *Theory and Applications of the Analytic Network Process: Decision Making with Benefits, Opportunities, Costs, and Risks. Thomas L. Saaty, 352 pp., RWS Publications, 2005. ISBN 1-888603-06-2*
- *The Encyclicon: A Dictionary of Applications of Decision Making with Dependence and Feedback Based on the Analytic Network Process. Thomas L. Saaty and Müjgan Özdemir, paperback, 292 pp., RWS*

It is necessary to assign these priority values for each category of criteria (i.e. technical, financial, social and environmental) and estimate the overall score as the weighted average of the four sub-total scores. This is the methodology adopted in this study as the base case[1].

However, in order to establish priority values for these four different sets of criteria, a qualitative judgement must essentially be converted into a quantitative value, which is a very challenging task. A brief overview of the methodology used in this aspect of the analysis is presented below.

Establishing Priority Values Using AHP

Many methodologies are available for the selection and construction of indices. These include Guttman scale analysis, scale discrimination technique, rating scales, semantic differential, multidimensional scaling and paired comparisons, to name a few. Among these approaches, AHP has been widely used in analyzing energy planning, planning the distribution of resources,

[11] A sensitivity analysis was also carried out in order to analyze the effect of this approach in terms of the final scores and rankings of technology options (see Annex 2.5).

resolving conflicts and selecting projects, among other undertakings, and useful results have been generated. Further, this method has been used for similar types of studies in which technologies are ranked and therefore selected for the present study.

As explained briefly in Annex 1.2, AHP is a method of breaking down a complex, unstructured situation into its component parts; arranging these parts, or variables, into a hierarchic order; and assigning numerical values to subjective judgements to determine which variables have the highest priority and should be acted upon to influence the outcome of the situation. AHP involves different steps: (a) stating the problem/objective, (b) identifying the criteria that influence the behavior of the problem, and (c) structuring a hierarchy of the criteria and alternatives. In AHP, the word 'alternatives' refers to the different solutions or choices available, for example the technologies selected in this study. For the purpose of establishing priority values, AHP uses pair-wise comparisons - that is, to compare the elements in pairs against a given criterion. The pair-wise comparisons for the different criteria and alternatives are obtained through feedback from different stakeholders (referred to as 'actors' in Figure 1 below).

The priority values assigned by seven different actors, based on their responses, are presented in Figure 1. An equally-weighted average of all the actors' responses is then calculated to produce overall priority values (mean values) for each of the four criteria. The final priority values are given in Table 2.

Figure 1: Priority Values of the Four Criteria

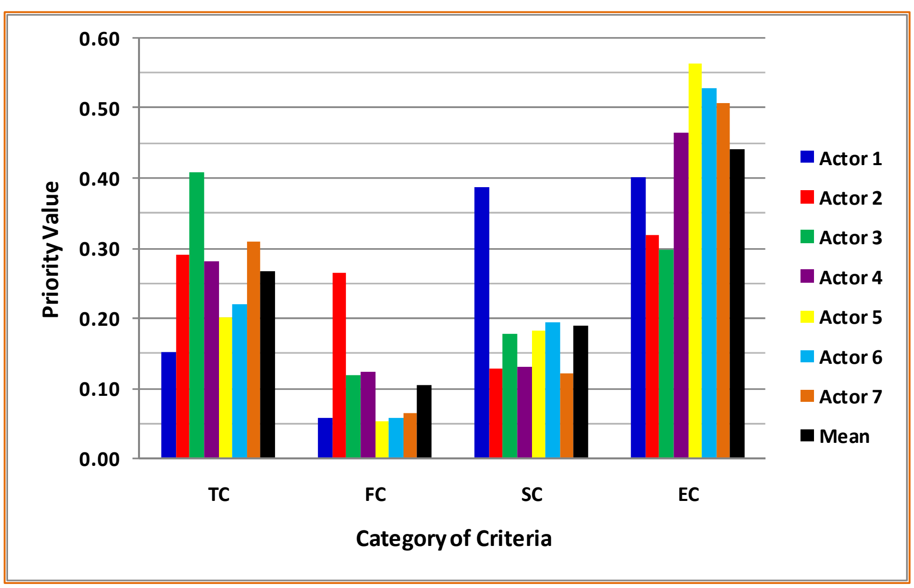


Table 2: Mean Priority Values of Criteria Derived through Pair-wise Comparisons

Category of Criteria	Priority Value
Technical	0.266
Financial	0.105
Social	0.188
Environmental	0.441

In this example, the final overall score was calculated as the normalized weighted average of the four scores. The final overall results of the analysis are presented in Table 3. A sample calculation for the first row is provided at the end of this Annex.

Table 3: Ranks of Technological Options Based on Pair-wise Comparison of Criteria

Techno-logy	Criterion (Priority Values)								Weighted Average Based on Pair-wise Comparison	
	Technical (0.266)		Financial (0.105)		Social (0.188)		Environmental (0.441)			
	Total[1]	%	Total[2]	%	Total[3]	%	Total[4]	%	Score%	Rank
A	137	53.7	56	39.7	47	47.5	74	61.7	54.63	11
B	203	79.6	76	53.9	19	19.2	72	60.0	56.93	9
C	161	63.1	67	47.5	45	45.5	90	75.0	63.44	7
D	217	85.1	84	59.6	74	74.7	95	79.2	77.97	3
E	224	87.8	84	59.6	74	74.7	95	79.2	78.71	2
F	184	72.2	78	55.3	52	52.5	78	65.0	63.59	6
G	114	44.7	77	54.6	39	39.4	71	59.2	51.05	13
H	164	64.3	56	39.7	54	54.5	74	61.7	58.83	8
I	201	78.8	76	53.9	19	19.2	72	60.0	56.72	10
J	127	49.8	79	56.0	53	53.5	66	55.0	53.42	12
K	106	41.6	44	31.2	54	54.5	63	52.5	47.81	14
L	213	83.5	90	63.8	64	64.6	95	79.2	76.05	4
M	222	87.1	87	61.7	66	66.7	66	55.0	66.54	5
N	232	91.0	109	77.3	65	65.7	102	85.0	82.17	1

1: Values obtained from Total Score – TC values for the respective technology from Table 1 of this Annex.

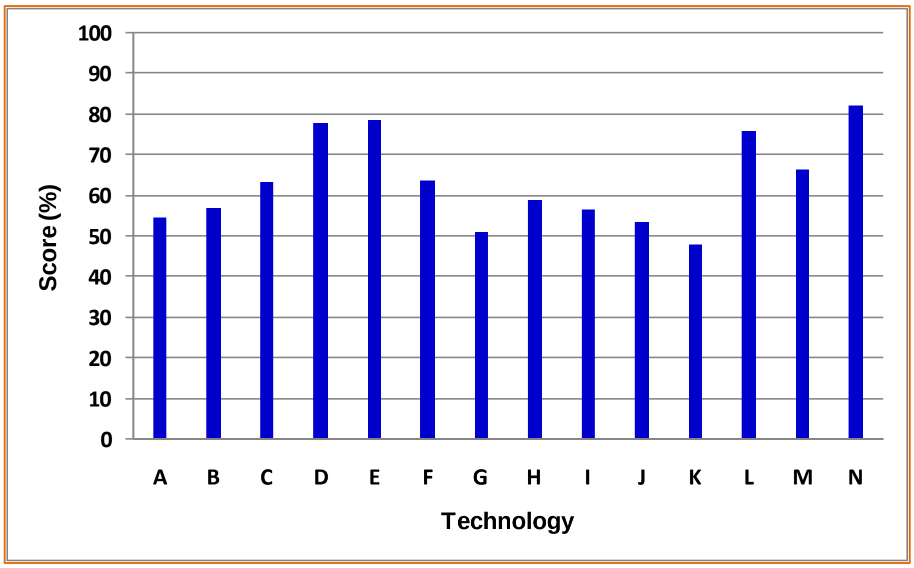
2: Values obtained from Total Score – FC values for the respective technology from Table 1 of this Annex.

3: Values obtained from Total Score – SC values for the respective technology from Table 1 of this Annex.

4: Values obtained from Total Score – EC values for the respective technology from Table 1 of this Annex.

The technologies' overall scores are also presented graphically in Figure 2.

Figure 2: Overall Percentage Scores of Different Technology Options



Sample Calculation for Row #1 of Table 3

Technology = A

Total Score - TC = 137

% = Total Score – TC / maximum weighted score for TC from Table 1 of this Annex

= 137 / 255 X 100 = 53.7

This gives a weighted score (calculated) as follows:
= 8 X 2

= 16

Similarly, for this technology, calculate percentages for FC, SC and EC.

To calculate the weighted average based on pair-wise comparison for a technology:

(a) Multiply % - TC with the priority value for the technical component (i.e. 0.266)

(b) Multiply % - FC with the priority value for the financial component (i.e. 0.105)

(c) Multiply % - SC with the priority value for the social component (i.e. 0.188)

(d) Multiply % - EC with the priority value for the environmental component (i.e. 0.441)

(e) Then, add the answers of (a) to (d) above to get the score in terms of a percentage for that technology

In the case of technology A, the weighted average based on pair-wise comparison is:

= 53.7*0.266 + 39.7*0.105 + 47.5*0.188 + 617.*0.441

= 54.63

Once all the values for weighted averages based on pair-wise comparison have been calculated, stakeholders may use the final column of Table 3 to arrive at the rankings for the technologies at the scoping stage. In this case, technology N scores the highest value and hence earns the first rank.

Annex 2.5: Detailed Assessment of Technologies (Including Sensitivity Analysis and Star Diagrams)

With the technologies selected through the Tier 1 assessment having undergone a detailed evaluation against 29 criteria in the scoping assessment[1], this level of assessment includes a sensitivity analysis, which will be used to investigate possible variations in ranking. Firstly, an analysis was conducted to determine the effect of priorities given in Table 1 for the four categories of criteria. Each category was assigned an equal priority value of 0.25.

Table 1: Rankings of Technological Options Based on Equal Weights for Criteria

Technology	Criterion (Priority Values)								Average Based on Equal Weights	
	Technical (0.25)		Financial (0.25)		Social (0.25)		Environmental (0.25)			
	Total	%	Total	%	Total	%	Total	%	Score %	Rank
A	137	53.7	56	39.7	47	47.5	74	61.7	50.65	12
B	203	79.6	76	53.9	19	19.2	72	60.0	53.18	10
C	161	63.1	67	47.5	45	45.5	90	75.0	57.78	7
D	217	85.1	84	59.6	74	74.7	95	79.2	74.65	3
E	224	87.8	84	59.6	74	74.7	95	79.2	75.33	2
F	184	72.2	78	55.3	52	52.5	78	65.0	61.25	6

[1] i.e. Eleven technical criteria, 7 financial criteria, 5 social criteria and 6 economic criteria

Technology	Criterion (Priority Values)								Average Based on Equal Weights	
	Technical (0.25)		Financial (0.25)		Social (0.25)		Environmental (0.25)			
	Total	%	Total	%	Total	%	Total	%	Score %	Rank
G	114	44.7	77	54.6	39	39.4	71	59.2	49.47	13
H	164	64.3	56	39.7	54	54.5	74	61.7	55.06	8
I	201	78.8	76	53.9	19	19.2	72	60.0	52.98	11
J	127	49.8	79	56.0	53	53.5	66	55.0	53.59	9
K	106	41.6	44	31.2	54	54.5	63	52.5	44.95	14
L	213	83.5	90	63.8	64	64.6	95	79.2	72.79	4
M	222	87.1	87	61.7	66	66.7	66	55.0	67.61	5
N	232	91.0	109	77.3	65	65.7	102	85.0	79.74	1

A comparison with the original results shows that the rankings of ten technologies, including the highest-ranking eight, remain the same. In fact, the change is primarily due to the rise in ranking of J from 12th to 9th.

When discussing the assignment of priority values, this manual explored the effect on priority values arising from pair-wise comparison (refer to Annex 2.4) vis-à-vis simultaneous comparison (where priorities are assigned simultaneously with detailed discussions among the participants and after arriving at common consensus). The priority values obtained through simultaneous comparison are given in Table 2, while Table 3 provides calculations for the weighted average based on simultaneous comparison.

Table 2: Priority Values of Criteria Derived through Simultaneous Comparison

Category of Criteria	Priority Values
Technical	0.20
Financial	0.10
Social	0.35
Environment	0.35

Table 3: Ranks of Technological Options Based on Simultaneous Comparison of Criteria[2]

Technology	Criterion (Priority Values)								Weighted Average Based on Simultaneous Comparison	
	Technical (0.20)		Financial (0.10)		Social (0.35)		Environmental (0.35)			
	Total	%	Total	%	Total	%	Total	%	Score %	Rank
A	137	53.7	56	39.7	47	47.5	74	61.7	52.92	10
B	203	79.6	76	53.9	19	19.2	72	60.0	49.03	11
C	161	63.1	67	47.5	45	45.5	90	75.0	59.54	7
D	217	85.1	84	59.6	74	74.7	95	79.2	76.85	3
E	224	87.8	84	59.6	74	74.7	95	79.2	77.40	2
F	184	72.2	78	55.3	52	52.5	78	65.0	61.10	6
G	114	44.7	77	54.6	39	39.4	71	59.2	48.90	13
H	164	64.3	56	39.7	54	54.5	74	61.7	57.51	8
I	201	78.8	76	53.9	19	19.2	72	60.0	48.87	14
J	127	49.8	79	56.0	53	53.5	66	55.0	53.55	9
K	106	41.6	44	31.2	54	54.5	63	52.5	48.90	12
L	213	83.5	90	63.8	64	64.6	95	79.2	73.42	4
M	222	87.1	87	61.7	66	66.7	66	55.0	66.17	5
N	232	91.0	109	77.3	65	65.7	102	85.0	78.66	1

The above results show that there has been no change in the ranking of nine of the technologies (including the top eight). Finally, another scenario is considered in which total marks derived from scores under all 29 criteria, without grouping into the four categories, are taken to rank the technologies[3]. The resulting total marks and the resulting rankings are presented in Table 4.

[2] The mode of calculations for this Table is the same as that employed for Table 3 of Annex 2.4.
[3] Refer to the column "Wt Score" in Table 1 of Annex 2.4.

Table 4: Ranks of Technological Options Based on Total Scores of All Criteria

Technology	Sub-Total Score of Criterion				Total Score	Rank
	Technical	Financial	Social	Environmental		
A	137	56	47	74	314	12
B	203	76	19	72	370	7
C	161	67	45	90	363	9
D	217	84	74	95	470	3
E	224	84	74	95	477	2
F	184	78	52	78	392	6
G	114	77	39	71	301	13
H	164	56	54	74	348	10
I	201	76	19	72	368	8
J	127	79	53	66	325	11
K	106	44	54	63	267	14
L	213	90	64	95	462	4
M	222	87	66	66	441	5
N	232	109	65	102	508	1

In this case as well, the technologies having the highest ranks remain at the same standing. There is no change in the ranking of eight technologies (including the top six). Note that in this case, as there are 11 criteria considered under the category of technical criterion –TC (against that of 7 in FC, 5 in SC and 6 in EC), there is a considerably higher priority given to TC in this analysis.

The results of all the scenario analyses shown above (in which there are considerable variations in the priority values among different criteria) indicate the insensitivity of the top ranking technologies to the relative priority values of the criteria. Therefore, it can be concluded that the top ranking technologies basically have higher scores in all the categories. Hence it is easier to arrive at a robust decision when selecting the technology.

Star Diagram for Detailed Assessment of Criteria

As mentioned in Part 2, numerical results given in tabular form are usually not very effective when one needs to investigate more closely the reasons for relative ranking of different technologies or identify critical or important criteria needing further consideration. One effective method is to employ a graphical representation of the results. In this section, star diagrams depict the scores in each of the four categories of criteria for the first four top-ranking technologies. These technologies are, in the order of ranking:

- Biogas generation from banana rejects to generate off-grid electricity (N);
- Process heat generation from paddy husks for indirect drying of vegetables/fruit (E);
- Process heat generation from paddy husks for direct smoking of lime (D); and
- Biogas generation from market waste for cooking and lighting applications (L).

(a) *Star Diagram for Environmental Aspects*

Environmental criteria is the category with the highest priority value[4] and therefore it is considered first in this analysis. There were six criteria considered under environmental aspects and Figure 1 presents the scores of the four highest ranking technologies in a star diagram. In this case, the scores are not very different for the four technology options. Out of the maximum score of 120 attainable under this category, the technology that ranked the highest (Technology N) scores 102 marks (i.e. 85%) while the other three all have equal marks of 95 (i.e. 79%)[5]. Therefore, all four of these technology interventions will have a considerable positive impact on the environment.

[4] Refer to Table 2 of this Annex.
[5] See final row of Table 1 of Annex 2.4.

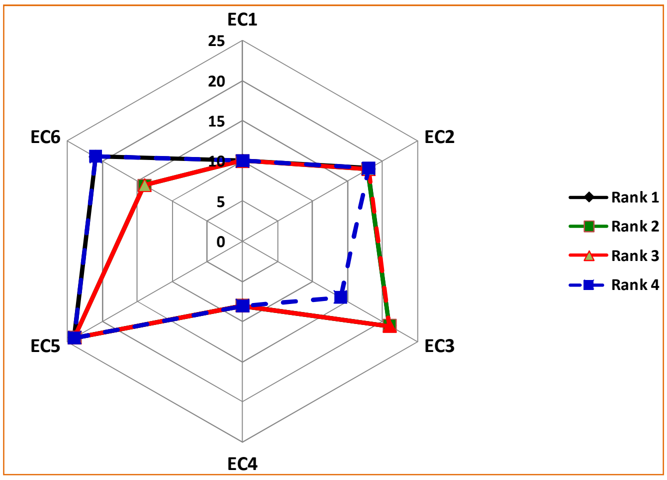


Figure 1: Star Diagram for Environment Aspects for the Four Highest-ranked Technologies

(b) *Star Diagram for Technical Aspects*

As for technical aspects, 11 criteria were included in the analysis and the results are presented in Figure 2.

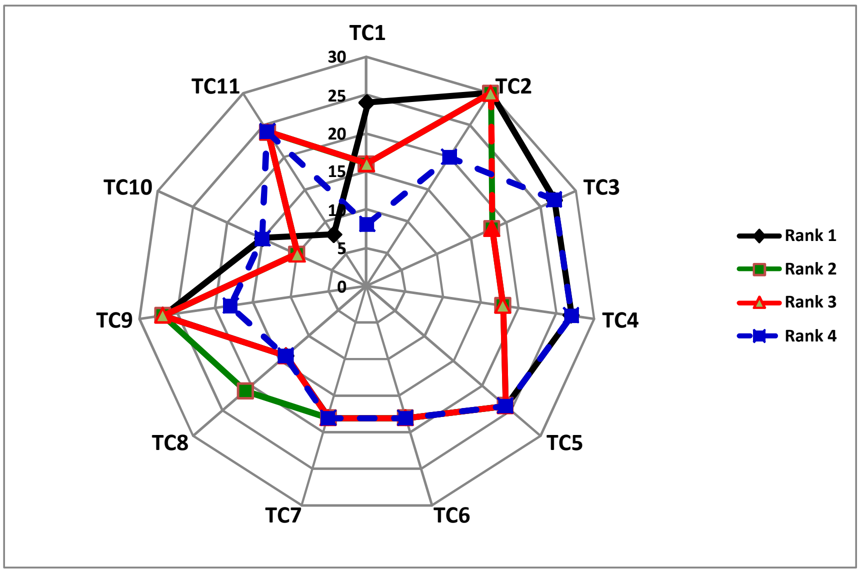


Figure 2: Star Diagram for Technical Aspects for the Four Highest-ranked Technologies

It can be seen that all four technologies have a lower score under criterion TC10, which is the ability to scale-up.

Yet, except for the technology that ranked the highest (Technology N), the other three technologies all have a high potential for replication (evident from the weighted score for TC11 – ability to replicate[6]). As Technology N is based on a very specific type of waste (banana rejects), the ability for future expansion as well as replication is low. However, this technology has obtained higher scores against all the other technical criteria, which contributed to its ranking of first.

As in the case of environmental aspects, all four technologies received high marks in technical aspects, indicating the high technical feasibility of the interventions. Specifically, out of the maximum score of 255, the scores of the first four technologies are 232 (i.e. 91%), 224 (88%), 217 (85%) and 213 (84%).

(c) *Star Diagram for Social Aspects*

The social aspects include five criteria as shown in Figure 3.

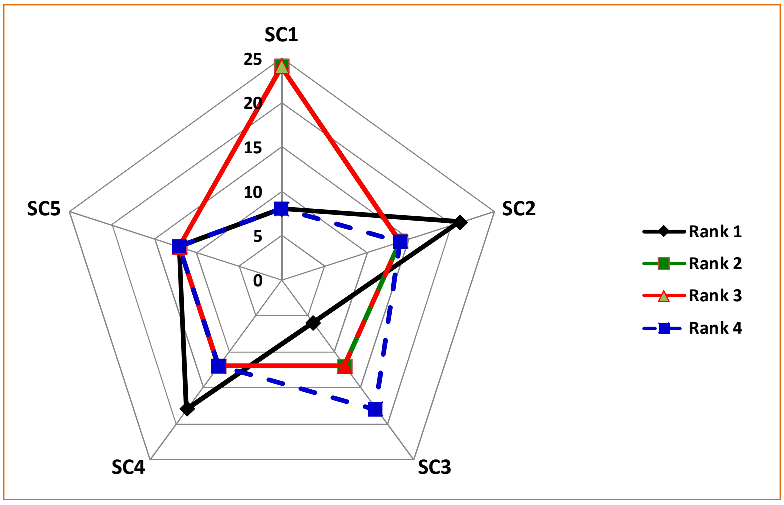


Figure 3: Star Diagram for Social Aspects for the Four Highest-ranked Technologies

In this case the technologies that ranked 2nd and 3rd (being similar applications) have an identical shape in the star diagram, with a total score of 74 out of 99 (i.e. 75%). The technologies that ranked 1st and 4th have very similar total scores of 65 and 64, respectively. In general, all these technologies have lower performances in terms of social aspects, compared to environmental and technical aspects. In particular, their scores for SC5, which indicates the improvement of local technical skills and the knowledge base, are quite low. Therefore, in order to improve the technologies'

[6] Refer to the weighted scores for these technologies under TC11 in Table 1 of Annex 2.4.

performance against social criteria, corrective interventions should be identified alongside the implementation of the ranked technologies[7].

(d) *Star Diagram for Financial Aspects*

This category has seven criteria. The scores of the four technologies are illustrated in Figure 4. Except for the first-ranked technology (N), all the technologies have poor performances against financial aspects, particularly when compared to environmental and technical aspects. Even the first-ranked technology has lower scores under criteria FC5, FC6 and FC7, which represent investor attractiveness, availability of co-financing and co-benefits, respectively[8].

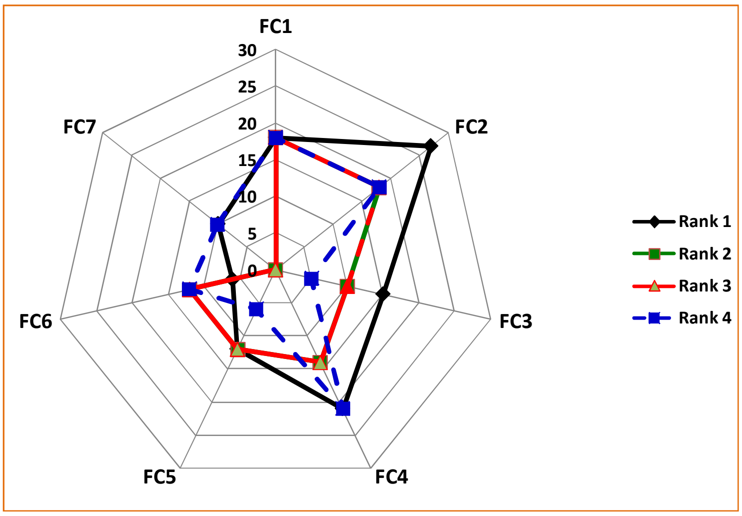


Figure 4: Star Diagram for Financial Aspects for the Four Highest-ranked Technologies

(e) *Composite Star Diagram for All Aspects*

It is also useful to represent the scores received by the four technologies against all 29 criteria in the same star diagram, as shown in Figure 5, so that an overall picture of the situation could be observed. The results primarily indicate weightiness towards technical aspects in terms of their performances.

[7] Refer to the row for "Total Score – SC" for these technologies in Table 1 of Annex 2.4.
[8] Refer to the row for "Total Score – FC" for these technologies in Table 1 of Annex 2.4.

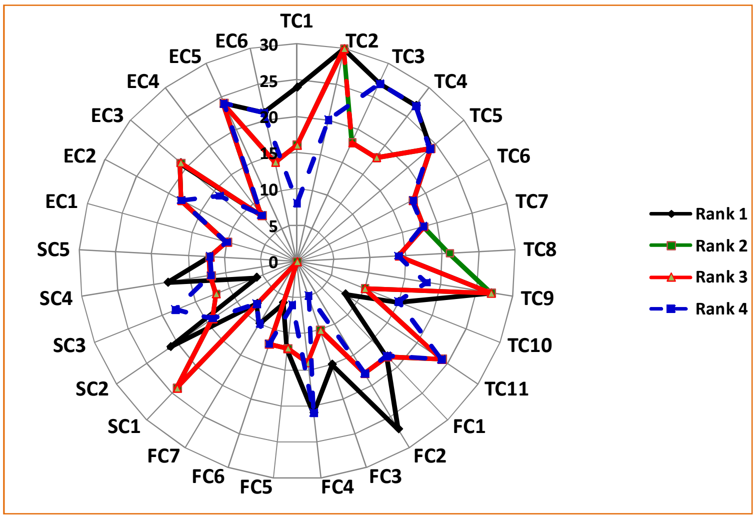


Figure 5: Star Diagram of All Criteria for the Four Highest-ranked Technologies

The weakest area is that of social aspects. Some environment aspects and financial aspects also show poor scores. In order to optimize the benefits of these technological interventions, more detailed analyses are required, firstly to identify the root causes of these weaknesses, and secondly to develop remedial measures to tackle them. Otherwise, the technological implementation may not be able to achieve the project's overall objectives and expected outcomes.

(f) *Star Diagram for Comparison of Two Distinct Technologies*

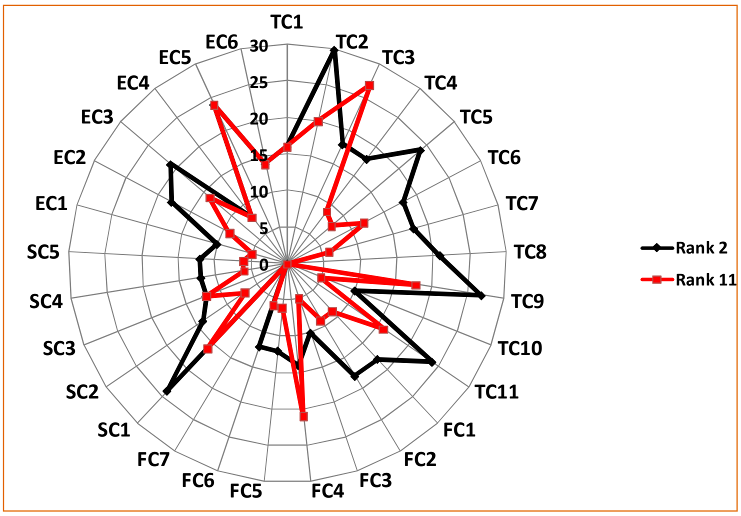


Figure 6: Star Diagram for Comparison of Two Technologies for Paddy Husk Management

Another important application of the star diagram representation of scores is to compare two different technologies in terms of their performances against all the criteria.

For example, consider two technology options for the management of paddy husks: direct combustion for process heat generation (Technology E, ranked 2nd) and densification through briquetting (Technology A, ranked 11th). The scores are presented in Figure 6 above. It is evident from the diagram that the direct combustion of paddy husks is better than briquetting against almost all criteria.

Meanwhile, performances of the same technology under different fuel categories could also be analyzed through a star diagram. For example, consider the briquetting technology option for the management of paddy husk and sawdust. The corresponding options are denoted by Technology A (ranked 11th) and Technology H (ranked 8th). Once again, the scores are presented in a star diagram, as shown in Figure 7.

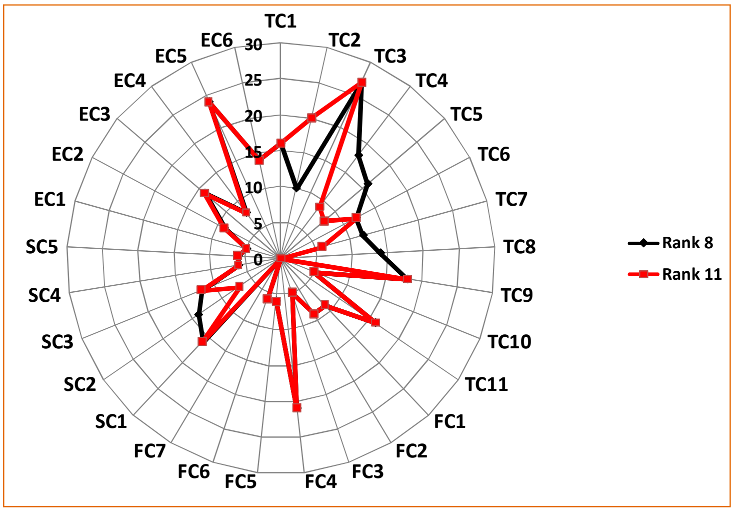


Figure 7: Star Diagram for Two Residues (Paddy Husks and Sawdust) Using the Same Technology (Briquetting)

The diagram indicates that sawdust briquetting is a better option than paddy husk briquetting as a waste management measure in the selected region, primarily due to its better technical performance. Financial and environmental performances are identical, though sawdust briquetting shows slightly better social benefits.

Annex 3.1: Literature on Technologies

The following technologies are reviewed in this Annex:

1. Manufacture of rice husk briquette fuel
2. Manufacture of honeycomb briquettes
3. Carbo-V® Process
4. Low cost rice husk gasifier stove
5. Biomethanation of vegetable market waste

Readers of this manual may also like to consider the following technologies (for which information is not provided in this Annex):

1. Sizing, mixing and densification (for use as animal fodder)
2. Off-grid electricity generation using a boiler with steam turbine
3. Strawboard manufacture using waste straw and extruding equipment

1. Manufacture of Rice Husk Briquette Fuel

Country	:	Bangladesh
Technology status	:	Commercial
Crop	:	Rice
Residue	:	Husk
Process	:	Densification
Equipment	:	Heated die screw press
Main product	:	Briquettes

Production Capacity

Rice husk as a raw material has a low bulk density (117.0 kg/m³), whereas after densification its bulk density rises to 825.4 kg/m³. This higher bulk density facilitates the handling, storing and transportability of this resource. The energy consumption of a briquette machine was found to be about 175 kWh (according to a 2006 field survey) to produce one metric ton (about 4200 kWh) of rice husk briquette fuel at the producer level. A previous field survey conducted in 2001 had found that the energy consumption for briquette production at the producer level was quite high at 250 kWh/t. These results show that system performances have been improving substantially at the production level. However, laboratory research shows average energy consumption to be only 116 kWh/t. This indicates room for investigating why energy consumption at the producer level is high and for determining proper corrective measures to be undertaken to overcome this problem. The total amount of rice husks available for densification is estimated at 1.0462 million metric tons. Total production of rice husk briquette fuel has been estimated at 0.942 million metric tons, which is equivalent to 0.493 million tons of coal. This in turn is equivalent to 2.34 times Bangaldesh's coal imports (0.211 million tons) in during 2002-2003.

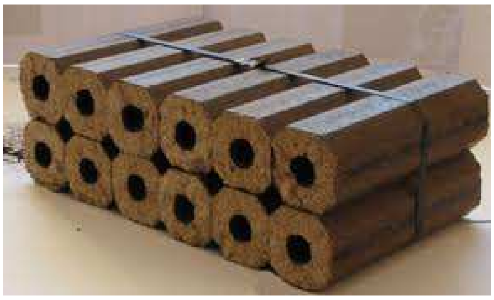


Figure 1: Briquettes Manufactured Using Rice Husks

Detailed Process Description

The employment generated due to the production and use of densified biofuel is calculated as 3.73 worker-days for producing each ton of densified biofuel.

The loose waste biomass materials are compressed into solid fuel by a densification process or briquetting process. The most widely used densification process in developing countries is a screw extrusion process, known as heated die screw press briquetting. The compaction ratio ranges from 2.5: 1 to 6:1 or even more. "During this process the biomass is forced into intimate and substantially sliding contact with the barrel walls. This also causes frictional effects due to shearing and working of the biomass. The combined effects of the friction caused at the barrel wall, the heat due to internal friction in the material and high rotational speed (~600 rpm) of the screw cause an increase in temperature in the closed system, which helps in heating the biomass. Then it is forced through the extrusion die, where the briquette with the required shape is formed."

Job Potential

The employment generated due to production and use of densified biofuel is calculated as 3.73 worker-days for producing each ton of densified biofuel. A 2002 study on the techno-economical aspects of biomass densification in India estimated that about 4.32

worker-days of employment could be generated for producing each ton of rice husk densified fuel, which is relatively similar to the results obtained in this study. Another study from 2003 also reported that biomass energy projects could create employment for rural people. The total employment generated in Bangladesh has been estimated as 14,048 employees for the whole year.

Job potential for the manufacture of rice husk briquette fuel	
Raw material collection (worker-days/ton)	0.75
Production process (worker-days/ton)	2.40
Transportation (worker-days/ton)	0.25
Trading (worker-days/ton)	0.33
Total employment (worker-days/ton)	3.73
Total potential production of densified fuel at the present time (million tons)	0.942
Total employees for a year (worker-years)	14,048

*One worker-day = 8 hours (Field survey results, 2005).

Environmental considerations

The data were analyzed using GEMIS (Global Emission Model for Integrated Systems) to compare CO_2 reductions of rice husk briquette fuel versus firewood in Mymensingh district town. It was found that reductions of about 1.81 kg CO_2 could be achieved for each kilogram of rice husk briquette fuel use over each kilogram of non-sustainable firewood use. Another study also reported that biomass energy projects could protect the environment.

Global emission CO_2 reductions with rice husk briquette fuel options over wood fuel in Mymensingh district, Bangladesh

Option	Annual demand X 10^6 (kg)	CO_2 equivalent X 10^6 kg/year	CO_2 emission (kg/unit)	CO_2 reductions vs. 100% fuel wood system 10^6 kg/year	Return from CO_2 X 10^6 BDT/year*	Return from CO_2 X 10^3 US$/year*
100% Rice husk briquette	9.039	0.954	0.105	16.42	4.33	65.65
100% Wood	14.244	17.37	1.219	0	0	0

*Numbers valid at the time this study was reported

Social Considerations

The time spent collecting the rice husk ranged from one sixth to one third of an hour. The amount of time savings for collecting rice husk briquettes versus firewood has been calculated as 24 worker-days/year, which could save almost one month of labor costs in a small restaurant (1 worker-day = 8 hours of work by a person or 1 laborer working in a day).

Advantages to Developing Countries

This technology could create employment in the rural areas.

Example of Real Life Applications

Commercial Use Rice Husk Densification Technology Bangladesh

References

"Converting Waste Agricultural Biomass into Resource" – Compendium of Technologies. Compiled by UNEP, Division of Technology, Industry and Economics International Environmental Technology Centre, Osaka/Shiga, Japan. © UNEP, 2009.

2. Manufacture of Honeycomb Briquettes

Country	:	**Nepal**
Technology status	:	Research
Crop	:	All types of biomass materials
Residue	:	Biomass waste
Process	:	Densification
Equipment	:	Charring drum
Main product	:	Honeycomb briquettes

Description of technology

The technique involves the following three stages:

(i) Partial carbonization of biomass residues,

(ii) Mixing of char with a binder, and

(iii) Briquette moulding and drying.

The procedure requires a charring drum in which the biomass is charred. The char obtained by the carbonization of biomass residues is crushed and mixed with a binder such as clay, and then briquetted in a briquette mould into cylindrical honeycomb briquettes. The details of the technique are presented below.

(i) Charring Drum:

The charring drum can be fabricated using an empty crude oil drum of 200-litre capacity. It is fitted with a conical shaped grate with fixed chimney and a top cover and water seal arrangements as shown in Figure 2.

(ii) Briquette Mould:

The briquette mould is made up of mild steel. It consists of three parts: the bottom plate with nineteen protruding rods each 13 mm in diameter, an outer cylindrical cover to fit the bottom plate, and a perforated plate to slide down along the rods into the cylinder, as shown in Figure 3.

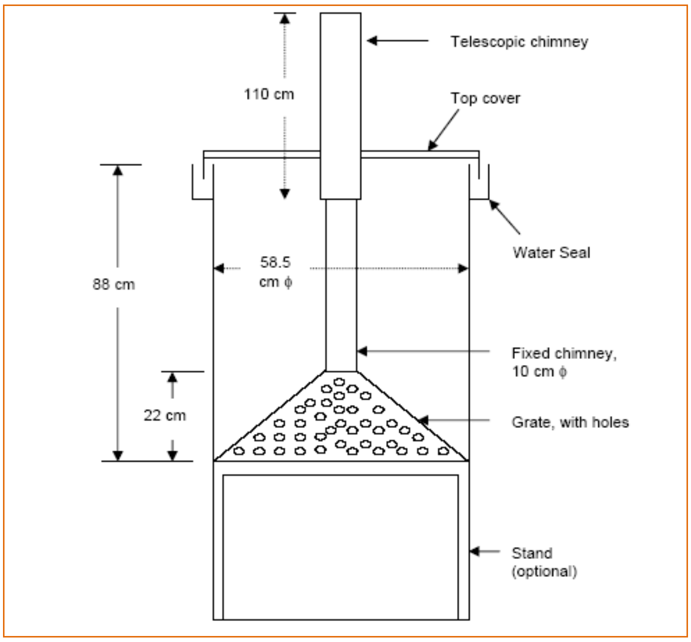
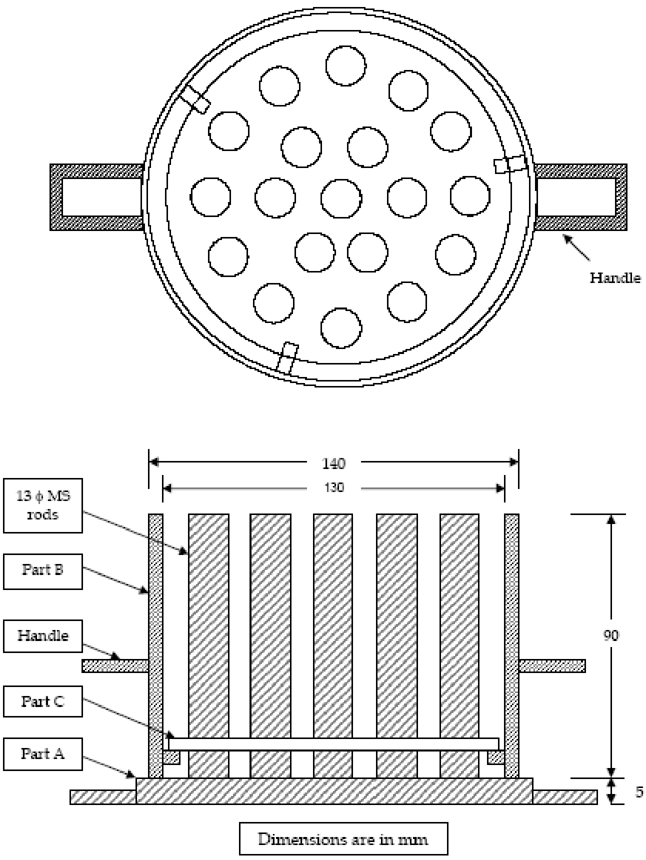


Figure 2: Charring Drum



[Note: A, B and C are separate parts of the mould]

Figure 7.5: Briquette mould

Figure 3: Briquette Mould

(iii) Charring Procedure:

All types of biomass materials can be used in a charring drum for char production. If the biomass material is too loose (e.g. pine needles, leaves etc.), then they can be made into small bundles of 7-10 cm diameter and up to 60 cm length. Depending upon the type of biomass, about 40-100 kg of biomass can be carbonized in the charring drum to get a yield of 25 - 35% char over a period of 2 - 3 hours. First, the conical grate with fixed chimney is placed inside the drum and the telescopic chimney is placed over the fixed chimney as shown in Figure 2. One to two kilograms of dried leaves or twigs are spread uniformly over the conical grate and ignited. Once ignition starts, biomass is added in small portions so that the material inside the drum does not burn fully or too fast and turn into ash.

Once the drum is full and the top layer is partially carbonized, the telescopic chimney is removed and the drum is covered with its cover. Water fills in the channel so that there is no leakage of air through the water sealing arrangement. At this stage, smoke will be released through the hole found at the center of the cover. When the smoke ceases to come out, the hole should be blocked with the stopper. There should be no leakage of air during cooling. The drum is allowed to cool for 2 to 3 hours before it is opened for removing the char and starting the next batch. The biomass residues should be sized properly and sun-dried to only 10-15% moisture (wet base). Depending upon the type of biomass and its moisture content, char yields of 25 - 35% can be obtained. During charring, a large amount of volatiles are released, so it is advisable to use these drums in open spaces. Further, these drums can be easily transported to areas of biomass availability. To get maximum production, the drum should be filled to the top and only then should the lid be placed and water seal made. To avoid rusting of the drum, it is coated with coal tar while it is hot. Due to heat, the applied tar will crack leaving behind an impervious coating of carbon on the surface, which prevents the drum from rusting.

(iv) Briquette-making:

The biomass char is crushed to fine powder form to get a particle size of not more than 0.8 mm. It is then mixed with bentonite clay or local potters' clay, which acts as a binder, at 20 - 30% by weight. Molasses or cooked starch may also be used as a binder. The amount of water that is sufficient can be judged by taking the mixture in hand and pressing it firmly to form a ball. If a ball cannot be formed, extra water may be added to the mixture. The mixture thus obtained is covered with wet gunny bags and left to mature for 24 hours.

For making beehive shaped briquettes from the char-clay mixture, different parts of the briquette mould set are placed one over the other in a sequence, as shown in For making beehive shaped briquette from the char-clay mixture, different parts of the briquette mould set are placed one over the other in sequence, as shown in Figure 2. First, the base plate, part 'A,' is placed on a levelled surface. The outer part 'B' is placed atop it. Finally, the plate with 19 holes, 'C,' is placed over the bottom plate 'A', in such a way that it rests on pin supports as shown in the figure.

The mould set is filled with the mixture, and after filling it to the brim, the top layer is levelled with a flat wooden piece. Now, holding the handles of both part A and part B, the mould is turned upside down onto firm ground. The mould is removed and the briquette is allowed to dry in the sun for 2 to 3 days. These beehive or honeycomb briquettes are superior to other briquette shapes as the honeycomb structure allows better contact between the fuel and air during combustion.

Examples of Real Life Applications

Research Centre for Applied Science and Technology (RECAST); Tribhuvan University, Kirtipur (Kathmandu, Nepal).

Supplier

RECAST,
Tribhuvan University, Kirtipur,
P.O. Box 1030 Kathmandu,
Nepal Tel: 977-1-330348 Fax: 977-1-331303.
E-mail: tu@recast.mof.com.np

Reference

"Converting Waste Agricultural Biomass into Resource" – Compendium of Technologies. Compiled by UNEP, Division of Technology, Industry and Economics International Environmental Technology Centre, Osaka/Shiga, Japan. © UNEP, 2009.

3. CARBO-V® PROCESS

Country	:	**Germany**
Technology status	:	Commercial
Crop	:	Solid biomass and other feed materials
Residue	:	Biomass waste
Process	:	Carbo-V® Process, using multi-stage gasification process
Equipment	:	Multi-stage gasifier
Main product	:	Syngas (a mixture of CO and H_2)

Technology

The globally patented Carbo-V® Process lies at the heart of CHOREN technology. Using this multi-stage gasification process, it is possible to convert solid biomass and other feed materials containing carbon into combustion or synthesis gas.

The Carbo-V® Process is a three-stage gasification process involving the following sub-processes: low temperature gasification, high temperature gasification and endothermic entrained bed gasification. During the first stage of the process, the biomass (with a water content of 15 – 20 %) is continually carbonized through partial oxidation (low temperature pyrolysis) with air or oxygen at temperatures between 400 and 500°C. That is, it is broken down into a gas containing tar (volatile parts) and solid carbon (char). During the second stage of the process, the gas containing tar is post-oxidized hypostoichiometrically using air and/or oxygen in a combustion chamber operating above the melting point of the fuel's ash to turn it into a hot gasification medium. During the third stage of the process, the char is ground down into pulverized fuel and blown into the hot gasification medium. The pulverized fuel and the gasification medium react endothermically in the gasification reactor and are converted into a raw synthesis gas. Once this has been treated in the appropriate manner, it can be used as a combustible gas for generating electricity, steam and heat or as a synthesis gas (i.e. syngas).

Environmental Considerations

The process also has an air pollution control system.

Syngas Production and Use

The gas that is produced is either directly converted into electricity and heat in gas engines or is re-synthesized using what is known as Fischer-Tropsch synthesis – a catalytic process for liquefying gas – to form a synthetic biofuel commercially known as SunDiesel.

Institutional and Regulatory Considerations or Requirements

Performed in strict accordance with the applicable ASME Boiler and Pressure Vessel Codes, the National Board Inspection Code, and any jurisdictional requirements that may apply. The company currently holds the following ASME and National Board Certificates of Authorization:

The gas that is produced is either directly converted into electricity and heat in gas engines or is re-synthesized using what is known as Fischer-Tropsch synthesis – a catalytic process for liquefying gas – to form a synthetic biofuel commercially known as SunDiesel.

- **A** for the assembly of power boilers which are designed and manufactured by others.
- **PP** for the design, alteration, manufacture, and erection of power piping.
- **R** for in-kind repair of boilers and pressure vessels.
- **S** for the design, alteration, manufacture and erection of power boilers.

Examples of Real Life Applications

Commercial use 2-Drum Top Supported Boiler
1650 International Court Suite
100 Norcross
GA 30093, USA

Supplier

CHOREN Industries GmbH
Frauensteiner Strasse 59 09599 Freiberg
Telephone: +49 (0)3731 26 62-0 Fax: +49 (0)3731 26 62-25
E-Mail: info@choren.com

Reference

"Converting Waste Agricultural Biomass into Resource" – Compendium of Technologies. Compiled by UNEP, Division of Technology, Industry and Economics International Environmental Technology Centre, Osaka/Shiga, Japan. © UNEP, 2009.

4. Low Cost Rice Husk Gasifier Stove

Country	:	**Philippines**
Technology status	:	Commercial
Crop	:	Rice
Residue	:	Rice husk
Process	:	Gasification
Equipment	:	Burner assembly, reactor assembly, and char chamber assembly
Main product and by-product	:	Gas for cooking and char

Description of Technology

A performance evaluation showed that the stove has a power output of 1.4 to 1.9 kW. It consumes rice husks at a rate of 1.4 to 1.7 kg/hour. Gas can be generated within 10 minutes for a 10 cm reactor and 40 minutes for a 60 cm reactor from the time the fuel is ignited using a burning piece of paper. One and a half litres of water can be boiled within 6 to 9 minutes. The flame temperature measured directly at the bottom of the pot ranges from 40° to 47° C. Results of the analysis revealed that the stove has a specific gasification rate of 81.5 to 97.1 kg/hr-m^2 and a fire zone rate of 1.6 to 1.9 cm/min. Thermal efficiency is relatively high for this stove, which ranges from 23.2 to 36.9%, especially through the use of a burner sleeve. The stove comes in four reactor heights – 30, 40, 50 and 60 cm. The 30 and 40 cm reactors are recommended for short time cooking, like heating water for coffee or for heating food. The 50 and 60 cm reactors are applicable for meal preparation (including rice and simple dishes) and other home cooking activities. Longer operation of the stove is possible by disposing the char and refilling the reactor with fuel.

The stove comes in four reactor heights – 30, 40, 50 and 60 cm. The 30 and 40 cm reactors are recommended for short time cooking, like heating water for coffee or for heating food. The 50 and 60 cm reactors are applicable for meal preparation (including rice and simple dishes) and other home cooking activities. Longer operation of the stove can is possible by disposing the char and refilling the reactor with fuel.

Detailed Process Description

The stove is basically of a modular type consisting of the following components:
(1) burner assembly; (2) reactor assembly; and (3) char chamber assembly.

The burner is where combustible gas is burned to produce the required heat for cooking. It consists of a rectangular holder that supports the pot during cooking, a burner plate that distributes the gas for even heating, air holes for the entry of the secondary air needed for the combustion of gas, and a handle for ease of removal of the burner, especially when reloading fuel. The reactor assembly is where rice husk is gasified by introducing a limited amount of air that is just enough to cause combustion of the fuel. It basically consists of inner and outer cylinders having diameters of 15 and 20 cm, respectively. Between the cylinders is rice husk ash insulation to confine heat inside the reactor. The char chamber assembly is where char is discharged. It consists of a cylindrical chamber for the storage of char having a diameter of 30 cm and a height of 15 cm, a sliding-type exit door for ease of removal of the char, a grate that holds the rice husk fuel in place and enables its discharge for disposal, and an air inlet port where an 220 V-0.15 Amp fan is placed to supply the air needed by the fuel to gasify.

Environmental Considerations

The stove is convenient to use and very similar to an LPG stove. Almost no smoke is observed during operation (Figure 4). It can be considered an environment-friendly technology since it can address the problem of rice husk disposal and CO_2 emission is very minimal compared with the traditional direct combustion stoves.

Figure 4: Low Cost Rice Husk Gasifier Stove

Investment and Operating Cost

The stove costs Rp 200,0000 (US$1 = Rp 8,915; as of 11 February 2011) for a unit made of ordinary steel sheet and Rp 250,000 for a unit with stainless steel parts. Operating cost analysis has disclosed that the stove operates at a cost of Rp 663.97 per hour of cooking. A yearly savings of Rp 2,596,455 or Rp 467, 612.14 can be derived through the use of this stove compared with kerosene or LPG fuel, respectively.

Examples of Real Life Applications

A low-cost rice husk gas stove has recently been developed for use by households. This stove is very cheap, being produced at a cost equivalent to only 25% that of its prototype model developed a couple of years ago at the CPU Appropriate Technology Center, Philippines. It has an improved design and is simpler, it uses locally available materials, and it follows a simple fabrication procedure. In combination this has contributed to the significant reduction in the cost of the stove. The design improvement was done by a group of researchers from the PT Minang Jordanindo Approtech – Research and Development Division, namely Franciscus Trya Garleman and Daniel Belonio.

Supplier

Interested individuals or organizations who would like to adopt this technology may contact:

The President Director,
PT Minang Jordanindo Approtech,
Adhi Graha Bldg., 15th Floor Suite 1502A,
Jl. Gatot Subroto Kav. 56,
Jakarta Selatan 12950,
Indonesia.
Telephone: 62-21-5262545, Fax: 62-62- 215262416
Email: djoewito@yahoo.co.id

or

CPU Appropriate Technology Centre,
College of Agriculture,
Central Philippine University,
Iloilo
Email: agriculture@cpu.edu.ph

Source

Improved Biomass Cooking Stoves at URL:
http://www.bioenergylists.org/en/beloniolowcostrhstove#attachments

Reference

"Converting Waste Agricultural Biomass into Resource" – Compendium of Technologies. Compiled by UNEP, Division of Technology, Industry and Economics International Environmental Technology Centre, Osaka/Shiga, Japan. © UNEP, 2009.

5. Biomethanation of Vegetable Market Waste

Introduction:

Vegetables, fruit and flowers are brought together in large quantities in markets, with the resulting wastes disposed along with municipal solid wastes in landfills or dumpsites, creating a place for vector, pest breeding, odor nuisance and greenhouse gas (GHG) emissions into the atmosphere. In India under the Waste-to-Energy Programme promoted by the Ministry of New Renewable Energy Sources (MNRE) (formerly Ministry of Non-Conventional Energy Sources), Government of India, demonstration *Biomethanation of Vegetable Market Waste – Untapped Carbon Trading Opportunities* projects on bio-energy generation from industrial and municipal solid wastes are being implemented.

Koyambedu Market, Chennai, India is Asia's biggest vegetable, fruit and flower market spread over an area of 60 acres with total waste generation of 80 tons per day. Disposal of the waste was previously at the Kodungaiyur dumpsite managed by Corporation of Chennai, which is close to the wholesale market.

The Central Leather Research Institute (CLRI), Chennai, India has carried out extensive studies on biomethanation of abattoir and tannery wastes and implemented Waste-to-Energy projects in various parts of India through MNRE.

In view of the inherent biodegradable characteristics of vegetable, fruit and flower wastes, MNRE proposed the implementation of a demonstration plant with a capacity of 30 tons per day for market wastes for bio-energy generation and manure production under the Waste-to-Energy programme at Koyambedu, Chennai jointly with the Chennai Metropolitan Development Authority (CMDA) and entrusted CLRI as the Technical Agency.

The prime objectives of the project are listed below.

- To evaluate the feasibility of biomethanation of vegetable, fruit and flower market wastes for energy generation and manure production;
- To strengthen institutional capabilities in developing indigenous technology;
- To absorb process technologies for the improvisation, scaling-up and widening the scope for implementation of biomethanation technology for management of the same or similar type of solid wastes; and
- To build capacity in technology package development, technology transfer, project management and implementation.

Project Details

Composition of the Market Waste

The major components of the wastes generated include vegetable wastes (21%), fruit wastes (15%), flower wastes (10%), banana stem and related materials (38%) and packing materials (hay, straw, paper etc. 16%). Materials in the form of stones, plastics, wood etc. were present in less than 1% of the waste quantity.

Characteristics of the Waste

Depending upon the season, there are large fluctuations in the quantity and nature of waste generated daily at the market. The total solids and volatile solids content are 25% and 73.7% respectively. The moisture content is 75% and these parameters were analyzed as per Standard Methods, 20th edition.

Description of the Process

The segregated wastes collected from the market complex are transferred to a receiving platform. The wastes are lifted by grab from the receiving platform and transferred into a hopper provided in the belt conveyor. The wastes are carried by the conveyor to a shredder to reduce the size of the wastes to a size of around 15-20 mm.

The shredded waste is blended with screw press water or make-up water in a collection tank. Mixed waste is macerated and pumped into the digester by means of screw pump. A Biogas Induced Mixing Arrangement (BIMA) digester has a unique mixing part which does not require mechanical moving parts and has the ability to control scum/sediment while handling high solids concentrations.

The biogas generated as a result of stabilization of the waste leaves the digester to a dry typed gas holder (530 m^3) made of a synthetic membrane (polyester). An in-situ biological desulphurization unit has been installed in the digester to reduce the H_2S concentration in the biogas to below 500 ppm. A group of facultative bacteria which adhere to the walls of digester separating the upper and main chamber are utilized for biological desulphurization.

After removal of H_2S, the biogas is used as fuel in the engine to produce electricity. The gas is drawn from the gas holder by gas blowers and fed into the gas engine and the alternator is connected to the engine to produce electricity. The net power generated after in-house consumption is exported to the Tamil Nadu Electricity Board (TNEB) grid.

In the case of maintenance of the gas engine and when the gas generated exceeds the storage capacity of the gas holder, the biogas is burnt by a flare. The flare is an automatic type with an auto ignition arrangement.

Residue from the digester is collected in the effluent buffer tank for dewatering. The digestate is pumped into a screw press by means of screw pumps. It consists of a rotating screw fitted closely inside a curb. As the screw is rotated, the material is moved forward and consequently the pressure is increased. Press water is discharged through openings in the curb and the dewatered cake is discharged at the other end of the press. The cake from the screw press is to be converted into manure by composting. The process flow diagram is shown in Figure 5.

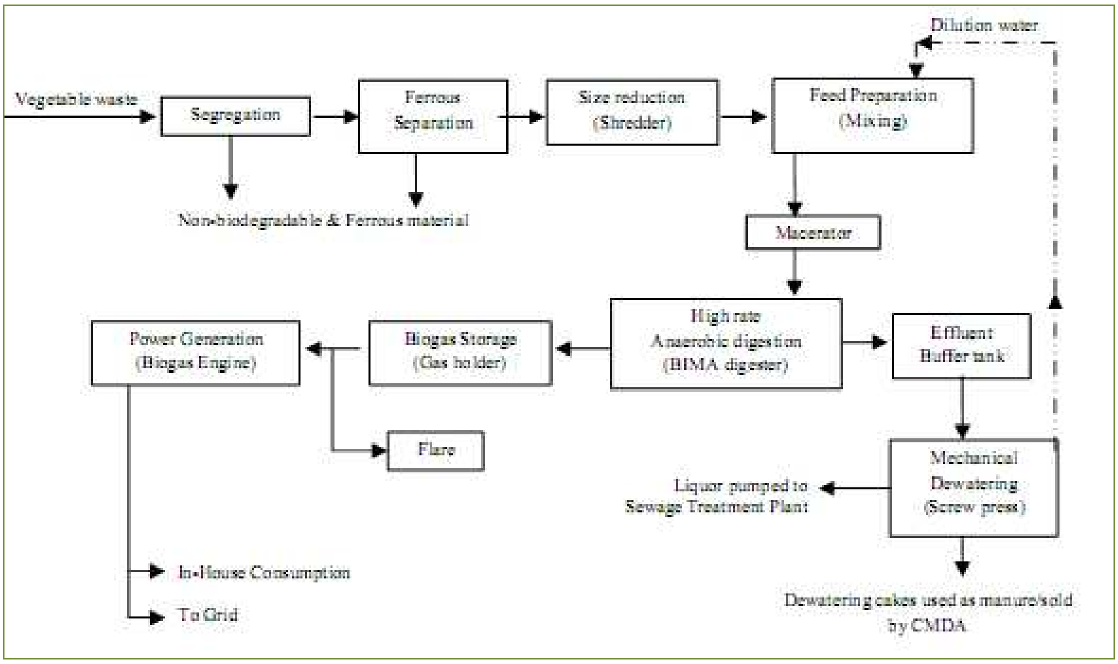


Figure 5: Process Flow Diagram Showing Biomethanation Process Using Vegetable Market Waste

Performance of the Biomethanation Plant

The Biomethanation Plant at Koyambedu was commissioned in September 2005. The average performance of the plant to date is presented in Table 1.

No.	Description	Design parameters	Average performance observed
1.	Throughput capacity	30 TPD	30 TPD
2.	Total and volatile solids content		
	Total solids	25 % - 7.5 TPD	9 % - 2.85 TPD
	Volatile solids	74 % - 5.7 TPD	75 % - 2.16 TPD
3.	Average gas production	2500 m^3/day	1143 m^3/day
4.	Specific gas production	0.44 m^3/ kg material fed	0.53 m^3/ kg material fed
5.	Specific power generation	2.0-2.1 kwh/m^3 of biogas	1.8 kwh/m^3 of biogas
6.	Power generation	5250 kwh/d	2047 kwh/d
7.	Net power export	4780 kwh/d	1279 kwh/d
8.	Power consumption by the plant	470 kwh/d	768 kwh/d
9.	Additional power drawn from TNEB	--	377 kwh/d

Table 1: Performance of Biomethanation Plant at Koyambedu

However, the overall efficiency of the biogas yield depends on the biodegradable nature of the constituents present in the waste. On the whole, the overall plant performance is consistent with respect to specific gas production and specific energy generation.

Issues to Be Considered

The following issues that emerged based on lessons learned and hands-on experience gained from this project activity need to be considered when implementing similar projects in future:

However the overall efficiency of the biogas yield depends on biodegradable nature of the constituents present in the waste.

- Standardization of country and waste specific emission methodologies;
- Development of guidelines for anaerobically digested material as manure;
- Assessment of compost quality and making it at par with organic manure;
- Creating market potential for anaerobically digested liquid manure and compost material;

- Nearness to the STP site to avoid transport costs for conveying liquid waste generated from the biomethanation of vegetable market waste;
- Planning Integrated Waste Management Schemes (IWMS);
- Biomethanation of vegetable market waste along with sewage sludge for continued and consistent bio-energy generation;
- Sharing of experiences by the project proponents regarding problems encountered.

Conclusions

Biomethanation of vegetable market waste is an economically viable option for bio-energy generation that also reduces greenhouse gas emissions. Nevertheless, various constraints and issues need to be thoroughly examined before implementing a biomethanation plant. That said, the biomethanation process is the most suitable process when compared to composting or dumping into landfills. Not only that, the European Commission introduced a landfill directive in 1999 and also set the Total Organic Carbon (TOC) content in the waste to be dumped into landfill at less than 5% from the year 2004 onwards. Similar or more stringent regulations may arise in India also in future. Keeping this situation in mind, biomethanation followed by aerobic composting is considered to be a feasible option for managing vegetable market waste.

Reference

"Biomethanation of Vegetable Market Waste – Untapped Carbon Trading Opportunities" by K. Sri Bala Kameswari, B. Velmurugan, K. Thirumaran and R.A. Ramanujam. *Department of Environmental Technology, Central Leather Research Institute (CLRI), Adyar, Chennai, India. Proceedings of the International Conference on Sustainable Solid Waste Management, 5 - 7 September 2007, Chennai, India. pp.415-420.*

Annex 3.2: Techno-commercial Information from ABC Company Pvt. Ltd.[1]

Sustainable Treatment of Vegetable Waste into Energy

Introduction

A reactor has been designed for decomposing used kitchen and agriculture waste to produce biogas for community use. The gas can be distributed to clusters of households for utilization in cooking, lighting and/or electrification. The digested slurry can be used or sold as an organic fertilizer.

Raw Materials and Feeding System

Factors which have a direct effect on gas production are: carbon/nitrogen ratio (C/N ratio), temperature, pH value of content in the digester, hydraulic retention time (HRT), input rate, and total solids content of the input material (TS).

The moisture content of the input material/biodegradable waste should ideally be over 40%. The material is chopped into small pieces and ground with water (using a mixing ratio of 1:2). The liquid is collected in a separate chamber, which in turn is connected to the biogas reactor. The collected liquid is stored for 24 hours in a separate tank before being fed into the biogas reactor. This tank can store up to 500 kg of biomaterial per day.

Components

This model consists of the following components:

- Chopping section
- 10 HP Motor (for chopping section)
- Pre-treatment tank
- Inlet tank
- Water reservoir tank of 8,000 L capacity
- Mixing tank for cattle dung/decayed organic material
- Manual mixing device for mixing tank
- Digester and dome
- Manhole and outlet chamber

[1] The details listed in this Annex have been provided by companies contacted for this information. UNEP does not assume any responsibility for the correctness or completeness of the same.

- Overflow tank
- Digested slurry drainage outlet
- 1.5" dia. GI pipe, for use as the main gas supply pipe line
- Gas control and supply section shed with an installed gas compressor (with 6 m^3 pure steel tank and gas supply meter, gas supply pipe and desulphurizer device)

Reactor Specifics

HRT = 40 days
Reactor size = 50 m^3
Feeding capacity per day = 1,050 L
Gas production rate per kg = 30 L
Gas production per day = 10,500 L

Equivalent Quantity of Fuel for 1 m^3 of Biogas

Fuel	Kerosene	Firewood	Cow dung cakes	Charcoal	Soft coke	Butane	Furnace oil	Coal gas	Electricity
Equivalent to 1m^3 of biogas	0.62 L	3.474 kg	12.296 kg	1.458 kg	1.605 kg	0.433 kg	0.4171 L	1.177 m^3	4.698 kWh

Operation of the Biogas Plant

The biogas produced will be supplied to chosen community households, all of which will need a GI supply pipe connection. These households will also need training to understand how to operate the apparatus. The costs of this training are not included in this proposal.

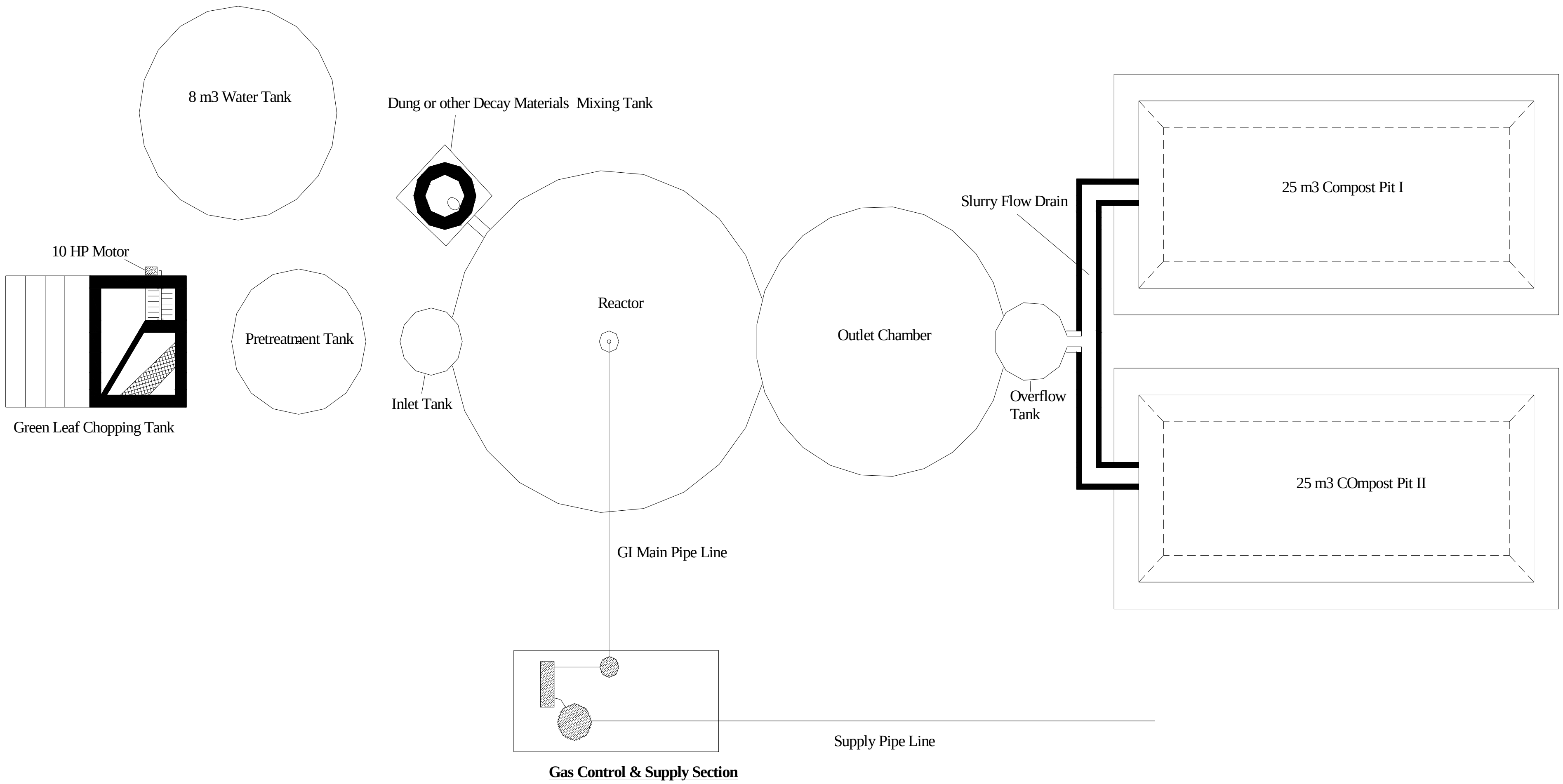
It is important that the production and use of the biogas is monitored regularly for two years.

Construction of the Biogas Plant

Construction of the plant would be conducted in three phases:

- First phase: Construction of reactor using standard construction materials (brick/sand/aggregate/rods/cement) and trained human resources
- Second phase: Installation of compost pit and pipelines, as well as gas reserve and supply system shed and associated equipment
- Third phase: Handover after testing

Diagram of the Biogas Reactor



Work Schedule

Table 1 indicates a proposed work schedule. The project is expected to be completed over four months, with monitoring to be conducted for 2 years thereafter.

Table 1: Work Schedule

No.	Activities / Year	2011															
	Month	1st Month				2nd Month				3rd month				4th Month			
	Weeks	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Recruitment of project personnel	■	■														
2	Selection and identification of construction site			■	■												
3	Assessment of raw materials for feeding the reactor, desk study and detailed design					■	■	■									
5	Construction of one bioreactor unit (50 m^3 capacity)								■	■	■	■	■	■			
6	Operation of bioreactor														■		
7	User training															■	■
Monitoring (2 years)																	

Digested Slurry Utilization and Benefits

Biogas slurry is one of the end products of anaerobic digestion using the biogas reactor. The mixer of animal/human waste put into the biogas reactor undergoes a process of anaerobic digestion or fermentation in the digester. During digestion, about 25-30% of the total dry matter (TS content of the fresh dung) of animal/human wastes is converted into a combustible gas and a residue of 70 – 75% of the total solids content of the fresh dung comes out as sludge, which is known as digested slurry or biogas slurry. The slurry contains important nutrients – nitrogen, phosphorus and potassium (NPK) – which under ideal conditions, can surpass the nutrient value of normal compost as well as farmyard manure.

Nutrient	Improved compost (but not slurry compost)		Farmyard manure		Digested bio-slurry	
	Value Range (%)	Average Value (%)	Value Range (%)	Average Value (%)	Value Range (%)	Average Value (%)
Nitrogen	0.5-1.50	1.00	0.5-1.00	0.8	1.40-1.80	1.60
Phosphorus	0.4-0.8	0.6	0.5-0.8	0.7	1.10-2.00	1.55
Potassium	0.5-1.90	1.2	0.5-0.8	0.7	0.8-1.2	1.00

In fact, the nutrient value of the effluent can surpass the benefits accruing from the value of the biogas. When slurry-handling techniques are not favorable or users tend to be negligent, almost all of the nitrogen may be lost due to volatilization of ammoniac nitrogen, which is soluble in liquid slurry. Likewise, other nutrients also get lost when slurry is exposed to the sun for long periods of time.

Application of the slurry will enhance soil properties by:

- Improving the soil's physical and chemical properties
- Improving its fertility
- Increasing its water holding capacity
- Enhancing the activity of micro-organisms in it

Effects of Bio-slurry on Crop Production

One study has reported experiments conducted at an agronomy farm in which the application of dry and wet slurry increased wheat yields by 16.2 and 55.4% respectively over the controls. Another study reported that dry slurry gave better wheat yield than wet slurry under irrigated conditions and vice-versa under rain fed conditions.

On the basis of the research conducted at an agronomy farm on azotobacter inoculation in different types of organic manures, including biogas slurry, on the grain yield of wheat, it was reported that biogas slurry inoculated with azotobacter increased wheat yield by 12% over the control. Application of 100:40:30 NPK kg/ha of azotobacter inoculated biogas slurry gave a mean wheat yield (2116.66 kg/ha) which was lower than that given by poultry manure and far lower than that given by ordinary compost, both with and without azotobacter inoculation and the same amount of chemical fertilizer.

A comprehensive review of literature on effects of slurry use on crop production leads to the following observations:

- A combination of biogas slurry at 12.5 t/ha and 100% NPK had a pronounced effect on rice yield.
- Seed coating with a combination of 50% (W/W of seed) digested slurry and 2% inorganic nutrient and 2% bio-fertilizer enhanced the growth and yield attributes of rice, soybean, black gram, green gram and jowar.
- Application of biogas slurry at 10 t/ha favorably influenced the yield of rice crops, followed by the yield of black gram crops. Slurry increased rhizobium nodules thus increasing the black gram yield by around 78%.
- Gypsum enriched slurry, when applied in combination with 75% recommended NPK, gave the maximum grain yield in a rice-black gram cropping system. It is estimated that there was a saving of 25 kg N/ha.

- Bio-slurry application on wheat, sunflower, safflower, hybrid cotton, and groundnut resulted in an average yield increase of 24% over the control.
- Application of bio-slurry at 10 t/ha in tomato, brinjal, groundnut, jowar, maize and okra gave better yields than farmyard manure. (The physical form of the slurry used is not identified.)
- Yield increase due to bio-slurry application have also been reported for many other crops including pea, mustard, watermelon, cabbage, banana, chilly, bajra, turmeric, sugarcane, deccan, hemp, mulberry, tobacco, castor and onion.
- A combination of liquid bio-slurry and chemical fertilizer enhanced carbon nitrogen transformation with substantive effects on crop yield. The yields in many instances were reported to be higher than that given by the combination of ordinary farmyard manure and chemical fertilizer. In China although the average yield increment reported is not as high as in India (somewhere around 10 to 18%), experiments in bio slurry-chemical fertilizer utilization showed a yield increment of as much as 37.8% in maize as compared to 16.8% and 9% respectively for use of effluent and chemical fertilizer alone. A comparatively lower, nonetheless increased, yield has also been recorded for rice through such a combination.
- Vegetable crops produced with bio-slurry have better quality as compared to those produced with chemical fertilizer. Studies have not pinpointed the differences between bio-slurry and farmyard manure in this regard.

With support from the Alternative Energy Promotion Centre, an experiment was conducted in farmers' fields in the Lalitpur district to study the influence of bio-slurry on the maize and cabbage yields. This research revealed that the application of slurry compost at the rate of 10 t/ha increased maize yield by 23% over the control (to which no fertilizer was added). The same experiment also reported a 10% increase in yield over the control with the application of bio-slurry (liquid form) at the rate of 10 t/ha, while the full application of chemical fertilizers (120:60:40 NPK kg/ha) yielded only 8% more than the control. The author also reported up to a 7% increase in soybean yield over the control. In a similar experiment conducted on cabbage, the application of slurry compost and liquid slurry each at the rate of 10 t/ha resulted in yield increment by 28 and 18% respectively over the control. Application of slurry compost (10 t/ha) with the recommended dose of chemical fertilizer (120:60:50 NPK kg/ha) yielded 36% more than the control.

One study based on the Biogas Users' Survey conducted during fiscal year 2004/5 reported that amongst the users surveyed, 58% obtained increased paddy yield with the application of slurry. Such responses in other crops like tomato, potato and vegetables were reported by 70%, 44% and 44% users respectively.

Financial Details - Tentative Cost of 50 m^3 Biogas Plant

No.	Description	Unit	Quantity	Rate	Amount Remarks
A	Human resources				
	Supervisor	Per	35.00	450	15,750.00
	Mason	Per	350.00	450	157,500.00
	Labor	Per	1200.00	350	420,000.00
	Cost of human resources				593,250.00
B	Construction materials				
	Brick	Nos	31000	10	310,000.00
	Stone	m3	38	800	30,400.00
	Cement	Bag	735	675	496,125.00
	Sand	m^3	36	1200	43,200.00
	Aggregate	m^3	32	1450	46,400.00
	12 mm Ø MS rod	kg	500	67	33,500.00
	10 mm Ø MS rod	kg	1100	67	73,700.00
	8 mm Ø MS Rod	kg	250	72	18,000.00
	6 mm Ø MS Rod	kg	110	72	7,920.00
	Binding wire	kg	25	125	3,125.00
	Wooden forma	ft^2	2600	36	93,600.00
	Cost of construction materials				155,970.00
C	Appliances and fitting goods				
	2"Ø GI dome gas pipe	Set	1	2100	2,100.00
	1.5" main ball valve	set	1	1850	1,850.00
	Emulsion paint	L	25	550	13,750.00
	Water drain	set	1	325	325.00
	1.5" Ø GI pipe	m	20	525	10,500.00
	1" Ø GI pipe	m	50	276	13,800.00
	Vertical mixer	set	1	1350	1,350.00
	8"Ø HDPE pipe for inlet	m	30	750	22,500.00
	Chopper device	Set	1	25,000	25,000.00
	10 HP Motor	Set	1	35,000	35,000.00
	Gas compressor device	Set	1	60,000	60,000.00
	6 bar gas reserve steel tank	Set	1	180,000	180,000.00
	Fitting goods		L.S.		50,000.00
	Cost of appliances				414,075.00
Cost of one Plant (A+B+C)					2,163,295.00
5% transportation cost					108,164.75
10% construction charge for company					216,329.50
10% design, costing & supervision cost					216,329.50

5% three-year after-sales service cost for company	108,164.75
Total project cost	2,812,283.50

Note: This cost is depended on local market prices. Changes in market prices will necessitate a revision of this estimate.

Mode of Payment

- 50 % - Upon signing of contract
- 20% - Upon transportation of construction materials
- 20% - Upon completion of dome concreting
- 10% - Upon submission of final completion report

Annex 3.3: Techno-commercial Information from XYZ Engineers Pvt. Ltd. Regarding Setting Up a Portable Waste Disposer Plant for Treatment of 500kg/day of Organic Waste[1]

Part A - Salient Features of the Proposed Portable Waste Disposer Plant

Capacity	500 kg/day of segregated organic food waste
Biogas produced	35-40 m^3/day, which is equivalent to 16-18 kg/day of LPG
Bio-manure generated	Approx. 17 ton/annum (with a portion to be removed half-yearly)
Water required	About 500 ft per day
Overflow	About 500 L per day (part to be recycled and the remainder to be disposed)
Electricity required	About 13 electrical units daily and connected load of 7.5 HP
Area required	5m (L) x 4.5m (W) x 4.5m (H) on hard strata which can take a load of about 40 tons

Part B - Advantages of the Proposed Biogas Project

- Neat and hygienic disposal of organic waste
- Cost savings in transportation for waste disposal
- No civil construction required
- Pre-assembled and factory tested, enabling immediate installation and commissioning
- Easy to relocate if required
- Very compact, conserving space
- Can be installed in a basement, a parking area or even on a terrace (provided that the structure is able to handle the load)
- No foul smell or flies/mosquito nuisance, since gas tight top covers are provided
- Easy maintenance and only one operator required
- Savings in power consumption
- Modular type, enabling capacity enhancement
- Helps in the reduction of GHG emissions
- Accelerated depreciation at 80%
- Exemption from excise duty (8.24%)

[1] The details listed in this Annex have been provided by companies contacted for this information. UNEP does not assume any responsibility for the correctness or completeness of the same.

- Concessional VAT at 4% (12%)

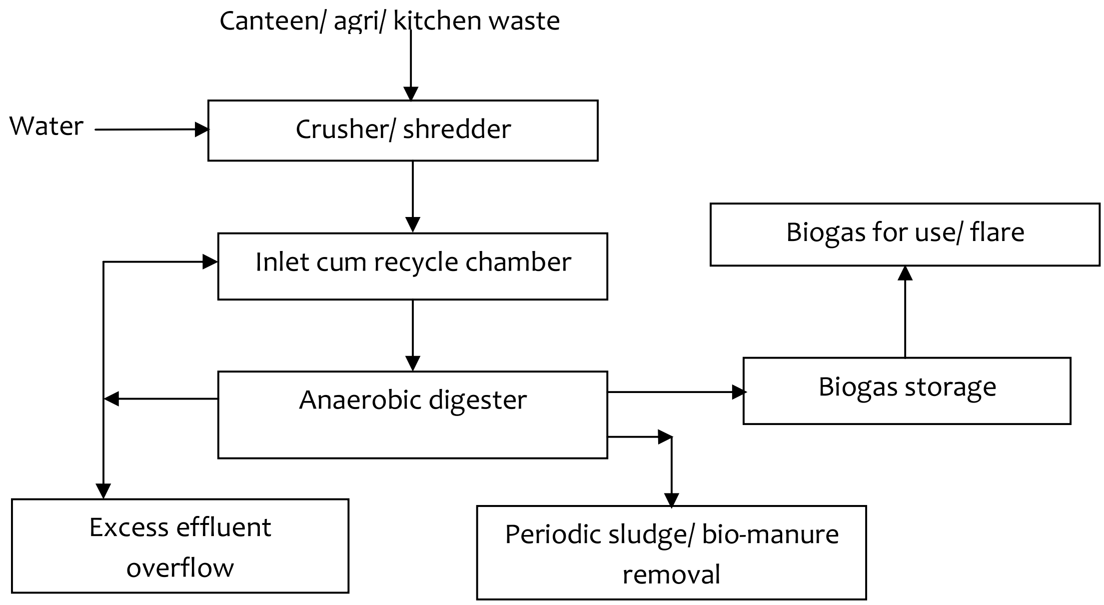
Part C - The Principle

The basic concept of our design is based on a process known as Upflow Anaerobic Sludge Blanket (UASB) developed by Dr. Lettingah in the Netherlands and specifically modified by XYZ ENGINEERS Pvt. Ltd. for waste containing a high percentage of suspended solids.

Part D - Brief Process Description

The segregated organic waste will be brought to the plant site. It will further be crushed through a shredder/crusher along with a suitable quantity of water to form a slurry. This slurry will be fed into the inlet cum recycle chamber. The slurry will be mixed properly and then pumped into the anaerobic digester where the organic waste will be converted into biogas. Part of this slurry will be recycled in the inlet cum recycle chamber and the remaining will be discharged suitably. The bio-manure (waste solids) will be periodically removed from the digester, dried and may be used as organic manure or soil conditioner. The biogas generated from the anaerobic digester will be collected in a biogas holder and suitably pressurized. The pressurized biogas will then be used for cooking applications. If the gas will not be used, it will be necessary to flare the same as the legal authorities do not permit discharging it into the atmosphere. Thus, this process will be based on a "zero garbage disposal" concept.

Part E - Flow Sheet Explaining the Process



Part F - Equipment List

FEED PREPARATION SECTION

Drum lifter cum titer –1 no.
Shredder/ crusher – 1 no.
Sorting table – 1 no.
Inlet cum recycle chamber – 1 no.
Pump for feeding slurry – 1 no.

ANAEROBIC DIGESTION SECTION

Anaerobic digester – 1 no.
Anaerobic digester internal proprietary modules – Set
Scum removal system –Set

BIOGAS STORAGE

Biogas balloon (15 m^3) – 1 no.
Compressor– 1 no.
Pressurized biogas tank – 1 no.
Pressure switch – 1 no.
Pressure gauge – 1 no.
Moisture traps – 2 no.
Biogas flare (manual) – 1 no.
Flame arrestor – 2 no.
Biogas burner – 3 no.
Tool box with tool kit - 1 no.
pH meter – 1 no.
Thermometer – 1 no.
Medical kit- 1 no.
Control panel – 1 no.
Electrical works – Set
Piping works – Set
Base Frame
Bio-culture

ADD-ON ACCESSORIES

Heating arrangements and insulation as required

Part G – Other Requirements

Organic waste	**The Client will provide the segregated waste at a sorting table and at a specified time every day.**
Biogas	Biogas generated from the digester will be collected in the biogas holder for utilization or will be flared. Biogas will be provided until 10 running meters from the outlet of the pressurized biogas tank.
Bio-manure	Bio-manure from the digester will be taken out half-yearly and will be disposed of by the Client. This is good manure and may have sale value or may find use in gardens after drying.
Effluent discharge	Overflow effluent from this is very rich manure and therefore must be diluted to a 1:4 ratio before being used in gardens or before it can be connected to an existing sewer line by the Client.
Electrical supply	The Client will provide 3-phase - 440 V electrical supply at the control panel incomer point in the proposed portable waste disposer plant.
Fresh water	The Client will provide a pressurized fresh water line at a point in the proposed portable waste disposer plant, preferably near the shredder unit.
Operation and maintenance	We will operate and maintain the plant for 6 months from the date of installation and thereafter will undertake annual maintenance on a contract basis.

Part H – Our Scope of Work

- Fabrication, supply and installation/erection of all mechanical and electrical items, listed above
- Issue of operation and maintenance manual
- Technical support thereafter on a chargeable basis
- Civil foundation drawing if required
- Conducting of awareness campaigns

Part H – Budgetary Estimate for the Proposed Project

Capacity of proposed project	**500 kg/day of organic waste**
Cost of equipment	INR 13,00,000.00
Cost for heating arrangements and insulation	INR 4,00,000.00

Annex 3.4: Techno-commercial Information from PQR Industries Pvt. Ltd. Regarding Technical and Financial Details For Gasifier Plant[1]

Services Offered

On confirmation of the order, an engineer visits the site and based on the requirements and existing arrangements, helps the buyer in determining the site layout. Though responsibility for the civil work for the foundation of the machinery sheds, go-downs etc. lies with the buyer, PQR Energy provides all civil foundation drawings and an engineer visits periodically to oversee the construction work. PQR Energy designs tailor-made systems catering to the actual requirements of the buyer, including end-use applications. Expert services are also available to modify any furnace/kiln for the firing of producer gas or for the generation of hot air/water/fluid etc.

Upon the dispatch of goods in 'knocked down' condition, a team of technicians goes with tools and tackles for site fabrication fittings and the erection of the entire system, including the electrical cabling work. The plant is commissioned and stabilized by a separate set of technicians generally over a period of 15 days while the technical personnel on the buyer's side are being trained for operation of the plant. Upon request, PQR Energy can provide technical staff beyond this period to supervise the operation of the plant at an extra cost.

For capacities of 1 MWe and above, the company can accept responsibility for the entire operation and maintenance of the plant on a contract basis. The plant remains under warranty for a period of one year from the date of commissioning. The company replaces or repairs the faulty manufactured part(s) free of cost, if found during the warranty period.

Upon expiry of the warranty period, PQR Energy enters into an annual maintenance contract with the buyer, under which engineers are dispatched four times a year (once every three months) for routine inspection and maintenance of the plant. Technicians are also sent as

[1] The details listed in this Annex have been provided by companies contacted for this information. UNEP does not assume any responsibility for the correctness or completeness of the same.

many times as necessary in emergency situations. If required, PQR Energy can also help the buyer in assessing the requirements, determining economic advantages and benefits and designing the affected infrastructural changes and modifications.

Process Technology

The gasification process technology is based on production of a highly combustible gas by controlled reactions of biomass, namely rice husks, wood, palm nut shells etc. with air and water vapor.

In the gasifier, solid biomass fuel not exceeding 25mm in size and having moisture content not exceeding 20% is fed from the top as air and steam are fed from the bottom. As it moves upward against the downward movement of the biomass fuel, this process of gas generation is called the Updraft principle.

A number of chain chemical reactions take place in the gas generator from the bottom to the top. A proper mixture of air water vapor passes through the channel-free, compact, fuel bed, ensuring that the following reactions take place.

Oxidation zone

$$C + O_2 = CO_2 + \text{Heat}$$

Primary reduction zone

$$C + CO_2 = 2CO - \text{Heat}$$

$$C + H_2O = CO + H_2 - \text{Heat}$$

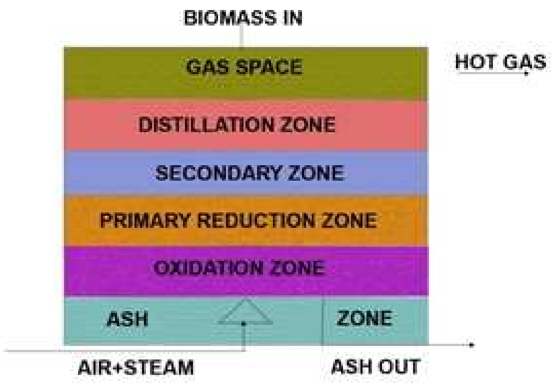
$$C + 2H_2O = CO_2 + 2H_2 - \text{Heat}$$

Secondary reduction zone

$$C + CO_2 = 2CO - \text{Heat}$$

$$CO + H_2O = CO_2 + H_2 - \text{Heat}$$

While the plant is under normal operation, the following zones are believed to exist in the gasifier, as shown in the cross sectional view below:



Applicability

The producer gas coming out of the gasifier can be used either for producing heat energy or electrical energy. For producing electrical energy, the producer gas can be used either with or without any other fuel.

Electrical Power

Dual Fuel Engine

A dual fuel engine is basically a diesel engine with a conversion kit to run the engine with diesel or any suitable gas having a certain calorific value, including producer gas. This works on the diesel cycle. Producer gas is added to the air, which is injected to the engine before the turbo-charger. This mixture of air and gas is compressed in the cylinder just as air is compressed in a normal CI engine. At the end of the compression, diesel is injected through a conventional fuel system. This diesel oil ignites first as pilot fuel and the heat released by its combustion leads to the combustion of the gas/air mixture. In the process, consumption of diesel can be reduced by 65% - 75%. Existing engines may also be retrofitted for dual-fuel operation.

In this case, 1 kg of rice husk or 0.80 kg of wood (moisture - 25%) along with 0.07 – 0.08 L of diesel oil can produce 1 unit (kWH) of electrical power. However, for existing DG sets, this figure may vary somewhat, depending on the condition of the set.

Spark Ignition Engine

In this case the producer gas is the sole fuel used in the spark ignition (SI) engine. A gas carburetor or mixer is used to prepare the air-gas mixture. The mixture is sucked into the engine during the suction stroke, compressed and then ignited by a spark from a spark plug in the cylinder head.

Here only 1.3 kg of wood or 1.5 kg of rice husk may be required to produce 1 unit of electricity.

Thermal Energy

Since producer gas is combustible in nature, it can be fired with the help of a suitably designed burner. Furnace temperatures up to 900 – 1000°C (flame temperature up to 1100 – 1115°C) can be achieved by effective firing of the gas. The temperature can be even higher if the combustion air is pre-heated with a recuperator.

Hence, producer gas is the cheapest source of energy for the firing of boilers/kilns/ovens/furnaces etc. or for heating air/water/fluid etc. It can replace costly fuels like oil and natural gas.

In this application, 5 kg of wood or 6 kg of rice husk or 3.5 kg of coal can replace a litre of oil.

PQR gasification plants can be of various capacities ranging from 100 kWe to 1,000kWe. They have been in operation for different industrial activities over a considerable period of time. Some of them have even crossed 30,000 hrs of rigorous operation. In many cases, gas from the same plant is used in more than one location and caters to both thermal and electrical requirements. Small systems of 10 kWe, 20 kWe and 100 kWe capacity are also running in the hilly regions for rural electrification.

Tunnel klin fired by producer gas

Boiler fired by producer gas

Small gasifier for remote village electrification

Aluminum melting by producer gas

Air heating by producer gas for grain dryer

100% producer gas genset in operation

DG Set in operation on dual fuel run by producer gas

Producer gas from coal

Gas Specifications

Slight variations in gas composition and heat value may arise because of differences in the biomass fuels and the coal used. However, indicative figures for the same are as follows.

Composition (v/v)	Biomass producer gas	Coal producer gas
Carbon dioxide (CO_2)	8 – 10 %	4 – 6 %
Carbon monoxide (CO)	23 – 26 %	26 – 28 %
Oxygen (O_2)	Less than 1%	Less than 1%
Hydrogen (H_2)	10 – 12 %	12 – 16 %
Methane (CH_4)	1.5 – 2.0 %	3 – 4 %
Nitrogen (N_2)	54 – 56 %	50 – 53 %
Gross calorific value (Kcal/Nm^3)	1200 – 1300	1450 – 1550
Yield of gas (Nm^3/kg)	1.80 – 2.20	2.40 – 2.60
Specific gravity (air = 1)	0.90	0.88

Benefits

PQR gasification plant users enjoy such benefits as:

- Low cost energy: The capital investment as well as the cost of energy generation are very low compared to any other system.

- High calorific value: The system is designed to produce a gas having heat value in the order of 1200 – 1300 Kcal/Nm^3 , which is higher by 20 - 25 % compared to other down-draft systems available in the market. As a result of this higher heat value, higher temperatures can be achieved consistently against lower consumption of feedstock.

- Continuous operation: A PQR gasifier plant is designed for continuous operation 24 hours a day and at least up to 300 days at a stretch, after which a brief shutdown of 15 days is recommended for annual maintenance. The plant may be put into operation again thereafter. Online stand-by for all mechanical items like blowers, motors, pumps etc. are provided for this purpose.

- High flexibility: This is a multi-fuel system. The plant can run on any one of a wide range of biomasses, using whichever is available locally. Beside rice husks, the same plant may also run with wood blocks, sawdust, wood bark, sunflower seed husks, ground nut shells, coconut shells, corn cobs etc. The same plant can even accept coal as feedstock with little modification.

- Unique gas cleaning system: A PQR gasification plant is coupled with a unique gas cleaning and cooling system. It is essential for the gas to pass through the system before any application. Tar generated along with the gas is a sticky material which harms the engine if it is not trapped efficiently. In the PQR system, for power generation purpose, such trapping is done in ten stages to ensure that tar and the particulate concentrations in the gas do not exceed 10 mg/Nm^3. For thermal application, tar is a good combustible material having a higher heat value, but it may choke the nozzles of burners and thus may interrupt operation if it is allowed to flow along with the gas. As a result, here a five-stage cleaning arrangement is provided to maintain a tar concentration less than 50 mg/Nm^3.

- True value for investment: Construction of the plant is made with good engineering practices to have a life of at least 15 years, if maintained properly. Great care has also been taken for operational safety, which is very important for any explosive gas plant.

- Carbon trading facility: The PQR gasification system reduces emissions of CO_2 in the atmosphere and as such qualifies under the definition of a CDM (Clean Development Mechanism) project as laid down in the Marrakesh Accord on Climate Change. Such a mechanism can provide a considerable amount of revenue inflow by way of trading of Certified Emission Reductions (CERs).

Economic Viability

The economic viability of PQR gasification systems is highly interesting. In some cases, the payback period for the investment is only a few months. However, the said viability largely depends on three major factors:

- Size of the plant (the higher the capacity, the lower the generation cost)
- Cost of input (the price of feedstock, labor, oil etc.)
- Plant load factor (the maximum utilization of the plant.)

An indicative cost of generation can be evaluated with certain assumptions. The economic viability is different for thermal application and energy generation.

For thermal application: In the case of a 350 kW capacity plant running 18 hours per day for 330 days per year using producer gas instead of using FO or LDO or HSD, Rs. 14 worth of producer gas (made from rice husks procured at Rs. 2000/ton) can substitute for 1 liter of FO valued at Rs. 22.

For power generation: A plant can be run either on dual fuel or on 100% gas mode. If the gas is produced from rice husks procured at Rs. 2000/ton the cost of the power generated would be Rs. 5.25 (using dual fuel) or Rs. 3.50 (100% gas mode) as against Rs. 10 using diesel. Recovery of the capital investment can be made within 1-1/2 to 2 yrs depending on the specific site conditions.

Budget

All given costs are in Indian rupees and valid for CIF India only. Customs duties and taxes will be charged extra as per actual cost. These are expected to be around 20%.

Dual Fuel Power (To operate by diesel ignition system); Unit: Rs. 100,000

Capacity	Gasifier with cleaning and cooling system	Operating shed and structure	Elevator	Boiler	E/C (extra)	Standby (extra)
75 KW	9.80	0.45	0.95	0.25	0.65	0.75
150 KW	15.85	1.75	1.10	0.25	1.25	2.00
250 KW	19.20	1.85	1.20	0.25	1.25	2.50
350 KW	25.90	1.85	1.35	0.90	1.95	2.95
450 KW	35.10	2.45	1.45	0.90	2.25	4.00
500 KW	38.20	2.45	1.45	0.90	2.25	4.50
600 KW	40.10	3.10	1.45	0.90	2.25	4.50

Thermal Energy (Producer gas production only; not operated with DG set); Unit: Rs. 100,000

Capacity	Gasifier with cleaning and cooling system	Operating shed and structure	Elevator	Boiler	E/C (extra)	Standby (extra)
75 KW	6.75	0.45	0.95	0.25	0.65	0.75
150 KW	13.35	1.75	1.10	0.25	1.25	2.00
250 KW	16.50	1.85	1.20	0.25	1.25	2.50
350 KW	22.75	1.85	1.35	0.90	1.95	2.95
450 KW	30.00	2.45	1.45	0.90	2.25	4.00
500 KW	32.15	2.45	1.45	0.90	2.25	4.50
600 KW	34.85	3.10	1.45	0.90	2.25	4.50

Service Requirements

Capacity	75 KW	100 KW	200 KW	250 KW	350 KW	450 KW	500 KW	1000 KW
Husk consumption, kg/hr (average)	75	100	200	250	350	450	500	**1000**
Diesel consumption, kg/hr	6	8	16	20	28	36	40	**80**
Steam consumption, kg/hr (average), at 2-4 kg/cm^2 pressure	21	28	57	72	100	130	145	**290**
Water requirement, L/day (average)	150	200	400	500	700	900	1000	**1000**
Power requirement, HP (average)	10	10	10	10	17	17	17	**17**
Area requirement (average)	40'x30'	40'x30'	60'x35'	60'x35'	60'x35'	70'x35'	75'x40'	**85'x40'**

Persons required	Skilled	1	1	1	1	1	1	1	**1**
	Unskilled	1	2	2	2	2	3	3	**5**
Civil engineering costs (as per actual costs)									

Annex 3.5: Techno-commercial Information from JKLL Pvt. Ltd.[1]

Raw Material and Finished Product Data

Every year millions of tons of agricultural waste are generated. These are either not used or burnt inefficiently in their loose form, causing air pollution. Handling and transportation of these materials are difficult due to their low bulk density. However, these wastes can provide a renewable source of energy through conversion into high-density fuel briquettes without the addition of any binders or chemicals.

Specifications of Applicable Raw Material

- Size of raw material: Up to 25 mm
- If the raw material exceeds the specified size, then the plant would also require a cutter
- Moisture content: Up to 12%
- If the raw material exceeds the specified moisture content, the plant would also require a dryer

Raw Material Types Accepted by the Plant

- Groundnut shells
- Cotton stalks
- Coffee/rice/sunflower husks
- Bamboo/coconut dust; sawdust
- Sugarcane bagasse
- Any type of agro forestry waste

Finished Product – Briquettes

Briquettes are a ready substitute for lignite/coal/wood in industrial boilers and brick kilns. Biomass briquettes are a non-conventional source of energy that are eco-friendly, non-polluting and economical. Moreover, the process of converting biomass to solid fuel is also non-polluting. As the process does not require the addition of extraneous binders/chemicals, it is 100% natural.

- Briquettes have a higher practical thermal calorific value of around 4,000 kcal/kg
- Briquettes are economical and cheaper than other solid fuels

[1] The details listed in this Annex have been provided by companies contacted for this information. UNEP does not assume any responsibility for the correctness or completeness of the same.

- Briquettes have a lower ash content (2 - 5%) compared to other fuel. There is no fly ash generated upon burning.
- Briquettes have consistent quality and a high burning efficiency and they are ideally sized for complete combustion.
- Combustion is more uniform than that of coal. Moreover, boiler response to changes in steam requirements is faster due to the higher quantity of volatile matter in the briquettes.
- Briquettes are usually produced near consumption centers and supplies do not depend on erratic transport across long distances (unlike coal, for example).

Briquettes are Widely Used in Multiple Thermal Applications

- Gasifier systems
- Brick kilns
- Chemical units
- Textile units
- Solvent extraction plants
- Vegetable plants
- Ceramic industries
- Milk plants
- Dyeing plants
- Lamination industries
- Food processing industries
- Leather industries

Technical Specifications and Other Data

- Briquettes diameter: 90 mm
- Briquettes length: 150 mm – 550 mm
- Production capacity: 1,800 kg/hr
- Raw material size: 1 mm to 25 mm
- Moisture content of raw material: Less than 10 – 12 % (If the raw material exceeds 15% moisture content, a dryer would also be required)
- Total weight of complete plant: ~ 8,600 kg
-

Electricity/Power Requirements

- Required power connection: 88.5 HP 66.37 KW 440 V
- Practical used Amp. Load: 75 –85 Amp
- Power consumption: 35 – 40 units / hr

- Press model: JUMBO-BRQ 9075

Labor Requirements

- Trained and skilled operator: One per shift
- Unskilled labor: Six per shift
- Manager in-charge: One

Production Capacity

Production capacity is highly dependent on the density of the raw material used.

- Sugarcane bagasse: ~ 1,000 kg/hr
- Groundnut shells: ~ 1,800 kg/hr
- Sawdust: ~1,600 kg/hr

SCOPE OF JKL Pvt. Ltd.

Providing the Main Unit

- Briquetting press
- Electric motor 75 HP, 1,440 rpm with motor rail and motor pulley
- Complete lubrication and filter system
- 2 HP electric motor for lubrication with oil pump and pressure gauge
- Feeding kupy with 5 nu gear and 7.5 hp 1,440 rpm motor and accessory
- Auxiliary spares like ram, taper die, collets, split die and oil seal
- Die holder and ring clamp
- Die holder press clamp
- Main get and cooling lines
- Electrical panel board for operating and controls
- Foundation bolts
- Endless nylon flat belt
- Heat exchanger (shell-tube type)
- Load wheel pulley

Spares etc. Provided along with the Plant

Continuous wear and tier parts supplied along with the JUMBO-BRQ 9075 press:

- Ram: 2 no.
- Taper die: 2 no.
- Collette: 4 no.
- Split die: 2 no.
- Oil seals (for crank, piston, ram, feeder box): 2 sets

- Kit of spanners and tools: 1 set
- Feeder box: 1 no.

Providing the Material Handling Unit

- Screw conveyor 20 ft long with 5 mm worm thickness
- Reduction gear with 3 HP electric motor
- Variable pulley and V-belt for speed control

Commercial Offer

Please refer to the table below for the cost of design, development, procurement of materials, inspection during construction, safe storage on site, erection, testing and commissioning of the Briquetting Plant.

No.	Particulars	Qty.	Rate	Amount (INR)
01	Briquetting Press	01	1,450,000.00	1,450,000.00
02	Material Handling Equipment	01	Included	Included
			Total	**1,450,000.00**

Terms and conditions

Payment Schedule

- 40% of the ordered value in advance, along with client's confirmed order.
- 20% of the ordered value within 30days from date of client's confirmed order.
- Balance at the time of delivery (before dispatch).

Taxes

Shall be charged extra as applicable at actual cost at the time of delivery.

Excise Duty

Shall be charged extra; however, at present it is exempted.

Octroi

If any are applicable, they shall be paid by the client.

Transportation

Our offer is ex-factory. Freight, transportation, unloading, crane charges, transit insurance etc. will be paid by the client. Any damages incurred during transportation are not the company's responsibility.

General Terms and Conditions

1. Prices: Prices quoted are ex-company works.

2. Packing and forwarding: Extra at actual (if required).

3. Taxes and duties: Central and state government sales taxes, VAT, Octroi and other statutory devices as applicable at the time of delivery will be borne by the client.

4. Delivery: The delivery period will be effected ex-company works from the date of receipt of the technically and commercially cleared order with advance payment. The delivery period quoted is good faith and is subject to a *force majeure* clause.

5. Erection: During erection and commissioning of equipment, the services of unskilled laborers, gas cutting/welding set, standard tools, chain pulley, crane, water supply, power supply, and oil supply would need to be provided by the client free of cost, as and when required by the company's erection team. The client shall also arrange for lodging for the company's erection team.

6. Inspection: If inspection prior to dispatch is required, inspection of various equipment can be accomplished at the company's works at the client's cost. At least 4 days advance notice is required of the specified date. All material shall however be tested under no load conditions.

7. *Force Majeure*: The company shall not be liable for causes beyond its control such as war, strikes, lockouts, fires, accidents, epidemics, failure of electric supply, shortage of materials or labor or order of government or other authority.

8. Warranty: The company will provide a warranty to replace free of cost ex-company works any component found defective. However, damages incurred during transit, improper storage or misuse in the handling of equipment at the client's site are not covered under this warranty. This warranty will be valid for a period of 12 months from the date of dispatch of equipment. Civil engineering works of any nature, water tanks/pipe lines, cabling to the control panel, and the shifting of equipment from the store to the erection site are also not covered under the warranty.

9. Validity: The offer is valid for a period of 60 days, after which it is subject to the company's confirmation.

About the UNEP Division of Technology, Industry and Economics

Set up in 1975, three years after UNEP was created, the Division of Technology, Industry and Economics (DTIE) provides solutions to policy-makers and helps change the business environment by offering platforms for dialogue and co-operation, innovative policy options, pilot projects and creative market mechanisms.

DTIE plays a leading role in three of the six UNEP strategic priorities: **climate change, harmful substances and hazardous waste, resource efficiency**.

DTIE is also actively contributing to the **Green Economy Initiative** launched by UNEP in 2008. This aims to shift national and world economies on to a new path, in which jobs and output growth are driven by increased investment in green sectors, and by a switch of consumers' preferences towards environmentally friendly goods and services.

Moreover, DTIE is responsible for **fulfilling UNEP's mandate as an implementing agency for the Montreal Protocol Multilateral Fund** and plays an executing role for a number of UNEP projects financed by the Global Environment Facility.

The Office of the Director, located in Paris, coordinates activities through:

> **The International Environmental Technology Centre - IETC** (Osaka), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.
> **Sustainable Consumption and Production** (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.
> **Chemicals** (Geneva), which catalyses global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.
> **Energy** (Paris and Nairobi), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.
> **OzonAction** (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.
> **Economics and Trade** (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies. This branch is also charged with producing green economy reports.

DTIE works with many partners (other UN agencies and programmes, international organizations, governments, non-governmental organizations, business, industry, the media and the public) to raise awareness, improve the transfer of knowledge and information, foster technological cooperation and implement international conventions and agreements.

For more information, www.unep.org/dtie

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This booklet contains the fundamental information needed to conduct the Sustainability Assessment of Technologies (SAT). The manual explains the basic steps along with case studies to determine technologies best suited for the stakeholders' needs.

Environmentally Sound Technologies (ESTs) in the context of sustainability were highlighted within the Agenda 21 at the United Nations Conference on Environment and Development (UNCED) in 1992. IETC accordingly initiated the development of the methodology for the Environmental Technology Assessment (EnTA). By further improving the EnTA methodology, IETC developed the Sustainability Assessment of Technologies (SAT), which focuses on both the process and outcome. This methodology has been extensively used in the field, and a guidance manual developed based on the feedback and requests from various stakeholders including policy makers and practitioners. This manual incorporates SAT methodology for both strategic and operational level assessments while enabling application on any or all scenarios in the context of sustainable socio-economic development.

DTI/1581/JA