Economics of Greenhouse Gas Limitations

Country Study Series

Senegal

Ministry of Environment and Nature Protection
Department of Environment

Senegal

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1 Country Profile

1.1 Geo-climatic Characteristics

Together with the Cape Verdian Peninsula, Senegal occupies the extreme expanse of West Africa in the Atlantic Ocean. Senegal has an area of 196 722 km^2. It is a flat country, which does not exceed 130 metres above sea level, except for the south-east region, which has an occasionally hilly relief and whose altitude does not exceed 581 metres at the peak of the Fouta-Djalon foothills.

The climate is subject to both geographical factors and atmospheric influences. Actually, the presence of a seashore extending over 700 km and its location on the West-end of the African continent, result in climatic variations between the coastal zone and the hinterland. Likewise, the atmospheric circulation, facilitated by an obstacle-free relief puts the country under the influence of the tradewind, harmattan and monsoon. Such masses of air determine two seasons which are differentiated by the amount of rainfall:

- a long dry season, from November to May/June, with a predominance of the maritime tradewinds along the coastal region, while the hinterland is under the influence of a Saharan continental tradewind: the Harmattan.
- a short rainy season, with the monsoon. Rainfall ranges from 800mm/year to 1500mm/year in the Southern region.

1.2 Demographic trends

The population is estimated at 8.133 million inhabitants. With a population growth rate close to 2.7% per year, Senegal experiences a very high pace of demographic growth. At this rate, the population of Senegal doubles every 25 years, and will exceed 15 million inhabitants by the year 2015. The steady drop in mortality (particularly that of children under 5 years of age) and the maintaining of a relatively stable fertility rate, have contributed to rapid population growth.

The last 1988 population census confirmed the present migratory trends. Thus, Dakar (Cape Verde region), together with Tambacounda, recorded the highest migration rate. Since 1988, the regions of Kaolack and Fatick, offshoots of the former Sine-Saloum region, have become regions of departure for migrants.

Such migratory influx, combined with the rapid growth in population, have led to far-reaching changes in population distribution over the past three decades which succeeded the period of independence. As a result, there has been an increasingly high demographic pressure in the Central and Western parts of the country where the level of economic and religious activities is very high, like Dakar, Thiès, Diourbel, Kaolack and Fatick. They, alone, accounted for 63.4% of the population in 1994, and yet they only cover 18% of the total surface area. Such a situation is reflected by great disparities in terms of density, ranging from 50 to 2730 inhabitants/km^2.

This demographic pressure creates problems in the management of household waste disposals, pollution by domestic and industrial used water, sanitation and water supply, thus exposing communities to health hazards. In the rural areas, the problems brought about by the demographic growth on the standard of life and the environment are generally in the form of pressure on natural resources (deforestation, overgrazing), which led to a decline in environmental potentials (loss of biological diversity, lowering of water tables, scarcity of halieutic resources, etc.).

According to the findings of the «Senegalese Surveys with ESAM Households, March 1994-April 1995», the Senegalese population is composed of 777 931 households (the average size of a household in the whole country being 10.2 persons).

As regards the level of comfort, it is observed from this survey, that 52% of households enjoy no comfort at all (being deprived of water, electricity and water Closets in their homes) and rural dwellers include the most affected (81%). In Dakar, less than 5% of the population are affected as against 23.8% in the other cities. In terms of the lighting system, 28% of Senegalese households use electricity, 60% of which reside in urban areas. Over half of the households (55.5%) use firewood as fuel for cooking and one out of five households, uses charcoal.

1.3 Socio-economic Context

The structure and functioning of the Senegalese economy remain marked by:

a) an agricultural system all the more dependent on rainfall and mainly extensive despite the dual impact of the demographic pressure on the soil since independence (from three million inhabitants in 1960, the population increased to over eight million in 1995);
b) a persistent deterioration of natural resources caused by repeated drought cycles and human activities (increased quantity of wood felling, bush fires, etc.);
c) an industry caught up in the difficulty of adapting to the new conditions of competition (opening up of borders and reduction in tariff protection);
d) a balance of trade structurally in deficit (by at least 25%) together with a persistent deterioration of foreign assets and an increasing external debt burden. The actual debt sky-rocketed from US$ 455 million in 1977 to US$ 4139 million in 1989;
e) gross domestic savings which still remains low (less than 10% of the GDP and inadequate for investment financing);
f) public services not commensurate with demand: inadequate health coverage, low school enrolment rate (63,4% of the population are illiterate according to the ESAM Households Survey, 1994-1995).

Following the currency devaluation of January 11, 1994, a new era with a number of challenges was ushered in. The breakdown with regards to the past which is symbolised by the devaluation, stabilisation, the rehabilitation of public finances and introduction of a solid dose of liberalism made it possible to revert to growth, which in December 1994 was to the tune of 2%. Both budget deficit and inflation have decreased considerably. Notwithstanding the various economic policy initiatives, the lack of dynamism in the economy remained a serious concern.

1.3.1 Primary Sector

The analysis of the 1990 Input/Output Table reveals that productive sectors are weakly inadequately integrated. At the level of the primary sector, agriculture has always occupied a strategic position in the economy due to its significant contribution towards the formation of the GDP. This contribution has nevertheless showed a downward trend, since between 1960/86 it was at 18.8% but between 87 and 93, it came to only to 11% of GDP.

Such a decline stems from the unfavourable evolution of rainfall and the steady removal of subsidies within the framework of the New Agricultural Policy (NAP) introduced in 1984. The objectives of this new policy were (i) a greater empowerment of peasants by transferring to them some of the roles formerly entrusted to state agencies (liberalisation and marketing of cereals in 1986); (ii) a review of the price policy for agricultural inputs; (iii) less government intervention and a reduction of the subsidies; and (iv) a development of a Cereal Plan to ensure food self-sufficiency.

The primary sector is endowed with significant potentialities: out of the 19.7 million hectares representing the country's total surface area, 3.8 million hectares are arable. Of these, 2.4 hectares are effectively cultivated. Senegal also has underground water resources and superficial water tables (hence the importance of the River Valley).

Regarding animal husbandry, the sharp increase in the number of cattle at the wake of independence has significantly declined. Small ruminants resisted better to the effects of drought. As for poultry, the number doubled during the period of the 8th Plan. This sub-sector contributes for close to 7.3% to the formation of GDP, which is 1/3 of primary sector GDP. From 1960, the implementation of the animal husbandry policy made it possible to obtain significant results in relation to cattle. Major accomplishments were recorded in the area of animal health and water supply.

Today, the sector is however faced with a number of difficulties which have had negative repercussions on the natural environment. The Structural Adjustment Policy has led to the disappearance of large poles of animal husbandry, and a new element has emerged in terms of pastoral problems: economic operators which are inserted into the animal production activity.

The high demographic growth and the expansion of agricultural clearings together with the rapid change in the modes of land use have brought about a reduction in the pastoral space. Moreover, the exploitation of fragile land through the use of bush-fires to stimulate fresh growth of grass makes soils vulnerable to erosion which leads to a rapid exhaustion of grazing land with bare soils.

Fishery, on its part, has recorded tremendous growth which places it among the most important sectors in terms of export earnings. With a sea surface of close to 700km, this sub-sector provides the domestic market with fresh products of high quality. It is also at the origin of a remarkable processing industry. In actual fact, this fishery sector accounts for 11% of primary sector GDP, with over 215 000 direct jobs.

Potentialities of fishing depend on two factors: the sea space with a zone of up-welling which is rich in mineral salts and suitable for the development of juveniles, and the large biological diversity. However, the tendency for over-exploitation of resources through industrial fishing and the use of explosives as well as pollution of our coasts are factors likely to hinder the development of this sector. It should also be noted that fishing has a certain number of negative environmental impacts including the destruction of certain habitats through the use some fishing devices, over-exploitation of the mangrove for the gathering and processing of sea products, and high human and industrial concentration in the maritime domain.

Regarding the forestry sector, the surface areas of forest formations continue to diminish, from 12.7 million ha in 1981 to 11.9 ha in 1991, which is a clear deforestation of 80 000 ha/year. In addition to human activity, the sector is beset with a drop in rainfall, resulting in a reduction in the water table, a salting and acidification of soils.

With the implementation of the Forest Development Plan, a lot of progress was observed with the development of rural forestry and participatory approach. The revision of the forestry code in February 1995 further encouraged the involvement of populations in the management of natural resources. The orientations of the plan were revisited in the Senegal Forestry Action Plan (PAFS) prepared in 1993.

1.3.2 Secondary and tertiary sectors

Well before independence, Senegal enjoyed an industrial infrastructure, with a market corresponding to the limits of the then French West Africa (AOF). Following independence, as each country resorted to import-substitution industrialisation, the Senegalese market became narrower and narrower, thus bringing industries to the level of very small national markets. However, in the last years the contribution to the GDP has increased from 16.6% in 1994 to 19.5% in 1995 year, being the agro-industry and extractive industries the main contributors.

In an effort to restore competitiveness and reduce distortions in the allocation of resources, in 1986, the state revised the industrial policy. Yet, the measures put forward were, to some extent, difficult to reconcile. Following the CFA devaluation a new industrial development policy was introduced (Adjustment and Competitiveness Project). This new strategy is essentially based on flexible market operations, the reinforcement of domestic competitiveness through price liberalisation and removal of obstacles to the entry of new competitors, the liberalisation of trade and promotion of export activities, and the enhancement of the legal and statutory framework and investment incentives.

In 1993/1994, the estimated number of industrial business organisations was 452, with a gross investment of 900 billion FCFA and a value added of 240 billion FCFA. Half of the industrial sub-sector turnover, which is 805 billion FCFA, was derived from food industries (56%). Then come chemical industries (26%), extractive industries (9%), textile industries (5%), fishery and agriculture (3%) respectively. It is worth noting that the volume of public investments in the industrial sub-sector dropped from 8.7 to 2.2 billion FCFA between 1994 and 1995, with a tendency for recovery in 1996.

The contribution of the Tertiary Sector to GDP rose from 47.82% in 1983 to 49.1% in 1994. This slight increase was due to the unfavourable development of the transportation sector as the main source of the tertiary.

Transportation is organised only in very few cities. In Dakar, where the size of the population and the level of economic activity is very high, this service is provided by private individuals and public operators. Public operators have an insignificant share of the traffic. SOTRAC has experienced a decline in its activities following a drop in its fleet. As for the *Petit Train Bleu* introduced in 1981, it operates with an estimated share of 2% of the traffic. The car fleet has an average of 13 years old. It is a large energy consuming sector compared to the consumption by industrial sector (53% in 1988 of the conventional final energy consumption). Hence, the sector contributes a great deal to atmospheric pollution in general, especially in the big cities.

1.3.3 Social Sectors

The economic and financial crisis confronting Senegal since the early 1980s has considerably undermined the capacity of the state to set up adequate infrastructures and in sufficient proportion in the social sectors.

In terms of operations and investments, resources allocated declined by 0.9% per annum during the Economic and Financial Recovery Programme - EFRP (PREF) and by 0.2% during the Medium and Long Term Adjustment Programme - (PAMLT). Public expenditure on the social domain has diminished. In the health sector, expenditure per head went from 653 FCFA down to 427 FCFA between 1985 and 1992. During this adjustment period, this sector was marked by a high rate of maternal mortality (51 for 1000) and infant mortality (68 for 1000).

From 1989, the Senegalese State adopted a new health based on the promotion of primary health care. Main strategies of this policy include the improvement of health coverage, particularly in rural and semi-urban areas, control of the demographic variable (with the National Family Planning Programme), reinforcement of mother and child health care, and the development of preventive actions.

Concerning education, expenditure per head has dropped from 2268 FCFA in 1978/79 to 1841 FCFA in 1988/89 at a time when demand for education experienced a steady increase. Illiteracy affects 77% of the rural population, 40% of the population in Dakar and 5O% in the other urban centres.

The Government has emphasised in a greater control of the influx between the various levels of education and on the management of education services. Restructuring measures are ongoing and these give priority to primary education in an attempt to increase the school enrolment rate and to narrow the gap between urban and rural areas, on the one hand, and between boys and girls, on the other.

1.4 Environmental Policies

Environmental policy in Senegal is characterised by two phases:

- an initial phase whereby the environment was perceived as an accompanying sector (successively for industry, town-planning, tourism, etc.) and where its link with development was ill-established ;
- a second phase where, with the release of the Brunthland Commission Report and the holding of the Earth Summit in Rio de Janeiro (Brazil), the Environment was then regarded as the fundamental basis of sustainable development.

This first phase was characterised by the adoption of a fairly centralising approach by the state. Being omnipresent, the state designs and implements large-scale projects, especially in the area of reforestation, a major axis of its environmental policy, without any attempt to involve local actors in the implementation and monitoring of environmental protection actions. Within the framework of this approach, some major shortcomings could be seen in:

- system of vertical planning;
- different statutory legislative system;
- lack of articulation between environmental and sectoral policies;
- inconsistency between spatial development scheme at national and regional schemes;
- poor adaptability of instruments to local conditions ;
- lack of information, education, and communication policy.

Added to these is a deficiency in the state services in the face of the new environmental challenges, i.e. the management of dangerous wastes, climatic changes, destruction of the ozone layer, etc. In the face of such challenges, the state structures are not well braced both in terms of training and financial resources.

Following the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in June 1992, the government has started to adopt a more consistent approach in dealing with environmental problems under a perspective of sustainable development. In this respect, highly strategic measures have been taken to readjust and reinforce the institutional machinery responsible for the management of the environment and natural resources.

1.4.1 The Institutional Context

The Ministry of Environment and Nature Protection (MEPN) was created in June 1993. This ministerial department responsible for formulating and implementing the Government's policy on environment, combines for the first time, the major technical departments charged with the management of the environment and natural resources. These include the Environmental Department, the National Parks Department, the Water and Natural Resources, and the Hunting and Soils Conservation Department.

The combination of these technical structures under the same ministerial head offers the advantage of reducing the possibilities of conflicts or competition and creates conditions for a better harmonisation of actions. Since then, environmental concerns were no longer subordinated to the desire of promoting one single sector of activity as was often the case in the past when the Environment was successively blended with the Industry, Town planning and Tourism. The objective is to break away from sectoral approaches which often contributed towards reducing the impact of programmes initiated and to bask in the conviction of the existence of a strong interdependence between the Environment and Development.

The Ministry for Environment has adopted a prevention policy around to the following major axes:

a) combating pollution and its harmful effects;
b) conservation and regeneration of soils;
c) reforestation, aforestation and bush-fire control;
d) preservation and extension of natural reserves and national parks;
e) partnership with local communities, NGOs and grassroots communities; and
f) environmental impact assessments of development projects.

Under the criterium that a single ministerial department cannot manage cross-cutting sector environmental issues, the government has established the High Council for Environment and Natural Resources and the National Commission for Sustainable Development.

1.4.2 The National Action Plan for the Environment (PNAE)

The formulation of PNAE has been the first priority of the Council for Environment. The PNAE is meant to be the frame for different sectoral strategies and policies. The plan was launched in February 1995 on the basis of a participatory and decentralised approach. It covers the following themes:

- institutional and legislative framework, land development, development planning;
- local land management and decentralisation policy within the framework of an integrated approach to environmental problems;
- issue of the deterioration of the living standards;
- environmental Research, Education and Communication;
- highly vulnerable eco-systems (maritime and coastal environment, humid zones, etc.);
- biological diversity;
- desertification; and
- funding mechanisms for management actions of natural resources and the environment.

1.4.3 International Conventions

Because of the cross-border nature most of environmental problems and the threats these exert on nature and men, Senegal has always shown great solidarity with the rest of the world and is part to a number of international conventions This commitment on the part of Senegal in the resolution of the problems confronting the whole planet reflects its determination to participate actively in the international mobilisation in favour of environment protection and the rational use of natural resources, as well as its political determination not to lag behind the rest of the international community.

Among the international conventions Senegal is party to, one can mention:

- the Abidjan Convention relating to the co-operation in the field of coastal zones protection and development, as well as its protocol relating to the co-operation in pollution control in critical situation, which came into force in 1984;
- the Vienna Convention and the Montreal Protocol on the substances depleting the ozone layer, ratified in 1993;
- the Convention on bio-diversity, ratified in June 1994;
- the International Convention on desertification control in severely drought-stricken countries and/or countries that are deeply affected by desertification in Africa;
- the Convention on Climatic Changes, ratified in 1994.

2 OVERVIEW OF ENERGY SECTOR AND GHG EMISSIONS

Like many non-oil producing countries belonging to the Sahelian region, Senegal exhibits an energy situation characterised by three (3) major factors:

a) an external energy dependence for nearly all the national hydrocarbon requirements meant for the production of commercial energies;
b) a high consumption of fuel wood in relation to the availability and regeneration rate of national forest resources;
c) power generation, essentially thermal, dependent on imported oil, and whose distribution is a monopoly of a single company.

2.1 Energy Resources

2.1.1 Fossil energies

Although several studies and oil exploration activities have identified probable reserves of fossil fuels, especially natural gas and crude oil deposits, no eminent plants for exploitation have been made. The domestic supply of fuels contributes marginally to the overall national energy supply.

Table 2.1. Primary energy production (toe)

	1988	1991
Crude oil	2560	579
Natural gas	7510	4 056
Methane		11
Wood and charcoal		310 758
Bagasse	149 330	123 620
Groundnut shells		50 856

In 1997, The General Manager of PETROSEN, (Société des Pétroles du Senegal) announced the discovery of a deposit of ten billion cubic metres of natural gas in Gadiaga, in the Region of Thiès, which can cover national requirements for at least thirty years. This announcement confirmed all the oil potential promised to the country by the numerous other more or less important discoveries in the early 60s, in the Region of Thiès, at Diam Niadio more precisely, and later, in the South of the country in Casamance.

Total deposits of peat resources are estimated at 52 million cubic metres mainly in the region of Niayes. According to the post-study valorisation option adopted, peat could substitute charcoal. By giving priority to this option at the detriment of industrial exploitation for power generation, the state intends to save thousands of hectares of forest, and after the exploitation of peat, stands the benefit from peat-rich zones with more fertile soils advantageous for market-gardening. For the time being, the technical and economic feasibility studies have been finalised and the concrete operational phase is expected to start off any time from now. Negotiations are underway with the African Development Bank (ADB) for the funding of a pilot project . It is believed that some forty thousand tons of briquettes over a period of twenty years could be produced annually.

The first traces of lignite were discovered in Senegal in 1982 within the framework of the oil and water explorations carried out in the upper layers of the Maestrichian. These traces were later confirmed during the two campaigns launched by the Government with the financial assistance of the *Coopération Française*. Presently, the ultimate objective is to pursue its prospecting, particularly around the Lac de Guiers, and it is believed that the use of this lignite could also contribute towards reducing the oil debt.

2.1.2 Hydro-power

Two international rivers, the Gambia and the Senegal, flow through and along the country's border. These rivers offer a substantial hydro potential of about 1000 Mw. Much of this potential lies in the Senegal river basin and requires ongoing coordination among Senegal and neighbouring Mauritania and Mali for full realisation. One dam has already been completed in Mali (Manantali) with plans under way for installing 200 Mw of power capacity and constructing transmission lines to load centres. It is expected that the project will be operational by the year 2000. An additional dam (Felou) with an expected capacity of 106 Mw is also planned. Undoubtedly, these plans will substantially contribute to reducing the country's energy dependence, pending further developments along the Senegal River or the Gambia River.

2.1.3 New and Renewable Energies

With over 3000 hours of sushine and a global radiation of 2000 kWh/m2/year, Senegal has a considerable solar energy resources which could encourage large-scale exploitation for energetic purposes. Already, as part of the bilateral cooperation with northern partners like Japan and Germany, the state has made concrete moves towards valorising such resource.

Important steps have been accomplished within the framework of the execution of certain projects. For instance, photo-voltaic solar stations (this form of valorisation seems to be the most promising) were installed in several places including Niaga Wolof, Notto, Diaoulé and Ndiébel - and over 1500 photo-voltaic domestic systems have been spread across the country. Today, it is a generally accepted fact that solar energy offers great opportunities, particularly for rural electrification. In this respect, a large-scale programme for the development of solar energy applications in rural areas, estimated at 40 billion FCFA, has been drawn up by the Government.

Concerning the wind energy potential few attempts have been made for tapping this resource. In the coastal strip located in the regions of Thiès and Dakar, a few windmills have been installed for the pumping of water, very often with the support of NGOs. But globally, there have been many failures due to the unwise choice of sites. That is why an evaluation of wind energy potential was undertaken and the findings are available at the National Meteorological Service in the form of wind speed maps.

And along the coastal-line between Dakar and St.Louis, the wind speed ranges between 3.7m/s and 6.1m/s.

Agricultural and animal wastes provide great possibilities for the utilisation of energy, which are presently largely under-exploited. Only a few agro-industries use agricultural residues in the production of electricity for self-consumption. However, since 1992, the state has shown a keen interest in the promotion of an alternative type of energy. Produced from the fermentation of organic wastes, biogas does not only make it possible to have an energy resource, but also to improve the environment and to get good quality manure.

2.2 Energy Supply and Consumption

Biomass energy accounts for 38% of total energy supply. This reflects the importance of the consumption of firewood in Senegal, particularly, in cities like Dakar which, in 1995 absorbed 93.000 tons, which is over half of the consumption of charcoal and 33 000 tons of firewood. Thus, some 4 million m^3 of wood, which is, (330 000 t. of charcoal and 1 500 000t of firewood) are consumed annually, which, given the highly uneven distribution of the forest cover in Senegal, leads to very serious problems of desertification in some regions. Production of such combustibles results from an exploitation of the forest which takes away some 30 000 hectares of forest per annum.

Table 2.2. Energy Balance - 1994

Unit: 10^3 toe	oil	Oil products	Gas	Electricity	Total	Biomass	Total
Production	0.3		16.9	83.5	100.7	530.1	630.8
Imports	303.7	794.0			1097.7		1097.7
Exports		87.7			86.7		86.7
Stocks	124.4	35.6			159.0		259.0
Total primary energy	179.6	670.7	16.9	83.5	950.7	530.1	1382.8
Refinery	179.2	-170.3			8.9		8.9
SENELEC		306.4	16.9	-80.2	243.1		243.1
Self producers		15.4		-2.7	12.7	155.1	170.5
Charcoal						292.2	292.2
Total transformation		151.5		-82.9	68.6	447.3	515.9
Loses, self-consumption	0.4	3.1		16.3	19.8		19.8
Final consumption		551.9		66.6	618.5	82.8	701.3

However, over the past few years, there has been a downward trend in consumption due to a highly voluntary policy of the state which, by increasing forest taxes and user fees, has made the firewood consumer-price less competitive. And gradually, the communities are shifting to such other sources of energy as butane gas which is increasingly in demand by urban populations. From 1974 to date, a butanisation policy has been embarked upon (55 000t. gas in 1995) by the public authorities. It made it possible to save 90 000 t. of charcoal in 1994, i.e. the preservation of some 10 000 ha of natural forest. Alongside this butanisation policy, some possibilities of substititution fuels are under study: kerosene, peat briquettes, rice straw balls.

Wood, in its natural state or when processed into charcoal, is used essentially for cooking. Because of the poor performance of traditional stoves, cooking requires 5 to 7 times more energy than in the industrial countries.

The quasi-totality of energies available in Senegal (petrol, gas, fuel, electricity) are produced from imported oil which represents 35% (oil fuels) and 5% (thermal power) of the energy balance. In addition to the external dependence caused by this, another negative consequence of this situation is the huge oil bill which represented up to 40% of the country's export earnings in the 80s.

The African Refinery Company (SAR), which owns a single refinery, is responsible for the refinery and supply of oil products for the national market and, where necessary, satisfies the demands of the neighbouring countries (Gambia, Guinea Bissau, Mali, Mauritania, etc.). On average, imports amount to 900 000 T per annum. For the year 1994, as a result of the devaluation of the CFA, the oil bill went from 57 billions of CFA to 78.9 billions of CFA out of a purchase of 302782 T of crude oil and 782344 T of finished product. Table 2.3 below shows the evolution of imports of oil products by S.A.R.

Table 2.3. Evolution of S.A.R oil imports from 1989 to 1995

Year	Crude Oil (10^3 Tons)	Products (10^3 Tons)	Total Costs (Million CFA)
1989	583.0	322.6	40933
1990	642.0	225.2	39727
1991	505.8	335.7	42100
1992	643.3	357.1	65100
1993	545.7	364.7	57000
1994	302.8	782.3	78921
1995	660.0	227.8	61096

Thermal electricity plays a key-role in the National Energy Policy and is almost exclusively produced by SENELEC which is also responsible for both distribution and sale. A few local industries like CSS, SONACOS, ICS, SAR, *les Grands Moulins* and SNTI, generate electricity which they use for their own energy requirements and resell the surplus production to SENELEC.

Thus, SENELEC has the monopoly of electricity distribution in Senegal and has a total installation capacity of 295.6 MW and produces about 1000 Gwh per year for a consumption of 300 000 tons of oil products. Distribution is carried out through the interconnected network of a total capacity of 271.3 MW to which are added two regional stations in Ziguinchor and Tambacounda, for a total capacity of 14.5 MW, as well as secondary stations of 9.8 MW distributed in 24 sites across the country. However, rural electrification is still limited, 3% against 50% in the urban environment.

Final energy consumption by main sectors and energy products is depicted in Table 2.4. Comparing across sectors, the transport sector accounts for 42% of total final consumption. This consumption represents 54% of oil products consumption in the country.

Table 2.4. Final energy consumption (1991)

Unit: 10^3 toe	Gasoline Kerosene	Diesel Fuel oil	LPG	Total Oil	Electricity	Biomass	Total
Industry		182.4		182.4	19.2		201.6
Fishery	21.2			21.2			21.2
Transport	193.7	113.5		307.2			307.2
Households	9.9	1.3	41.8	52.9	44.2	104.4	201.5
Total	224.8	297.2	41.8	563.7	63.4	104.4	731.5

Electricity accounts for 14% of final energy consumption. Electricity demand is concentrated in urban areas. Electrification rate is 50% in urban areas and 5% in rural areas, and the national average rate of electricity spread is 28.50%. In sparsely populated rural areas electricity demand is concentrated in several low-capacity consumption centres, ranging from a few kws to some hundred kws. Urban population who represent about 42% of the total population consume 95% of the commercial energies.

2.3 Energy Policy

With the exception of the supply of fuel wood combustibles placed under the authority of the Ministry of Environment and Nature Protection and managed by local communities, the responsibility for the administrative and technical management of all the energy sector is entrusted to the Ministry of Mines and Industry. Nevertheless, the choice and orientations in the area of energy policy are defined by the National Energy Commission which is an inter-ministerial organisation presided over by the Prime Minister.

In the specific area of research on and promotion of new and renewable energies, in addition to the role played by such administrative and technical structures as the *Direction de l'énergie* and the *Délégation aux affaires scientifiques et techniques*, there is the outstanding contribution on the part of the *Centre d'Etudes et Recherches sur les Energies Renouvelables* (CERER) and the *Ecole Supérieure Polytechnique* (ESP).

A certain number of funds have been allocated to assist in the implementation of the energy policy. The National Energy Fund (FNE), is supported by fiscal returns realised on oil products. It enables, among other things, the funding of rural and urban electrification programmes, conducting priority studies on the energy sector, covering the transport costs of oil products between Dakar and the regions in order to not penalise energy prices in rural areas.

A Preferencial Fund, intended to assist enterprises in difficulties in relation to their energy bill, was established from a tax on electricity consumption.

The oil crises of the 70s and 80s provided the occasion for Senegal to measure all the magnitude of its external energy dependency and to be aware of the extreme vulnerability of its economy in relation to the brutal fluctuations in the hydrocarbon prices on the international market. As misfortunes never come alone, negative impacts were also worsened by an often inadequate rainfall whose effects, coupled with those of excessive deforestation due to the ever-growing needs in fuel-wood, dealt a severe blow on forest areas.

This series of constraints deeply affected the national economy and, as a matter of fact, encouraged public authorities to set up a well-articulated policy in this field, given the strategic nature of the energy sector on which economic activities depend. Consequently, the state formulated the Energy Re-deployment Programme of Senegal (RENES) together with two (2) sub-programmes of rehabilitation of the electricity sector and of energy economics in the industries. Based on the characteristics of the energy situation, the policy designed by the public authorities for the promotion of the energy sector was mainly targeted at:

- reducing the energy dependence of the country on imported products;
- easing up the pressure on forest resources to contribute towards preserving the environment;
- supplying energy to urban and rural communities, in an efficient and sustainable manner, and at low cost;
- reducing the costs of the productive factors by reducing, if possible, the energy cost.

This policy is based on the deliberate application three principles: (i) energy re-deployment in favour of national fossil fuels and new and renewable energies; (ii) reduction of fuel-wood consumption; and (iii) rehabilitation and modernisation of energy infrastructures and rationalisation of distribution and consumption.

In order to implement such principles and attain such policy objectives, the state chose to integrate its action around the following axes:

- the institutional development and enhancement of managerial capacities of the sector ;
- the development of energy supply by embarking upon the valorisation of the hydro-electric potential and more consistent use of fossil fuels;
- the rationalisation of conditions of energy production, distribution and consumption, through the rehabilitation of the power sector, the gradual

readjustments of prices of oil products; for instance, energy savings in industries, dwelling places, and transports;
- the development of new and renewable energies and technological know-how by promoting the creation of an industrial fabric around research findings in the area of renewable energies;
- the acceleration of the pace of rural electrification.

2.4 The GHG Inventory

Following the IPCC Guidelines a Greenhouse Gas emissions inventory was established for the 1991 year. The inventory has been updated to 1994 year. A summary of the 1994 inventory is presented in Table 5.

The inventory has been carried out in the frame of a collaborative effort of the following agencies:

- Department of Environment (Direction de l'Environnement);
- Department of Energy (Direction de l'Energie);
- Centre for Ecological Monitoring (Centre de Suivi Ecologique);
- ENDA-Energy Programme (ENDA-Programme Energy);
- Department of Water, Forests, Hunting and Soil Conservation (Direction des Eaux et Forêts, Chasse et Conservation des Soils);
- Department of Agriculture (Direction de l'Agriculture);
- Department of Animal Husbandry (Direction de l'Elevage);
- Department of Industry (Direction de l'Industrie).

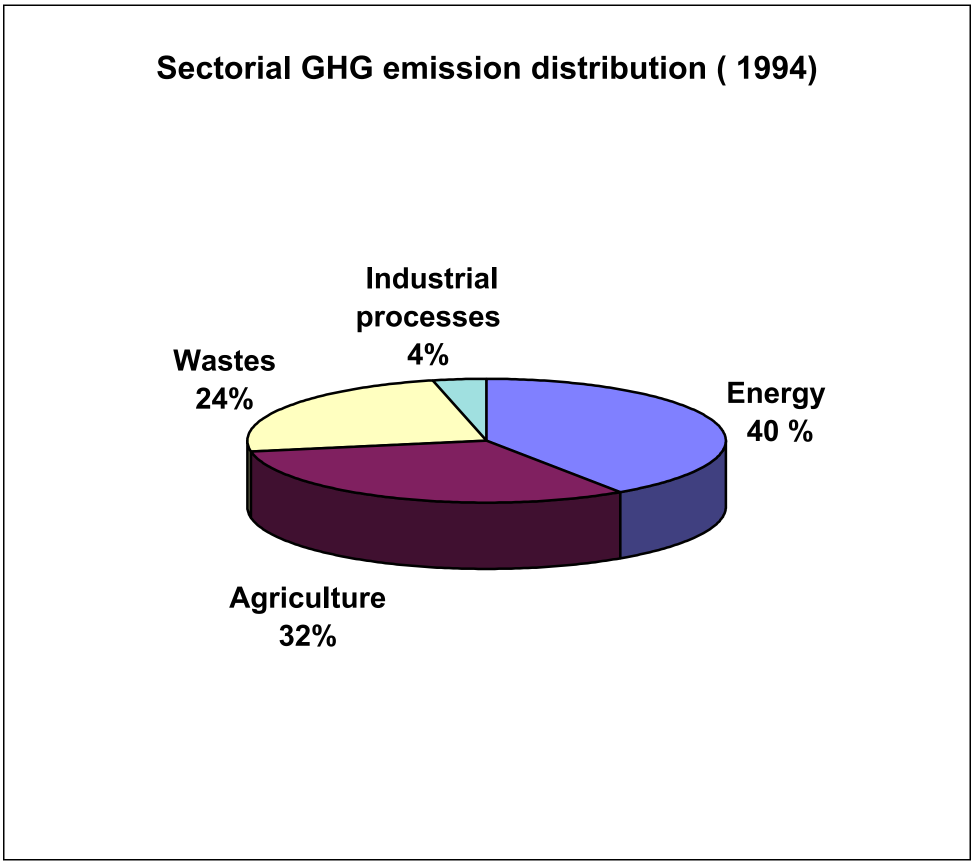
Raw data obtained from the energy balance were processed by multiplying the activity levels by a correspondent emission factor. All the emission factors used in the national inventory were IPCC default figures. It should be noted that CO2 emissions from biomass fuels, namely fuelwood and charcoal, were not included under the energy sector since in accordance with IPCC methodology, they are counted under the land-use change and forestry.

Emissions from land-use activities in Senegal originate mainly from forest clearing and on site burning, forest biomass decay, and off-site burning of fuelwood and charcoal. Carbon released by forest clearing was determined from estimations on annual loss of biomass, the fraction of biomass burnt on-site, the fraction of biomass oxidated, and the carbon content.

Regrowth of natural forests, regenerating after managed cultivation and/or abandonment of cultivated lands and reforestation plantation are the main carbon sinks considered in the inventory. The carbon uptake was calculated on the basis of estimations about biomass increment, taking into account of forest/biomass abandoned over 20 years, annual growth rate, and carbon fraction of dry matter.

Table 2.5. GHG Inventory (1994)

Modules	Emissions (Gg)					Gg Equivalent	
	CO_2	CH_4	CO	N_2O	NO_x	CO_2 equiv.	%
Module 1-Energy							
Energy sources	3660	5,38	41,25	0,032	1,17		
Petrol production/ Gas		0,27					
Total Module 1	3660	5,65	41,25	0,032	1,17	3788,6	40,6
Module 2-							
Industrial processes	345,5						
Total Module 2	345,5					345,5	3,7
Module 4- Agriculture							
CH_4 emission Animal		137,98					
Savannah Incineration		0,99	26	0,012	0,44		
Agricultural residues		1,19	25	0,034	1,25		
Total Module 4		140,16	51,00	0,046	1,69	2957,6	31,7
Module 5- Forest							
CO_2 from forest clearing	19244,5						
Trace gas		25,04	219,15	0,17	6,21		
Removal from exploited forest	-25820,0						
Total Module 5	-6575,5	25,04	219,15	0,17	6,21	-5997	
Module 6- Wastes							
CH_4 Public discharges		86,80					
CH_4 industrial wastewater		19,21					
Total Module 6		106,01				2226,2	24 %
Total of emissions	-2570	276,86	311,4	0,248	9,07	3321	100 %
GWP (100 years)	1	21		310			
GWP Equivalent CO_2	- 2570	5814		77		3321	100%



Net GHG emissions in Senegal are estimated at 3321 Gg of CO_2 equivalent. This amount represents an average of 408.3 kg ECO_2 per habitant. Energy related activities are the major source of emissions and accounts for more than 40% of total GHG emissions.

It is worth noting that GHG emissions have been largely mitigated by the sequestration capacity of protected forests. The residual sequestration capacity of forests being at 5997 Gg. CO_2, emissions from other sectors are added to this and this amounts to 9318 Gg ECO_2. There net emissions result in 3321 Gg of CO_2 equivalent.

3 METHODOLOGY AND BASELINE DEFINITION

3.1 Methodological Approach

This study largely draws on the guidelines developed by the UNEP Collaborating Centre on Energy and Environment (UCCEE) as part of the GEF project 'The Economics of Greenhouse Gas limitations'. The UCCEE guidelines provide a general overview of the main components of climate change mitigation assessment and define an analytical structure enough flexible to enable national analysis to be carried out with different focus and ambitions. The application of this analytical structure to the case of Senegal resulted in the following steps:

1) Comprehensive description of national framework for climate change mitigation including the analysis of the GHG inventory which provides information on emissions by sources and economic sectors; and an evaluation of main national economic and social trends and the expected associated GHG emissions.

2) Selection of the methodological approach to the mitigation analysis. There are two methods that are currently in use: (i) the top-down approach, more adapted to the industrial countries as it requires a maximum of data and adequately inter-related economic sectors and; (ii) the bottom-up approach, more appropriate for sectoral analysis, and also for developing countries like Senegal. This last method has been adopted in the present study.

3) Selection of quantitative models to be used in constructing scenarios as well as in the evaluation of mitigation options. The LEAP model has been selected for the analysis of the energy sector, while the mitigation options in the forestry sector were analysed with the aid of COMAP model. These models are briefly described in the next paragraph.

4) Baseline scenario projection which serves as a reference point for the whole analysis. The baseline scenario represents what might be happen if not effort was made to limit GHG emissions. At this level the future evolution of the economy is explored in relation to population growth trends, share of economic sectors in the economic growth, and the impact of technological change on both energy consumption and energy production.

5) Identification and selection of a set of relevant GHG abatement technologies. The cost assessment of technological options is complemented taking into account broader criteria as their sustainability, the adequacy for national environmental objectives, and their impact on other economic sectors.

6) Construction of a mitigation scenario based on a screening of potential individual projects for the sectors considered in the analysis. The mitigation scenario serves as a structural framework for assessing the impacts for implementing climate change mitigation options.

7) Qualitative description of main macroeconomic and social impacts and identification of main implementation requirements including: financial support, regulation policies, technologies, and institutional capacity building.

8) Use of results as main input for the formulation of a national climate change mitigation strategy.

3.2 Sectoral Models

The Comprehensive Mitigation Analysis Process (COMAP) is the model used to evaluate the forestry mitigation options. The model consist of a series of procedures allowing for: (i) identification and screening of mitigation options appropriate for carbon sequestration; (ii) assessment of the current and future land area for the selected mitigation options; (iii) determination of land area and wood production scenarios by mitigation option; (iv) estimation of the carbon sequestration per unit area for major available land classes, by option; and (v) evaluation of the cost effectiveness indicators for ranking mitigation options. A project by project evaluation has been undertaken with the aid of the structure of the COMAP model as illustrated in the process depicted in Figure 3.1.

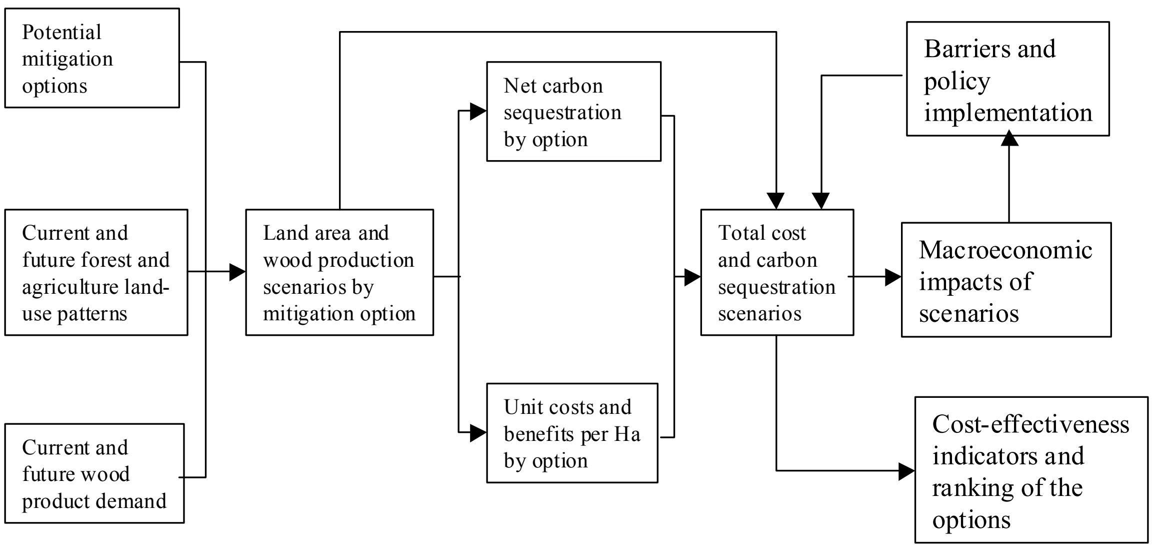


Figure 3.1. Comprehensive Mitigation Analysis Process (COMAP) for forestry

The analysis of energy scenarios and their associated emissions has been undertaken using the Long-Range Energy Alternatives Planning System (LEAP) model. The model enables users to analyse final energy demand, energy conversion process, resource requirements, and environmental impacts within an integrated framework. Driven by the results of the demand module, the transformation programme of the model simulates energy flows and calculates the primary energy resources to satisfy the demand. Emissions from energy conversion and final energy uses are calculated at all stages using technology specific emission factors.

The demand module of the LEAP model provides a disaggregated end-use approach to the analysis of energy consumption. Energy demand is assembled in a hierarchical structure made up of different levels: sectors, subsectors, end-uses, and devices. The calculation of energy demand for each end-use is carried out within the frame of scenario approach which allows for the account of technical, economic and social factors. The transformation programme is used dto simulate the energy supply and energy conversion processes required to meet the set of energy demands calculated in the demand programme. The system is driven by the results of the demand module: as each module operates, successive modules one set of final energy requirements but create another set of primary energy requirements. The final outcome is primary resource requirements for the system. The Environmental Data Base on environmental loads allows for calculating the emissions resulting from the energy demand and energy transformation scenarios.

3.3 Baseline Scenario

The baseline scenario is based on a business as usual development of the economy under the assumption that no climate change mitigation policies are undertaken by the government. The purpose of the reference scenario is to simulate land-uses, energy consumption, and energy supply patterns according to a set of hypothesis on population growth, economic and social policies, and to estimate GHG emissions resulting from the development path. Assumptions regarding demographic and economic growth are drawn from indicative estimates developed by the national team according to the orientations of government development strategies.

In 1995 Senegal's population was estimated as 8.1 million. Trends in population growth have slowed down in the last decade as result of decreasing fertility rates: 6.6 in 1986 and 5.7 in 1997. In the reference scenario the population is projected to grow at an average rate of 2.5% until 2010 and then at 2.0% growth rate during the period 2010-2030. These growth rates indicate that population is expected to reach 11.8 million by year 2010 and 17.7 million by year 2030. In 1995 urban population represented 39% of total population and the rapid urbanisation process experienced in the past years is expected to continue.

Table 3.1. GDP and sectoral economic growth

Unit: 10^6 CFA	1995	2005	2010
Agriculture	335.4	408.8	451.4
Oil	9.1	11.0	12.2
Other Industries	302	368.0	406.0
Transport	152.9	186.0	205.7
Trade	338.5	412.6	455.5
Other services	272.5	332.0	366.7
Others	189.0	230.0	254.0
Total GDP	1599.4	1948.4	2151.5

Following a period (1989 – 1993) of economic stagnation, the economy of Senegal has experienced a relatively high economic growth in the last years: 4.8% in 1995, 5.6% in 1996 and 6% in 1997. The currency devaluation in 1994 boosted national exports and spurred internal investment (14% of GDP en 1996) where the private sector participation accounted for 40% of the total investment.

The country's economy is expected to grow at a relatively modest rate of 3% over the next fifteen years. This represents a rather modest assumption growth taking into account a population growth of 2.5% over the same period. No significant changes are assumed in the structure of economic sectors. Agriculture will remain the driving force of economic growth with a contribution of around 21% to the total GDP. The contributions of economic sectors to the GDP is showed in Table 3.1.

Increased liberalisation policies, privatisation of state-owned companies, and a more welcoming stance toward foreign investment are expected to foster a steady economic growth in the future. On the other hand, long-term perspectives for the Senegal economy rely on a more favourable prospects for regional integration within the UMOA countries. The progressive removal of custom barriers among these countries provides a favourable context for export growth and diversification. Exports prospects together with a more dynamic internal market allow for expecting a fast growth of key mineral and industrial sectors, namely phosphates, fertilisers, and chemical industry as depicted in Table 3.2.

Table 3.2. Projections of key commodity production

Unit: 10^3 ton	1997	2000	2005	2010	2015
Phosphate	1482.3	1500.0	1590.0	1685.0	1786.0
Sulphur	280.4	647.0	647.0	755.0	755.0
Sulphuric acid	813.5	1876.0	1876.0	2180.0	2188.0
Phosphoric acid	298.5	685.0	685.0	800.0	800.0
Fertiliser Production	218.5	250.0	435.0	583.0	781.0
Ammoniac	35.6	40.7	70.9	95.0	127.2

Following two decades of performance decline, agriculture has started a recovery process as result of new policies being currently implemented. New strategies are focused on granting selective subsidies, facilitating the access of peasants to credits and basic inputs, increasing the groundnut production, and construction of irrigation infrastructure.

Concerning the energy sector, basic assumptions in the baseline scenario are as follows:

- Effects of successful completion of plans to develop hydroelectric resources jointly with neighbouring countries. This includes the operation of 200 Mw of power capacity from the Manantali dam and the implementation of Felou and Gouina projects whose contribution to electricity supply is expected to be around 300 Gwh per year.

- The continued promotion of an urban transition from charcoal to LPG. Early government efforts to encouraging the penetration of LPG benefited middle class rather than poor households and have had little impact on overall charcoal demand. More recent LPG subsidies and promotions appear to have been more successful. In a 1989 survey LPG was the primary household fuel in 47% of Dakar households, compared with 24% in 1987. It has been estimated that each additional kilogram of LPG consumption displaces from about 1.6-2 kg of charcoal use. It is assumed here that the transition will continue though at more slow pace.

- Development of natural gas resources. At present three gas turbines have been installed at the power station in Cap des Biches. Reserves of natural gas estimated in 500 million cubic metres allow to envisage the construction of 50 Mw of additional capacity which represents an estimated output of 350 Gwh of electricity per year.

- Introduction of wind and solar technologies for power generation. Solar energy is expected to generate 160 Gwh of electricity by the year 2015, while the installation of 15 Mw of wind turbines is expected to generate 80 Gwh of electricity by the same year.

Electricity demand is expected to growth at 4.4% during the period 2000-2005. The growth rate will stabilise around 5.4% within the next ten years resulting in an average growth rate of 4.8% along the period 1997-2015.

Table 3.3. Projected electricity generation

Unit: Gwh	1997	2000	2005	2010	2015
Total sales	1350	1500	1860	2420	3145
Hydro			345	330	310
Natural gas		100	350	350	350
Wind			80	80	80
Solar		15	41	93	160
Total		115	816	853	900
SENELEC		1385	1044	1567	2245
Cap des Biches	730	750	522	783	1122

4 MITIGATION OPTIONS

4.1 Rural electrification

4.1.1 Prospects for Renewable Energies in Senegal

The Government of Senegal has taken a definitive option for the exploitation of renewable energies specially as these contribute to the protection of the environment (non-pollutants and non-GHG propagators). A Solar Equipment Programme 1995-2000, estimated at 25 billion FCFA has been initiated, with the objective of raising the rural electrification rate to 15%. Public investments estimated at 13 billion FCFA is expected to help mobilise some additional funds of 10 billion from private investors, banks or rural communities.

In partnership with a European firm, provision has been made for the installation of a 10-15 MW wind power. There are some Enterprises and Associations which are already installed in the country for selling and promoting solar devices. A plant for the production of photo-voltaic solar modules in partnership with American partners is under study. However, the technological development of solar and wind energies still remains hindered by investment costs which, are relatively compared to conventional options, although they are in constant decline. .

With the privatisation of SENELEC in 1998, a company will be created with the main responsibility of promoting rural electrification in close coordination with the Energy Control Agency. The mandate of these two structures will include the development of new and renewable energies for rural electrification. These policies are aimed at raising the rate of urban electrification to 65% and that of rural electrification to 15% by the year 2000.

Concerning the potential applications of new and renewable energies in Senegal, we will only consider here energy options which are cost-effective and adapted to energy requirements in rural areas.

The rural population of Senegal represents about 58.08% of the country's total population. Today, rural electrification coverage ranges between 2 and 5%. This low rate is due to the excessively high cost of investments and operations, dispersal and low level of consumption. There is no doubt about the benefits of rural electrification: it significantly improves the quality of life of communities, increases productivity, and prevent rural migration to urban areas.

4.1.2 Selection of options

Energy requirements of rural communities that can be met by renewable energies are related to household lighting, energy needs of community infrastructures (schools, mosques, churches, health centres, rural community headquarters, tourist camps, etc.) and village water-pumping. Therefore, options considered under the mitigation strategy of new and renewable energies refers to:

a) Decentralised electrification of Households

This option consists in the electrification of 121.660 households through the installation of photovoltaic modules in the next 15 years. SENELEC electrification plans intend to bring electricity to 200 villages by the year 2000. In the present analysis information is based on data from the DAST (Programme for the Development of Solar Energy Applications in Rural Settings, DAST Report, 1994). In this report, the authors have assessed rural household demands from 1994 to 1999, as shown in Table 4.1. For the following years, a 5% growth rate per annum until the year 2010 is applied. It must be noted that the annual growth rate before 1999, has been very high. However, possibilities of demand saturation should be taken into account, knowing that the natural population growth rate in rural areas is close to 3%.

b) Solar electricity for Water Pumping

As already known, the village water supply system is part of the government priorities. A vast programme of rehabilitation and installation of new rural water works which have just been implemented, may be subject to electrification. At this level, an assumed 25% growth every five years, appears reasonable to better adhere to the realities of the national budget programming.

c) Electrification of Community Infrastructures

Village communities often have infrastructures which require electric power to operate properly. This is the case of schools, mosques, churches, post-offices and health centres, and also of rural community houses. An assumed 30% growth rate every five years seems reasonable, given the data produced by the DAST Report referred to above and the budget constraints mentioned earlier.

Table 4.1. Potential for solar power generation

Uses	1994	1995	1996	1997	1998	1999	TOTAL in Kwc
Decentralised Electrification	128	690	980	1250	1485	1679	6211
Water pumping	29	135	120	150	150	150	734
Community Infrastrutues		108	219	333	396	469	1525
Administrative Infrastructures		7	14	26	35	42	125
Total (Kwc)	157	940	1333	1759	2066	2340	8595

d) Electrification of Administrative Infrastructures

There still exist administrative infrastructures which operate without electricity in the rural areas of the country. As suggested in the DSAT report these infrastructures must the priority targets of the Electrification Programme. It is reasonable to assume that the electrification process can take place by the year 2000.

According to a study carried out by the Programme de under the Programme for the Development of Solar Energy Applications in Rural Settings (DAST, February 1994), the requirements of photo-voltaic power capacity has been estimated in around 8.600 kwc (see Table 10), amount representing an equivalent of 2.8 million tonnes of oil per year.

4.1.3 Costs and avoided GHG emissions

Table 4.2 shows power capacity requirements and investment costs for the four rural electrification mitigation options. It is assumed here that the implementation of the options spans a period of five years.

Total cost of the investment amounts 76.4 billions FCFA for an installed capacity of around 8.6 Mw of solar power generation. Average cost per Kw of installed capacity has been estimated in 9.000 FCFA.

Table 4.2. Power capacity and investment costs

Year	Mitigation options Households		Water pumping		Communities		Administration	
	Power Kwc	Cost 10^6FCFA	Power Kwc	Cost 10^6FCFA	Power Kwc	Cost 10^6FCFA	Power Kwc	Cost 10^6FCFA
1	680	6.021	135	1.310	108	69	7	62
2	980	8.916	120	1.164	219	1.970	14	126
3	1 250	11.229	150	1.455	313	2.820	26	234
4	1 485	13.364	150	1.455	396	3.565	35	319
5	1 679	15.111	150	1.455	469	4.222	42	381
Total	6 085	54.748	705	6.839	1 525	13.727	125	1.122

The costs assessed in this analysis have been evaluated in accordance with the methodological guidelines developed by the UNEP Centre. The assessment has been carried out at project level considering individual projects as an isolated implementation without affecting any other part of the economy.

The total levelised costs C_O of individual projects are calculated as:

$$C_O = NPV \times i / (1-(1+i)^{-n})$$

where

i = discount rate;
n = the life-time of the project; and
NPV = net present value, calculated as:

$$NPV = \sum_{t=0}^{n} C_t (1 + i)^n$$

Thus, net present values of investment costs are transformed to constant annual flows or levelised costs over the lifetime of the investment. Table xx shows the levelised costs for individual options as well as the annual electricity consumption, the diesel consumption for an equivalent thermal power generation, and annual CO_2 emissions avoided by implementing the mitigation options.

Table 4.3. Annual electricity demand, costs and avoided emissions

	Required capacity 1995 – 2005 Kwc	Levelised Costs (10^6 FCFA)	Annual consumption (Mwh)	Equivalent diesel consumption (10^3 ton)	Avoided CO_2 per year (ton CO_2)
Households	6.085	81.337	32.579	16.289	51.636
Water pumping	705	8.078	27.784	13.756	43.606
Communities	1.525	22.723	8.914	4.457	14.129
Administration	125	1.957	723	3.614	11.45

Within a time life of the options spanning for 15 years total avoided CO_2 emissions amount to around 1.1 million tonnes. This amount corresponds to the consumption of 674 Gwh of electricity generated from photo-voltaic panels instead of conventional diesel-fired power plants.

Table 4.4. Total electricity consumption and avoided CO_2 emissions (15 years)

Options	Units	Electricity consumption GWh	Avoided emissions Ton CO_2	Levelised cost in 10^6 FCFA
Households	121.660	488,66	774.540	81337
Water pumps	235	412,26	65.400	8078
Communities	2.773	133,71	211.935	22723
Administration	1.039	10,84	17.175	1957
Total demand		674,47	1 069.050	114095

Table 4.5. Specific CO2 reduction costs

	Levelized cost per Kwh		Cost per ton of avoided CO_2	
Options	FCFA	US$	FCFA	US$
Households	166,45	0,27	105 014	175,0
Pumping	195,78	0,33	123 517	206,0
Communities	169,94	0,28	107 217	179,0
Administration	180,53	0,30	113 945	190,0

4.1.4 Assessment of broader social, economic and environmental impacts

The above identified mitigation options will have a number of important impacts additional to those measured in monetary units in the cost analysis. These impacts include indicators that cannot always be measured quantitatively, but that can be assessed in a qualitative basis. A set of indicators have been adopted for a further evaluation of the options. The set of criteria includes:

- Overall impact of mitigation options at macroeconomic level. This criteria deals with a descriptive assessment of the effects of options on economic trends.

- Employment generation which accounts not only for the employment related to the project implementation but also to the maintenance and operation services required during the life-time of the project.

- Additional environmental benefits at local or regional level.

- The national capacity for implementing the options.

- The capability of target groups to operate, maintain and eventually improve the new technologies.

- The adequacy of the options for meeting national development objectives.

- The impacts on other economic sectors.

Table 4.6 below summarises the broader assessment of the rural electrification mitigation options. A more detailed discussions of the overall impacts is provided in Chapter 5.

Table 4.6. Broader assessment criteria of mitigation options

Option / Criteria	Household	Water pumping	Community Infrastructure	Administrat. Infrastructure
- Potential for CO_2 reduction	High	Medium	High	Low
- Cost	Low	High	Low	High
- Economic impact	Average	Low	Low	Low
- Employment	Low	Low	Low	Low
- Other environmental benefits	High	Low	Average	Low
- Implementation capacity	High	High	High	High
- Sustainability of the option	High	High	High	High
- Adequacy to nat. objectives	High	High	High	High
Impact on other sectors	High	High	High	Low

4.1.5 Conclusions

The implementation of decentralised photovoltaic systems for rural electrification presents several advantages. Among them:

- Alleviates the physical work of women for pumping water;
- improves sanitation in water supply (reduction of water-borne diseases);
- provides more comfortable lighting for educational and cultural activities;
- allows for the development of health coverage through immunisation, notably among youths;
- fosters the development of income-generating activities;
- decreases the intensity of rural migration to urban areas.

Moreover, The introduction of solar energy promotes the development of human capacities for innovation, as well as for research and development of new technologies. It promotes the creation or reinforcement of enterprises and infrastructures for the manufacturing, experimentation, dissemination and maintenance of equipment.

4.2 Carbon Sequestration

4.2.1 Overview

In Senegal, carbon sequestration appears as a promising option for partially offset the release of GHG emissions into the atmosphere. Indeed, forests constitute both sinks and sources of atmospheric CO_2 They absorb CO_2 during the process of photosynthesis while rejecting some of it through decomposition and man-made bush-fires. A rational management of local forests would enable to maintain and increase the carbon they absorb while reducing the CO_2 content in the atmosphere. Moreover, protection and enhancement of forestry areas are in the interest of Senegal since these strategies are the most appropriate mechanisms against desertification and soil degradation.

Carbon sequestration options refer to the following practices:

- Forest protection through controlled deforestation, management of natural reserves, protection against bush-fire and other antropogenic disturbances (intensive clearings).
- Increased fixation and storage of carbon through reinforced forest eco-systems (increased surface area and/or bio-mass in natural forests and plantations), forest regeneration and agro-forestry plantations, and increased storage in durable wood products.
- Substitution practices to increase the use of biomass in the share of energy consumption and of forestry products in other uses such as building materials, provided that biomass and wood are produced on a sustainable basis.

However, the implementation of such developments requires the availability of adapted land not subject to competition with agricultural activities and with satisfactory bio-physical characteristics, i.e. availability of water, adequate drainage capacity, fertile soil, among others. Furthermore, political and socio-economic considerations should be integrated into the development of such activities, because even if sustainable development of forests remain appealing, implementation requires, on the one hand, the participation of local communities and those responsible for the deforestation to whom alternative livelihoods must be proposed (marketing of forest products). On the other hand, a political support combined with favourable land tenure systems and rights, may prove useful.

The selection of mitigation options has been undertaken under the following considerations:

- choice of appropriate sites for increasing carbon sequestration;
- evaluation of the current capacity of these sites;
- evaluation of the costs per carbon ton avoided and carbon gains; and
- formulation of projects.

The selected sites and the carbon sequestration options analysed in the present study are:

a) Afforestation/rotation and forest protection in Koumpentoum, Tambacounda region; and
b) Bush-fire control in the Kolda region.

A detailed assessment of these option as well as an overview of the the forestry situation in Senegal is provided below.

4.2.2 Forest Resources in Senegal

Forestry Resources

According to the FAO Study, the national forest production is estimated at 11.9 million ha, which is, 65% of the national territory. It represents a gross volume of 139 million m3 of standing trees unevenly distributed across the national territory.

The thinly planted wood forests and dense forests are concentrated in the south and South-East and represent 20% of surface areas, which is 2 281 200 ha, while constituting 93% of the standing volume of which 58% for Casamance and 35% for Eastern Senegal.

Savannahs and steppes cover 80%: 5,364,300 ha of steppes, mainly in the Ferlo and 5,077,000 ha of savannahs, especially in Eastern Senegal, and to a lesser extent, in Sine-Saloum and Casamance. However, their potential in standing trees is very low. They are located in high population density areas like Diourbel, Thiès, Dakar, Kaolack, etc...

Productivity of forest formations is low. It stands at 0.1 to 0.4m3/ha/annum in the Sahelian or Sudano-sahelian zone and reaches 1.5m3/ha/annum in the Sudanese or Sudano-sahalian zone. This results in a total gross productivity of 6.8 million m3/y to which the production of a dead wood of 1.8 million m3/y should be added, which is, a total available volume of 8.6 million m3/y.

Against this background and given the fact that all the potential of wood available is not accessible for exploitation (enclavement of some areas, inadequate access roads, sparsely populated areas), only 36% of this volume can be tapped, which is, 3.1 million m3/y.

Forest Management

As early the 1960s, the Senegalese State had delineated protected areas which amount to 31.71% of the country's territory. This Classified Domain consist of 213 classified forests covering a surface of 6,237,648 ha including 20 sylvo-pastoral reserves. Management of such forests is not efficient as most of these are ill-delineated, and resources made available to forest services inadequate to ensure their control. Even more so, because of the lack of data on the productive potential of each classified forest. Consequently, illegal felling and clearing are rampant, and their magnitude is difficult to assess. Subsequently, some classified forests exist only on paper, their plant cover being completely wiped out.

As regards the protected areas, that is, the non-classified formations developed for agricultural and pastoral purposes but which do not include the local lands (terroirs), their management is virtually non-existent, due to lack of resources.

The Forest Code which was prepared in 1965 and reviewed in 1974, indicated that, except for the user fees, rights to tap national forests remain the prerogative of the state which ensures their control through the Forest Service. This code is too repressive and prevents communities from keeping an eye on the management of their own local resources. It has on no account encouraged the involvement of the local communities in the management of classified domains.

Consequently, there is an inadequacy between the de facto situation and the law pertaining to the classification, as the state assumed the traditional management power, hardly taking into account the customary rights of neighboring residents. As a result, there was an antipathy in the conservation of such forests, as the residents no longer considered them to be their own property. This disengagement on the part of the population is partly responsible for the current degradation of the natural resources, notably forest resources.

By 1992, under the instigation of the New National Forest Plan (pafs or updated pddf), a strong desire towards modifying this legislation was articulated, resulting in the redefinition in 1993 of the Forest Code made operational by an implementation decree in 1995. This was reinforced by the law on Regionalisation passed in 1996, and encouraged a decentralised management of the forest space. The new Forest Code established by the Law 93-06 of 4 February, and Decree 95-357 of 11 April 1995, paved the way for a co-management of forests by the state and the local communities. According to this code (articles 11 and 16), the state can grant rights to local communities to tap forest resources, on the basis of a development plan.

This involvement of the local communities in the management of their natural resources, notably forest resources, offers greater possibilities of success to degradation control programmes in these places.

Forest Degradation

Agro-forestry is nowadays confronted with major difficulties: for the period 1985-1995, the forest regression rate was 9.2%, according to FAO studies. Indeed, between 1980 and 1990, the surface area of forest formations went from 12.7 million down to 11.9 million, which is a loss of 800,000 ha in ten years, or 80,000 ha/y. This decline in the forest space is due to a combination of factors, namely:

The population growth (3% growth rate) which exerts a heavy pressure on land use. There has been an extension of cultivated land, now reaching 2.4 million ha out of the 3.8 million arable land, in response to the increasing community food requirements, but especially in compensation for the low agricultural production yields caused by the impoverishment of soils, salinisation phenomena and obsolete farming techniques.

Bush-fires associated with north-southwards encroachment on agricultural land (average of burnt land over the past ten years is estimated at 190,000 ha), with great damages in the South and south-east (the well-wooded areas), result in an accelerated reduction of the plant cover, hence, of national carbon sequestration capacities.

Anthropogenic degradation remains largely due to over-exploitation of forest resources to respond to the important needs of the populations in fuel-wood. Indeed, forest formations provide fuel-wood to households, in addition to gathering products. Energy of fuel-wood origin represents 95% of household energy requirements. The surface areas felled are ill-known. Yet, assuming that 0.12 ha of forest has to be chopped in order to produce one ton of charcoal in the producing regions, the current charcoal consumption-induced deforestation would be more than 30,000 ha per annum.

Despite the scale of this deforestation, the fuel demand remains unsatisfactory. Indeed, in relation to the 3.1 million m3/y national production available, there is a demand to the tune of 3.5 million m3/y (1.3million tons), a large gap in the existing forest stock that cannot regenerate at the pace of the current exploitation process. Moreover, this deficit which is manifest in all the regions, except for charcoal producing regions of Thiès (80 km from Dakar), Tambacounda and Kolda (350 and 400 km from Dakar, respectively) where the currently remaining forests are located. If this fuel-wood consumption pattern continues within the context of population growth, the national demand will reach 4.4 million m3.

Hence, while the degradation phenomenon is particularly alarming, the reafforestation efforts, which is, 20,000 ha per annum, appear inadequate compared to the magnitude of the degraded surface areas.

Charcoal production

During the colonial period, a regulation for the exploitation of forest resources was developed by the colonial authorities as a result of rate of deforestation initiated for the supply of cities like Dakar, Thiès and Kaolack in charcoal. As early as in 1940, as a result of the degradation induced, exploitation of the forests in the vicinity of urban centres was limited through the setting up of a rotation system. This made the front of charcoal exploitation move towards the regions of Sine and Saloum. From 1950 to 1969, consecutive to the demographic pressure, this front is increasingly receding from the Central West of the country, a trend reinforced by the protection of forests in Thiès and Diourbel.

Hence, in the course of history, forest exploitation for the production of charcoal and fuel-wood has very much contributed to the destruction of the vegetation and has, consequently, resulted in reduced national carbon sequestration capacities. Notwithstanding a few reafforestation initiatives (20,000 ha), this degradation process is still receding towards the South and South-East where a few forests can still be found that can supply urban areas in woody materials, in particular in fuel-wood.

Table 4.7. Eco-geographical zones of Senegal

Eco-geographical Zones	Bio-physical Characteristics	Wood Formations	Parcelling Practices	Constraints of the Zone
The River Valley Zone Area: 11500 km2 (6%) Situation: north of St. Louis region and north-east of Tambacounda region (includes the administrative departments of Dagana, Podor, Matam and Bakel)	Sahelian region which includes three main zones: • The Walo: Hydromorphic, easily flooded and vertisoil types of land • The Delta: fine soils • The Diéri: isohumic soils with sandy, fragile, wind erosion-sensitive texture and favourable for niebe and millet growing.	Shrubby steppes with trees. Gonakié (acacia nilotica), the predominant specie, is in strong regression due to the lowering of the water table. Insignificant vegetation coverage, of shrubby type formation. Zone serious degradated due to droughts, overgrazing as well as concentration of animals around water points during the dry season.	Continued rehabilitation of the Gonakié plant cover. Extension of wind-break plantations and agro-forestry.	Lack of control over water management. Problems of water drainage in zones liable to inundation. Land issues associated with land developments.
Sylvo-pastoral Zone Area: 56,269 km2 (29%) Location: south of St. Louis region and north-west of Tambacounda region (departments of Louga and Linguère).	Two main zones: • The North-west Ferlo, with isohumic soils (red-brown soils) with sandy, wind erosion sensitive, texture and ferruginous soils exposed to wind and water erosion. • The South-east Ferlo with little developed lateritic soils.		Restoration of the sylvo-pastoral balance with developments of sylvo-pastoral reserves. Restoration of gum plantations with the view to boosting gum production.	High cattle population density. Spatial competition between pastoral and agricultural activities. Lack of water and inadequate management and distribution of fodder.
The Niayes Zone Surface: 2 130 km2 (1%) Location: a coastal strip of about 5 km wide between Dakar and the mouth of the river.	Succession of sandy dunes and depressions between dunes with hydromorphic soils, a zone favourable for market-gardening	Highly degraded vegetal formation of Guinean origin in the South of the Niayes Degraded plant cover due to abusive clearings and cuttings.	Maintenance and regeneration of old artificial plantations of filaos Development and maintenance of the artificial forest of eucalyptus in Mbao	Extension of urban agglomeration Lowering of the water table resulting in gradual salinisation Existence of mining activities

Table 4.7. Eco-geographical zones of Senegal (cont.)

Eco-geographical Zones	Bio-physical Characteristics	Wood Formations	Parcelling Practices	Constraints of the Zone
Senegal-Oriental Zone Area: 51 210 km2 (26%) Location: centre-east and south-east of the country, it is the Tambacounda region	Deep soils over a lateritic cuirass	Formation of savannah/sudanese type. This zone supplies 41% of the national quota in terms of charcoal requirements. Progression of shrubby species at the expense of big trees like Sterculia setigera	To check the intense forest exploitation through control over clandestine deforestation, clearing, and pastoral practises Protection against bush-fires.	Enclavement Bush-fires Important fraudulent cuttings Fraudulent cuttings Bush-fires
The Southern Zone Surface Area: 28 000 km2 (14%) Location: It concerns the regions of Ziguinchor and Kolda	Humid Zones It includes: The Lower Casamance (Ziguinchor), with hydromorphic or saline soils along the River Intense forest exploitation which supplies the Middle Casamance (Sedhiou) with essentially ferruginous or ferralitic soils The Upper Casamance (Kolda) with ferruginous soils covering a lateritic cuirass	In the estuary, the Rhizophora and Avicennia populated mangrove stretches over 100 000 ha. Salinisation of land in the vicinity of streams, has led to clearings for the development of new land plots. The vegetion is of Sudano-guinean type in these areas, with such woody species as Bombax costatum and Daniellia oliveri which are associated with a cover made up of dense and high gramineae: 60% of the national fuel-wood quota. There is a stepped-up process of savannahisation of plant formations.	To Rationalise forest exploitation and set up forest and forest resource management projects	
The Ground-nut Basin Surface: 47 611 km2 (24%) Location: centre of the country, covers the departments of Louga, Kébémer, the regions of Thiès, and western part of Tambacounda region.	Soils are either of unleached, sand rich and ferruginous type, or of leached type with a superficial sandy and muddy texture and a muddy underground texture. Such soils are sensitive to both wind and water erosion. These are favourite soils for ground-nut growing.	Existence of a 200 km long artificial trip with filao trees (over 8000ha) to fix the sand dunes and protect areas between dunes (market-gardening depressions) against siltation. Shrubby and arboreal savannah zones with Acacia savannahs up North and Borassus and Adansonia savannahs in the West and South, and Cordyla and Sterculia savannahs in the East.	Incorporation of trees in the agrarian systems, namely acacia albida Restoration and conservation through fallow practises Meeting local community needs in fuel-wood	Concentration of 60% of the population over 1/3 of the country's surface area. Encroachment of agriculture on forest and sylvo-pastoral reserves and classified forests. Impoverishment of soils and salinisation of land, water problems due to irregular rainfall

Conclusion

In order to prevent such processes of desertification and degradation of natural resources, notably forest resources, from destroying the remaining forest potential in the South and south-east, it has become indispensable to maintain it through an optimal management and expansion of the fuel wood and timber producing areas in these sites.

In effect, these areas have for long been spared because of their enclavement in relation to the capital city, Dakar, and to the other urban centres, but with the growing demand in domestic fuels and the exhaustion of the plant cover in the southern and central regions, the charcoal exploitation front has shifted towards the southern regions, particularly Tambacounda and Kolda.

By virtue of the more humid climate in these regions, fertility of their soils (rich in organic matters, clayey-sandy soils), national economic interest they have and especially because of the large space available there, seem very appropriate for the setting up of an option aimed at increasing the national capacities for carbon sequestration. This option should meet the needs of the populations, and involve them in its implementation. Above all, it should be economically and politically realisable.

4.2.3 Characteristics of areas selected for GHG mitigation actions

A. The Tambacounda Site

Located in the south-east, the Region of Tambacounda is characterised by a Sudanese type of climate and an annual rainfall of over 1000mm. It constitutes one of the largest regions in terms of area, since it stretches over 51 210 km2, which is 26% of the national territory. This region, despite its sylvo-agricultural potentialities, still remains sparsely populated, and is credited with the lowest population densities.

Management of Forestry Potentials

The Department of Tambacounda presents 11 classified forests, in addition to the Niokolo Koba Park (930 000 ha). Their boundaries are not clear-cut and the inadequate technical and logistical means of the Regional Forest Service does not allow a good management of such classified surface areas. Fraudulent operations are rampant in these places and villages have settled in some of the classified perimeters. The magnitude of the degradation cannot, however, be measured, since the forest potentialities are not really assessed. Paradoxically, clearing and user licenses are issued without taking into consideration the volume of standing wood available on the site.

Production of fuels is high in the region of Tambacounda. For the year 1996, the total quota of charcoal extracted was 375 000 quintals, which is 41% of the national quota ; to this quota is to be added that of the supply in timber and in craft wood and that of the ever-increasing production of fire-wood for which no quotas are established for the moment. The Forest Service has issued in 1995 licenses to tap some 74 000 cubic metres.

Evolution of the Forest Resources.

Adding to the reduced forest spaces resulting from the production of domestic fuels, is the growing practice of agricultural clearing, mainly by migrants from the Groundnut Basin, in search of new arable land in the south-east. Agricultural land is expanding further and further. A control over clearing practises becomes necessary because of the destruction of the wood potential, consequently, of the carbon sequestration capacities of the region, more so of the country.

This pace of clearing at the expense of the forest resources is nevertheless facilitated by Law 64-46 pertaining to agricultural exploitation on the National Domain. This law is an incentive for peasants to undertake actions of deforestation in order to settle in vacant pieces of land, leading to a significant reduction of the fallow and thus, to a degradation of the ecosystems.

The new forest code calls for the involvement of communities in the management of forests and decentralisation confers to the rural communities the responsibility of managing their own local land through the Rural Council. Any request for clearing should now be submitted to the latter, which after consultation with the forest services via the Prefecture, may give his opinion. The advantage of such a new regulation is justified by the involvement and responsibility of the rural community in the management of its own natural resources.

Being in direct contact with the ecosystems, and drawing economic benefits from such resources, local social actors will be in the best position to preserve them against any illegal exploitation. Bush-fire control is also facilitated by the vicinity to these ecosystems.

However, a campaign of sensitisation, training and information for rural advisors on environment and its management modalities should be carried out so as to avoid management errors that could be detrimental to the natural environment. No doubt that the rural populations will be able to design a local management of natural resources. But they will need technical assistance to assume their responsibility correctly.

Land development practices

In the region of Tambacounda, forest exploitation is mainly concentrated in the districts of Koussenar, Koumpentoum and Maka Coulibantan. There has been a rapid degradation of these zones, after several years of deforestation, notably in the District of Koumpentoum, a sylvo-pastoral area due to its proximity with to Ferlo region. Under the impact of such human activities as charcoal production, this zone has become a shrubby savannah forest rich in combretaceae and high gramineae (fast regenerating species) but almost deprived of those trees valued for the quality of their timber wood like Sterculia setigera (Mbep) (slowly regenerating species).

Aware of the magnitude of the deforestation in this district and the vicinity of the desert front in the sylvo-pastoral zone, the populations of Koumpentoum and Maka Coulibanta organised themselves into groupings and, with the support of the regional forest services, set up village nurseries with a view to promoting reforestation in the district. In the case of Koumpentoum, there are youth and women's groupings, as well as elderly people's groupings that are organised around some fifteen private nurseries, against eight in Maka Coulibanta,

The setting up of these different village groupings at the district level shows how much the neighboring residents are concerned about the magnitude of the degradation. That is why it is essential to support such village groupings, in particular those of Koumpentoum, in their reforestation and parcelling activities, as these fit into the option of increasing the carbon gas sequestration wells, option that has been adopted as a strategy to be implemented in order to mitigate the GHG effects.

The increased carbon sequestration capacities could be considered in the Koumpentoum District, in close collaboration with the population. The objectives of such an operation are as follows:

- To increase the wood bio-mass in Koumpentoum;
- To involve the local community, namely women and the youth;
- To provide the latter with subsidiary revenues;
- To slow down deforestation while ensuring the supply of domestic fuels to populations;
- To gradually introduce village households to fuel-wood savings through the improved stoves;
- To promote the «meule casamançaise» as carbonisation technic (name of the grinding machine).

Rationale for parcelling activities

The plantations to be set up should be relevant to the community if fraudulent fellings are to be minimised. Indeed, the community prefers fruit trees such as citrus fruit trees, cashew-nuts, gum-trees, so as to commercialise the gathering of produce and to benefit from selling the proceeds. This operation will contribute to job creation, and more specifically, to keeping the youth busy during the long dry season, hence reducing the outflow of migration towards the major cities. Likewise, the rural community will be able to benefit from returns obtained as taxes and forest user fees.

The supply in fuel wood for households will require the presence of such fast regenerating forest trees as Eucalyptus (exotic species) and Combretaceae (local species). These trees will be planted within the framework of a short rotation production system managed by village groupings. This practice will help slow down the deforestation process and will promote the gradual reconstitution of the forest.

As the vocation of this region is becoming increasingly agricultural with the presence of new peasants, it will also require the sensitisation and introductory training of the latter on agro-forestry techniques. The integration of trees in the field will improve its fertility and thus, its yield, while protecting soils against (wind and water) erosion. Indeed, these soils cleared for agricultural purposes ultimately lose their fertility. In this respect, the presence of Acacia albida (Kad) or other leguminosae in the fields is to be promoted. This strategy will also reduce the propagation of itinerant crops, since the peasant will have to invest in his agricultural domain.

B. The Kolda Site

The Kolda region is located at 240 km from Tambacounda. It is characterised by a humid Sub-Guinean climate and an average rainfall of 1200 mm/year, conferring it important forest and agricultural potentialities. Sparsely populated, this zone is covered over more than 2 100 000 ha by a vegetation of dense and clear forests.

It is the current national forestry producing zone. It provides 60% of the national fuel wood quota, which is 500 000 quintals. For timber, the regional quota is 25 000 standing trees, against 300 for crafts wood involving mainly venn, palm trees, and dead palmyras. As regards lumber, the quota is fixed at 15 000 standing trees and involves mainly bamboo. The level of exploitation in the Kolda region, has, however, recorded a soaring growth over the past few years, from 200 000 quintals in 1990 (or 20% of quota) to 500 000 quintals (60%) in 1996.

Forest degradation

These considerable forest resources should be exploited in a more efficient manner. Indeed, some are endangered because of excessive fellings. A case in point is venn which is well appreciated as timber. Indeed, if there still exists a sizeable forest stock , a conservation and protection strategy should be put into place so as to avoid uncontrolled tree-felling, since the actual potential of this forest has not been taken stock of.

There is a gradual process of deforestation taking place in the region. It is caused by:

- The very frequent bush-fires sweeping across the country every year. According to the forest protection workers in Kolda, over 8O% of the space covered by the forest, or 1 680 160 ha are swept each year by bush-fires, which corresponds to 5205.4 Gg of carbon released into the atmosphere;
- The intense agricultural clearings by the new migrants from the Groundnut Basin. Fleeing the drought and the poor northern soils, these migrants occupy the fertile available land in the South at the expense of the forest spaces.
- Forest exploitation for the production of fuel-wood, timber and lumber in quantities exceeding the quotas allocated.

Parcelling Practices

The frequency of bush-fires and their destroying effects on the forest and villages considerably reduce the CO_2 sequestration capacities, while annihilating natural regeneration of precious species (venn, caïcédrat, etc...). Hence, according to the Water and Forest Resources Department Workers, a reduction by 50% of the bush-fires would allow to maintain on a constant basis, the plant potential of the Kolda region.

This strategy for the reduction of bush-fires and conservation of the existing bio-mass should go through:

- a sensitisation of the inhabitants on the harmful effects caused by bush-fires;
- the setting of early fires by November and December so as to reduce dry weeds and thus, lessen the extension of the fires and their impact on the plant cover;

- fire-resistant plant species, green fire-breaks like cashew-nut tree which, not only increase the number of sequestration wells, but can also a source of subsidiary income for the local communities (the cashew-nuts are valued at the international level, the United-States is the world largest consumers of cashew nuts).

These developments are welcomed by the populations. For according to the Regional Forestry Service, a community drive for fruit plant is noted, notably for cashew-nut trees which play a dual role of natural fire-break and producer of edible fruits. An increase in the demand for plants in the region, especially the fruit species, is, therefore, noted. Yet, the Forestry Service can only provide up to 20% of the demand. As demand is higher than supply in this case, there is in the region a clear need for protection against bush-fires, but also for acquisition of alternative sources of income through fruit forest products. Those parcelling practises to be practised should be mainly addressed in these needs.

4.2.4 Forestry Mitigation Options

Option 1: Afforestation/rotation in Koumpentoum (Tambacounda site)

This option refers to the plantation of 250 ha of fruit trees including: 150 ha of cashew-nut trees; 50 ha of mango trees; and 50 ha of citrus.

The choice of species has been made following field surveys. The cashew-nut tree is adapted to the new environment, and starting from the third year of plantation, its production of cashew-nuts helps in improving the community income. The citrus and mango trees are fruit plants that are in great demand in the country and they play a key economic role because of the commercial value of their fruits. Basic data inputs for the analysis are summarised in Table 4.8.

Table 4.8. Baseline data for mitigation option 1

Afforested area	250 ha.
Tree species	• Cashew-nut: 150 ha with a rotation period of 25 years • Citrus fruits and mango trees: 100 ha with a rotation period of 25 years
Quantity of carbon in the soil	60 t/ha (Cf. IPCC guidelines).
Period of matter decomposition	Two years for eucalyptus and four years for the other species.
Carbon produced by biomass	200 ton/ha.
Initial cost	3000 $/ha

The amount of carbon sequestration and the costs and benefits of the fruit tree afforestation option are summarised in Tables 4.9 and 4.10. These results have been obtained by using the COMAP model.

Table 4.9. Costs, benefits and carbon sequestration by fruit tree afforestation

Unit: ton C / Year	2000	2001	2002	2003	2004	2005	2006	2015
Incremental carbon (tC)	8288	8288	8288	8288	8288	5180	5180	0
Baseline scenario (tC)	19500	19500	19500	19500	19500	19500	19500	19500
Mitigation scenario (tC)	27 788	36 077	44 365	52 653	60 942	66 122	71 302	71302
• Wetlands	16 380	13 260	10 140	7 020	3 900	1 950	0	0
• Reforested land	11 408	22 816	34 224	45 633	57 041	64 171	71 302	71302
Incremental benefit ($)	35 910	71 819	107 729	143 638	179 548	201 991	224 435	224 435
Annual cost (US$)	26 149	52 298	78 447	104 596	130 745	147 088	163 431	163 431
Annual Benefit (US$)	62 059	124 117	186 176	248 234	310 294	349 080	387 866	387 866
Cost per avoided ton CO_2	0.94	1.45	1.77	1.99	2.15	2.23	2.29	2.29

Table 4.10. Mitigation option 1: summary of the results

Initial quantity of carbon	19500 Tons
Total sequestered carbon (2000-2006	359 249 Tons
Costs of land preparation (2000-2006)	699 439 $
Total benefit from land exploitation	1 343 806 $
Net benefit (2000-2006)	644 367 $
Average cost per ton of avoided carbon	1.89 $/ton

Option 2: Forest rotation (eucalyptus forest)

This option consists in the afforestation of 250 ha by planting eucalyptus trees. The eucalyptus is a fast-growing species which is adjust well to the climate of the region. When planted in rotation, it helps to meet the needs of the populations in timber and fire-wood. The amount of carbon sequestration and the costs and benefits of the forest rotation option are summarised in Tables 4.11 and 4.12.

Table 4.11. Carbon sequestered and costs of forest rotation

	2000	2002	2004	2005	2009	2010	2015	2025
Area (ha):								
a) baseline								
• Wetlands	250	250	250	250	250	250	250	
b)mitigation scenario								
• Wetlands	230	190	150	130	60	50	0	0
• Reforested	20	20	20	20	10	10	10	0
Net sequestered carbon (tC)	830	830	830	830	415	415	415	0
Total Carbon (tC):								
a) baseline	19500	19500	19500	19500	19500	19500	19500	19500
b)mitigation scenario	20 330	21 989	23 648	24 447	27 380	27 795	29 869	29 869
• Wetland	17 940	14 820	11 700	10 140	4 680	3 900	0	0
• Reforested area	2 389	7 168	11 947	14 337	22 700	23 895	29 869	29 869
Incremental benefit	81 150	243 449	405 748	486 897	770 921	811 496	1 014 370	1 014 370
Annual cost	13 813	41 440	69 067	82 881	131 228	138 135	172 668	172 668
Annual benefit	94 963	284 889	474 815	569 778	902 149	949 630	1 187 038	1 187 038
Cost per ton of carbon	0.68	1.88	2.92	3.39	4.79	4.97	5.78	5.78

Table 4.12. Summary of results

Initial quantity of carbon Total sequestered carbon (2000-2015) Cost of land preparation (2000-2015) Total benefit from land exploitation Net benefit (2000-2015) Average cost per ton of carbon	19 500 tons 413413 202 tons 649 232 $ 4 463 262 $ 3 814 031$ 3.77 $/ton

Option 3: Forest protection in Koumpetoum

The aim of this programme is to ensure a «pure» protection of the forest in the Koumpentoum District, without any form of exploitation in order to promote its regeneration. This forest experiences an annual regression rate of 7.5% (Forestry Plan of Action). This zone is highly affected by degradation. By the end of the 1980s, it used to produce over half of the country's needs in domestic fuels and in timber.

Basic input assumptions in the evaluation are as follows:

- Surface area: 199 875 ha;
- Regression rate: 7.5% per year;
- Bio-mass density:150t/ha (IPCC Guidelines);
- Fraction of carbon in the bio-mass: 0.5

Table 4.13. Forest protection option: summary of results

	1999	2004	2009	2014	2029
Land area (10^3 ha):					
• Baseline	185.0	125.3	84.8	57.5	17.8
• Mitigation	185.0	185.0	185.0	185.0	185.0
Biomass density (t/ha).					
• Baseline scenario	147	132	119	108	79
• Mitigation scenario	147	162	177	196	264
Soil carbon density (tC/ha):					
• Baseline scenario	60	60	60	60	60
• Mitigation scenario	60	63	66	70	81
Total carbon density (tC/ha):					
• Baseline	134	126	119	114	100
• Mitigation	134	144	155	168	213
Cost of protection (US$/ha):					
• Baseline	0,5	0,5	0,5	0,5	0,5
• Mitigation	10	10	10	10	10
Incremental cost (10^3 US$)	3 644	3 408	3 199	3 058	2 854
Annual carbon sequestration (10^3 ton)	2 487	1 876	1 377	1 039	786
Total carbon (10^3 ton):					
• Baseline	24 697	15 785	10 137	5 989	1 779
• Mitigation	24 697	26 651	28 678	31 503	19 355
Benefit (10^3 US$):					
• Baseline	386	283	191	130	40
• Mitigation	- 3 258	- 3 125	- 3 008	- 2 929	- 2 814
Average cost per ton of carbon	1.465	1.816	2.32	2.94	3.63

The potential for carbon sequestration has been estimated in around 38.3 million tons at an average cost of 2.4 US$ per ton of carbon.

Option 4: Protection of Forests against Bush-fires (region of Kolda)

The Kolda forest is currently the main source of bio-energy products. The region provides over half of the national quota of domestic energy and wood. However, the pace of present exploitation coupled with the effects of bush-fires bring about an accelerated degradation of this forest. A preservation of zone against bush-fires by the planting green fire-breaks from 1999 will help not only to stop regression process of the forest, but also maintain the forest exploitation on sustainable basis and provide extra revenues (sale of cashew-nuts) to the riverside populations.

The implementation of forest protection option in the Kolda region has two main objectives:

- reduction of GHG emissions (by avoiding bush-fire induced emissions and by allowing for carbon sequestration through forest protection); and
- desertification control through forest protection.

The option includes several components:

- opening of 500 km cashew-nut trees as natural fire-breaks ;
- material support to local communities and populations regrouped into bush-fire control committees;
- community sensitisation;
- community training on bush-fire control techniques.

Assuming: (i) a regression rate of 15% per year; (ii) a biomass density of 190 t/ha; and 0.5 as the fraction of coal in biomass, the results of the assessment are shown in Table 4.14.

4.2.5 Conclusions

The study on the growth of carbon sequestration capacities shows that Senegal has great potentials towards the reduction of Greenhouse Effect gases in the atmosphere through the practice of reafforestation, forest protection against bush-fires and campaign against excessive tree felling.

The implementation of land development options in the regions of Tambacounda and Kolda which present available lands and favourable climate offers not only great carbon sequestration capacities at moderate cost but also favours the active involvement of the riverside population in the preservation of forest resources.

Table 4.14. Forest protection in Kolda region: summary of results

	1999	2004	2009	2014	2029
Land area (10^3 ha):					
• baseline	1 785	792	351	156	14
• mitigation	1 785	1 785	1 785	1 785	1 785
Biomass density (t/ha):					
• baseline	186,2	168	152	138	102
• mitigation	186,2	206	227	251	337
Soil carbon density (tC/ha):					
• baseline	100	100	100	100	100
• mitigation	100	105	110	116	135
Total carbon density (tC/ha)					
• baseline	193	184	176	169	151
• mitigation	193	208	224	241	303
Cost of protection ($/ha)					
• baseline	0,5	0,5	0,5	0,5	0,5
• mitigation	3	3	3	3	3
Incremental cost (10^3 US$)	-93 960	- 94 909	- 95 705	- 95 741	- 95 928
Net carbon sequestered (10^3 tC/year)	59 636	32 794	17 485	11 338	8 500
• baseline	290 156	145 853	61 874	26 314	8 662
• mitigation	349 792	371 085	399 752	430 894	541 609
Cost of sequestered carbon ($/tC)	- 1.57	- 2.89	- 5.47	- 8.44	-11.28

4.3 Energy Efficiency Improvement in Industrial Sectors

4.3.1 Overview of options

According to GHG inventory 44% of energy-related CO2 emissions in Senegal result from industrial activities. In this respect, any national strategy for limiting GHG emissions, should pay particular attention to the industrial sector. Main objectives of the present analysis have been focused on:

a) assess the levels of energy production and consumption, as well as related GHG emissions;
b) analyse production processes and their energy efficiency;
c) identify concrete actions of energy efficiency likely to stand as plausible alternatives for the reduction of GHG emissions, with a technical and financial study.

Taking into account both resources and time constraints three representative industrial cases have been selected for evaluating efficiency improvements as potential climate change mitigation options. The industries selected are:

- power generation: the power station C3 in Cap des Biches,
- agro-industry: SONACOS; and
- Chemical Industries of Senegal: ICS plants of Darou, Mbao and the Phosphates of Taïba.

Main findings of the analysis are summarised in Table 4.15. A detailed description of the mitigation options is provided in the next sections.

Table 4.15. Summary results of efficiency improvement options

	Power generation (SENELEC)	Agro-industry (SONACOS)	Chemical industry (ICS)
Time-frame horizon (years)	20	15	20
Annual Fuel Savings (tons)	6194	26 864	210
Total Savings (tons)	122 850	402 960	8 197
CO_2 Emissions avoided (tons)	374 692	1 378 050	25 000
Investment Cost (10^6 CFA)	2 500	3 842	150
Cost of CO_2 Avoided (US$/tC)	11.1	6.4	10.0

4.3.2 Efficiency improvement in power generation (Cap des Biches)

The Cap des Biches Power Station comprise two main units: (i) the power steam unit made up of three turbo-alternators and individual boilers; and (ii) the gas-turbine units.

Table 4.16. Fuel consumption and electricity generation at Cap des Biches power plant

	1995	1996	1997
Electricity generation (Gwh):			
• Steam turbines	344	483	589
• Gas turbines	153	122	105
• Auxiliaries	29	31	36.6
Fuel consumption (ton)			
• Heavy fuel	109.4	146.7	179.6
• Diesel oil	10.9	4.2	22.5
• Natural gas (10^3 m3)	54.4	50.2	27.6
Specific consumption (g/kwh)			
• Steam turbines	317.6	303.6	304.7
• Gas turbines	453	348	415
Load (Mw)			
• Steam turbines	54.6	70.4	71.8
• Gas turbines	35.1	33.6	28.9
CO_2 emissions (10^3 ton CO_2)	495	578	684
• Heavy fuel	334	447	548
• Diesel oil	34	14	72
• Natural gas	127	117	64

Efficiency improvements in Cap des Biches power generation comprise the following specific actions:

a) <u>Rehabilitation of the burners</u>

Existing burners are manually operated for ignition and operation and their efficiency is quite low. The replacement by Pillard type burners will result in combustion performance close to stoechiometric conditions as well as in substantial reductions of particulates and volatile compounds.

b) <u>Rehabilitation of the boiler's regulatory chain</u>

This regulation is currently of pneumatic type which means lack of fuel-flow monitoring, inadequate air supply, and significant emissions of unburned residues. A new digital monitoring system to control the excess oxygen will result in savings on fuel of around 10%.

c) Improvement of boiler air heater

The air-heater allows to raise combustion air temperatures to 70°. This substantially improves the yields.

d) Improvement of boiler (unit 302)

It has been estimated that technical improvements in this boiler will reduce the overall unit fuel consumption in approximately 6%.

e) Rehabilitation of super-heaters

The advanced clogging of the horizontal heaters, as well as of the descending tubes has led to productivity losses of 10% and capacity losses of between 40 and 50%. This was due to the poor quality of oil products supplied by the Raffinerie de Mbao between 1990 and 1995. Major actions to rehabilitate the super-heaters include the replacement of a number of components, among them: descending tubes (boiler-tubes), lateral shell tubes, saver coil, air heater tubes, smoke sheath, and boiler-tube cleaning system.

The above mentioned actions will bring down specific consumption in power generation from 322 g/kwh to 300g/kwh as well as will allow to recover the nominal capacity of 30 Mw instead of 15 Mw at the present time. The average cost of the option is estimated in 11.1 US$ per ton of CO_2 reduced. Details are provided in Table 4.17.

Table 4.17. Fuel saving and CO2 reductions

	2000	2005	2010	2015
I. Base case				
1.1 electricity generation (Gwh)	715	522	783	1 122
1.2 fuel consumption				
• Heavy fuel (10^3 ton)	184.5	128.4	192.6	276.0
• Diesel oil (10^3 ton)	23.1	16.1	24.1	34.6
• Natural gas (10^6 m^3)	28.4	19.8	29.7	42.5
1.3 CO_2 emissions (10^3 ton CO_2)	702	489	733	1 050
II. Mitigation case				
2.1 Fuel saved (ton)	6194	6364	5278	6644
2.2 CO_2 emission reduction (ton)	18890	19410	16100	20260
2.3 CO2 emissions (103 ton	664.7	682.8	472.6	712.8

4.3.3 Energy efficiency improvements in agro-industry

This mitigation option refers to energy efficiency improvements in SONACOS plant, a oil-seed processing industry in Senegal. In the last years SONACOS has experienced a progressive decline of both production and technical performance due to several factors including: international competition, trade liberalisation of oil-seeds, unreliable agricultural production, promotion of substitution products (water melons, etc.) as well as the obsolescence of equipment.

The oil-seeds grinding process operates below its capacity due to a persistent deficit of ground-nut production in the last years. High levels of idle capacity decreases energy efficiency per unit of output. However, the refining of vegetable oil has maintained relatively high production levels thanks to imports of crude oil from Europe.

Table 4.18 shows SONACO's energy consumption and related CO_2 emissions. It is worth noting that CO_2 emissions has decreased compared to emissions in year 1995 due to low activity levels of the oil-seed grinding process, which in 1997 only operated at 47% of its nominal capacity.

Table 4.18. Energy consumption and related CO_2 emissions

	1995	1996	1997
I. Energy consumption			
• Electricity (Mwh)	2 908	2 359	4 892
• Gasoil (ton)	11 170	8 633	8 811
• Fuel oil (ton)	2 705	1 255	2 866
• Agricultural wastes(ton)	36 907	39 146	18 780
II. CO2 emissions (ton CO2)	71914	70661	44341
• Electricity	2732	2216	4595
• Gasoil	35	27	28
• Fuel	8250	3828	8741
• Biomass	60897	64590	30987

Future strategies for oil-seed development industry rely on several targets; among them: reconstitution of seed stocks, subsidies to the sector, research on seed varieties better adapted to local climate conditions, peasant access to agricultural inputs and credit. A programme on adjustment of both the land and tax systems to the new agricultural policy is going on.

The opening of the future WAEMU market provides very great opportunities for SONACOS EID in the area of oil-seed refining and conditioning. Production is projected to growth at a rate of 2.6% per year.

Both current low levels of efficiency and expected growth rates of oil-seed industry provide a wide scope for implementing actions oriented to improve levels of energy use and therefore to limit GHG emissions. Table 4.19 shows a summary of main technical measures considered in the present analysis.

Table 4.19. Technical measures

Measure	Cost (10^6 FCFA)	Effects	Expected Energy savings
Use of paper wastes and installation of a counter-pressure turbo boiler	4 650	• Efficiency improvement of boiler • Controlled combustion of paper wastes • Re-use of steam in low-power turbine	• biomass: 1498 tons • electricity:1767.2 Mwh • fuel: 832 tons
Replacement of pumps	100	Higher efficiency of circulation pumps	• biomas: 2639 tons
Improvement of the boiler regulation system	200	Higher output of boiler through a more fine regulation	• biomass: 1406 tons
Recuperation of the heat dissipated by compressor radiators	30	• electricity saving in the heating water system • energy savings in the fire chamber steam	• electricity: 412.5 Mwh
Automation and improvement of the lighting system	104	• more economic exploitation of system • savings on electricity consumption by using more efficient lamps	• biomass: 481 tons • electricity: 394 Mwh
Variable speed drivers	80	Electricity savings	• electricity: 310 Mwh
Insulation of transporters	30	Savings of energy on losses in line	• biomass: 1103 tons
Better insulation of the steam system		Savings on steam consumption in the boiling room and in the reactors.	• biomass: 10290 tons
Installation of condenser protectors	40	• savings of steam re-vaporisation • savings on the heating of water supply to the boilers	• biomass: 305 tons
Hermetic drive steam pumps for the condensers	20	Savings on losses of condenser systems	• biomass: 905 tons

Concerning future energy consumption the following assumptions are made:

- The consumption of empty shells (production and purchase) will be proportional to the level of grinding in the year 1996 (ground-nut production in 1997 was extremely low and important production share was used for reconstitution of seed stocks).
- Electricity consumption is expected to be inversely proportional to the level of grinding, this last estimated in 350.000 tons per year.
- The consumption of gas-oil and fuel will be proportional to the grinding level occurred in 1996.

- The contribution of the empty palm shells, empty cotton husks and balls of rice to the total energy consumption is expected to be marginal.
- Energy consumption in the conditioning and refining process will increase by 70% compared to 1996 levels.

The average cost of limiting CO_2 emissions through the implementation of the technical measures listed above has been estimated in 8.54 US$ per ton of CO_2. Levels of energy consumption and associated CO2 emissions under the base case and the mitigation scenarion are summarised in Table 4.20.

Table 4.20. Energy consumption and CO2 emissions under the baseline and mitigation cases

	1997	2000	2005	2010	2015
Groundnut production (10^3 t)	100	900	1100	1200	1300
Grinding process (10^3 t)	25	180	205	233	265
I. Baseline					
1.1 Energy consumption					
• electricity (Mwh)	4 892	2 327	2 043	1 797	1 580
• gasoil	8 811	6 514	7 474	6 576	5 790
• fuel oil	2866	2 566	2 722	3 321	3 777
• biomass	18 780	76 862	87 536	100 344	113 157
1.2 CO_2 emissions (ton)	44 351	220 728	178 305	198 192	218 033
• electricity	4 595	2 185	1 919	1 688	1 484
• gasoil	27 879	83 894	23 648	20 807	18 320
• fuel oil	8 741	7 826	8 302	10 129	11 519
• biomass	30 987	126 823	144 435	165 568	186 710
II. Mitigation case					
2.1 CO_2 emissions (ton)	36 851	166 728	116 305	128 192	138 033
2.2 Avoided emissions	7 500	54 000	62 000	70 000	80 000

4.3.4 Efficiency improvement in chemical industries

The ICS constitutes a chemical and mining industrial complex. It includes the processing plants of Taiba, Darou, and Mbao.

The Taiba Plant

It is a mining industry. It extracts and processes tricalcic phosphate ore from Taïba deposit which extends over some 40 km2. The 6-7 m thick phosphatic layer is made up of dune sand, consolidated sands and sandstones. It is recovered by dead grounds of between 25 to 42 m.

The plant is dry operated after the folding back of the layer. Scoop excavators carry out the levelling of the upper dead grounds. The excavated materials are carried by belt-conveyors. The draglines ensure the levelling of the lower dead-grounds. Treatment of the ore involves four successive operations:

- Untamping: through a sifting operation, the crude ore is rid of the biggest kidney stones essentially made up of flint modules. These are then washed in a sluice before it is deposited in a spoil heap.

- Preparation**:** the ore thus sifted is then hydraulically transported to processing factory. It undergoes a grinding and sifting operation that reduces the ore to a scale below 800 microns. The smallest particles (below 40 microns) are essentially made up of clay. They pass through hydro-cyclone separator. The water undergoes a decantation process and it is recycled. The dried matter is deposited on the debris.

- Floating: the ore is floated in order to separate the phosphatic ores from siliceous impurities so as to produce a highly concentrated ore of payable grade. The floating residue, in the form of a 20% solid pulp is deposited into the spoil heap through pumping.

- Drying up: the floated concentrate is filtered. The part allocated to the sulphuric acid plant of Darou is transported by conveyor belts with an average humidity of 20%. The remaining part after dried up through two rotating furnaces exported.

The Darou Plant

This plant includes two main units: the sulphuric acid unit and the phosphoric acid unit. Sulphuric acid production is used an input for processing phosphoric acid. Electricity is produced by TA generators from the steam coming from regenerating boilers. Main production processes of the plant are as follows.

- Handling engines fill up a bin feeding three intensive melters. Sulphur is melted in these with the help of steam coils. The overflow of the melted and liquid sulphur go down into the two sulphur pits, before it is pumped to feed three horizontal plate filters.

- The combustion of sulphur takes place in two parallel sulphur furnaces. Filtered liquid sulphur feeds the burners before entering into the furnaces.

- Conversion of SO_2 into SO_3 takes place in a catalysis pan using a catalyst and Vanadium oxide.

- The combustion and diluted air provided by one of the turbo blowers is dried up with sulphuric acid (95%) in a stool-lined tower where water flows backwards.

- The absorption tower is used to produce sulphuric acid. Acid is maintained at a constant level and concentration in the tower and is cooled by two exchangers. Honeycombs and panels remove acid vesicules from the fumes coming out of the tower. The sulphuric acid produced is stocked in four tanks.

The MBAO Plant

Mbao plant basically consists of granulation unit. At Mbao plant fertilisers from the granulator go through a rotative furnace where they are dried with combustion gases from a furnace which energy consumption is 1000 litters of heavy fuel per hour. The granulation unit receives a mixture of NP and SA at a temperature between 120 and130 degrees. The mixture includes also crystallised ammoniac sulphate, potassium chloride KCI, and water steam. The mixture of such diverse compounds at varying proportions gives different formulas of desired fertilisers to be transformed into grains.

The ICS industry uses three sources of energy (Table 4.21):

- Electricity provided by SENELEC network. SENELEC supplies all energy requirements by phosphate mining operations in Taïba; 10% of power consumption at Mbao and a small fraction in Darou.

- Self-generated electricity from sulphuric production at Darou.

- Oil products (heavy fuel, light fuel, diesel oil) consumed by the boilers in Mbao plant ant by engines.

Table 4.21. Energy consumption and CO2 emissions (1997)

	Taiba	Darou	Mbao
I. Energy consumption			
1.1 electricity (Mwh)	104 718	2 314	1 489
1.2 fuel oil (ton)		5 224	5 544
1.3 light fuel (ton)		159	1 780
II. CO_2 emissions (ton)	98374	18 592	24 135

Concerning the future perspectives of the ICS industry, the removal of customs barriers, standardisation of fiscal systems among the 15 member countries, provides a favourable context for exports of fertilisers to UMOA countries. This opportunity presents optimistic prospects for ICS plans to review their NPK fertiliser granulation programme. Moreover, The nature of the agreements with main ICS commercial partners guarantees stable prices. Hence, the quality of the phosphate received as well as the technical skills represent the fundamental elements of productivity for the factory at Darou.

The international competition, the performance of the Senegalese agriculture, as well as the world prices for main raw materials as sulphur and ammoniac, have a significant impact on the production level of the granulation factory of Mbao. It has been assumed here that the annual production of fertilisers will reach 345 000 tons by the year 2001, production level equivalent to an increase of 50% respect to current production. Long-term production growth has been assumed at 2.6% per year, in line with the population growth (see Table 3.2).

Potential efficiency improvements analysed here have taken into account power generation plans at the Darou plant. At the present time, Darou produces surplus energy, and inter-connection with SENELEC only occurs during stoppage for maintenance purposes. The on-going project of doubling of the production at Darou will enable to supply most energy requirements to the Taïba mining operations(105 millions Kwh). Since electricity consumption at Mbao plant is relatively low (12 million Kwh), excess of power generation at Darou will be transferred to the national network provided that the national network stability are improved.

Initially intended for the granulation of the binary compounds, the fertiliser factory has, over time, adapted In order to meet demand fertilisers demand requirements, the fertiliser plant has gradually included tripple NPK fertilisers in its production process. This has resulted in emanations of fertiliser dust forming a deposit all over the plant, the machines and the neighbourhood. An estimated 5% of production losses is associated with this problem.

The installation of emanation control facilities will allow to reduce the specific consumption by around 4%. Such facilities include:

- recovery pipes and tubes
- draught and blast ventilators
- a cycloning system
- a dust removal system by filtration
- a handling system
- storage tanks.

Projected energy consumption and CO_2 emissions under the baseline case and the mitigation scenario are presented in Table 4.22. Results of the analysis show that the specific cost of this option is 10 US$ per ton of CO_2.

Table 4.22. Energy consumption and CO2 emissions in the base and mitigation cases

	2000	2005	2010	2016
I. Energy consumption				
• Electricity (Mwh)	105	3.105	38.314	47.566.
• Diesel oil (ton)	1.780	2.000	3.500	6.500
• Fuel oil (ton)	10.927	35.000	40.000	50.000
II. CO2 emissions (baseline)	141.101	142.220	169.100	217.300
• Electricity	98.374	29.170	36.000	44.700
• Diesel oil	24.135	6.300	122.000	152.000
• Fuel oil	18.592	106.750	11.100	20.600
III. CO2 emissions (mitigation)	136.600	141.470	167.800	214.900

5 CONCLUSIONS

With the implementation of these different options one should not expect changes on the orientations and objectives of growth. On the one hand, they constitute axes taken into account in the macro-economic framing of the 9th. Plan (96-2001), and on the other hand, their impacts on the macro-economic plan remain negligible for some people. We are therefore going to try to determine the contribution of these different options in the objectives of growth.

5.1 Rural electrification

5.1.1 Households incomes

Average household expenditure on energy has been estimated at 4.000 FCFA per month in rural areas. This amount includes 5.51 FCFA in kerosene, 2.000 FCFA in candles, and 2.000 FCFA in batteries.

The use of solar photovoltaic panels (SPP) implies the replacement of batteries every three years at a cost of 30.000 FCFA. Therefore, the savings realised by a family during one year amount to 38.000F. The cost of the solar system is estimated in 450.000F, which represents a payback period of the investment of around 12 years. Therefore, the investment on the photovotaic alternative is justified by the savings realised on the purchase of traditional energies.

5.1.2 Employment

To evaluate the effect of solar systems on employment, we will assume that installation fees represent 25% of the investment cost, and manpower fees 20% of these installation fees. By bringing all the installations to SPP equivalence, we will therefore have a need of 168760 SPP, and consequently, as much batteries and charging regulators

Most of the employment created is temporary, related to the installation realisation phase of solar systems. The only permanent creation of employment involves that regarding the drivers of drilling machines (235). The unit labor force salary is estimated at 30000 FCFA per month. It is also worth noting that the number of employment created does not take into account the skilled labour force required by the maintenance and operation.

Within a period of 5 years, total temporary employment created has been estimated on the basis of 6 months per employment. These employment will thus contribute to the reduction of rural migration and the raising of the standard of life and technological standard in the rural area, through a transfer of know-how. If the potential demand were satisfied, it would have permitted a considerable growth of the market of different components of the SPP.

Total electricity requirements represents the installation of around 168.760 SPP systems including batteries, stands, regulators and different accessories. The expansion of the market will therefore permit the raising of the turnovers of producers from different components thereby creating a value added supplement which could increase the creation of employment.

Table 5.1. Employment in Rural Areas

Options	Installation fee (Billion CFA)	SPP units	MOD fee (billion CFA)	Men/month
Domestic lightin	13,7	121.662	2.737	91.246
Village water pumps	1,7	14.100	342	11.398
Community infrastructures	3,4	30.505	686	22.879
Administrative infrastructures	0,3	2.493	56	1.870
TOTAL	19,1	168.760	3.822	127.392

5.1.3 Balance of Trade

The implementation of the mitigation options requires imports of equipment which represent around 60% of the total investment cost, that is an amount of 45,861 billion FCFA. Part of this loss of foreign exchange will be compensated by government revenue increases from value added taxes.

Taking into account the opportunity cost of avoided oil imports (20820 barrels) over a 15 years period, the savings realised will amount to 3,18546 billions of FCFA . This shows that the savings realised does not compensate foreign exchange required by the importation of SPP modules. In conclusion, the implementation of the mitigation option will contribute to widening the deficit balance. Table 5.2 shows savings in kerosene imports under the assumption of US$ 17 the cost per barrel of oil.

In the middle- and long-term, it would be necessary to envisage the production of modules at the national level. It is only from this perspective that projects in this domain could have an effect on the balance of trade.

In the final analysis, the state derives a sure benefit from the implementation of this project, in the sense that it obtains a certain value added in terms of taxes and salaries paid to nationals.

Households also gain from this project. In fact the electrification of 121662 households,,235 drilling machines, 2773 health centres and 1039 administrative infrastructures will surely contribute to the development of the localities concerned. The spd permit the households to satisfy the energetic needs which include lighting, radio and television.

Table 5.2 Estimates of Kerosene Importation

Imports	1995	1996	1997	1998	1999	2000	2001	2002
Value added	78,9	68,9	79,7	81,2	87,5	102,4	109,2	114,1
Crude oil in billions	19,8	43,4	44,9	47,1	49,3	62,4	67,5	70,4
Crude oil in billion tons	302,8	649,5	650,0	650,0	650,0	787,2	814,7	814,7
Crude oil (price)FCFA/kg	65,5	66,8	69,1	72,4	75,8	79,3	82,8	86,5
Finished Petroleum prod	59,1	25,5	34,8	34,2	38,2	40,0	41,8	43,6
Finished petrol prod (vol)	782,3	324,0	427,7	400,0	427,7	427,7	427,7	427,7
Oil products (price)	75,5	78,8	81,5	85,4	89,4	93,5	97,7	102,0

Concerning the impacts of rural solar electrification, it must be noticed that an equipped water point cover, in addition to the site concerned, satellite villages located less than 5 km, so the overall benefited population have been estimated in 1400 inhabitants. For the entire water system component therefore, there will be 47000 households of seven individuals each as beneficiaries.

On the level of health and administration, additional benefits such as more increased capacity of intervention in the health domain and best working conditions have to be taken into account.

5.2 Forestry

In their objectives, forestry projects are aimed at the insertion of riverside rural settlements of forests into forestry according to speculation.

In the present circumstances, all the value added produced by the sector is re-exported into the urban zone to the detriment of rural populations. The installation of rural settlements into the segments ofthe sector which encourage the injection of revenue in the rural area will make forestry exploitation play a catalyst/pivotal role of development by virtue of its practice in the other sectors.

For this insertion to be viable and lasting, it must necessarily be done within associations or well structured groups.

The effect of reorganisation of the economic sector of the rural environment will be to valorise natural resources (Agro-forestry). The impact of this on the environment will be the creation employment and revenues earned from both wood and proceeds from picking produce.

5.2.1 Employment and Revenue

Shifting afforestation of 150 hectares of cashew nut plants, 100 hectares of mango trees and 250 hectares of eucalyptus will contribute to the production of firewood (eucalyptus) and fruits (mango and cashew nut trees) They will need financial resources in the order of $ 6.846.000. If the document gave the necessary investment, it provides information neither on annual distribution nor on distribution per tree type, making the evaluation of the exploitation uneasy. But by focusing on the ESMAP /World Bank study, we will be able to determine the costs of reafforestation of 250 ha and reduce the returns which the populations derive from it.

According to this study, the reafforestation of one hectare of forest cost 150000FCFA (before the currency devaluation), if we integrate this devaluation and inflation while also taking account of the figures of the DEFCCS (Department of Forestry) (500000FCFA)/ha, the cost price will be 532000F/ha, for a production of 437 trees/ha (eucalyptus) for a volume of 0,043 m3 per tree having reached maturity.

Given that a m^3 of firewood weighs 750 kg. We end up in a production per ha of 14093 kg/ha which is to the total of 3523250 kg at the total of firewood, for a cost of 133 000000.

Thus the cost price per kg of firewood produced will be at 38 FCFA. It is worth realising that 5,5 kg of wood is needed to produce 1 kg of charcoal, this production will encourage the obtaining of 640591 kg of coal. Since the cost of charcoal is presently 100 FCFA, the returns expected are at 64.059.100 FCFA (the assumption that is made is that every investment is realised in the year zero and that exploitation is done only once, at maturity).

For other tree species, fruit trees, citrus fruits) given the size of trees having reached maturity plants will be more spaced than those of eucalyptus which bring about a number of trees at a maturity lower than that of eucalyptus. Out of the 250 ha remaining we believe that only a maximum of 100 trees /ha can be planted, which is 25000 feet, if the average proceeds per feet is by 70kg per feet, production will be 1750000 kg, if the kilo is valorised in average to 100 FCFA the value will be 17500000 FCFA. The local populations will therefore take part from these different speculations in terms of revenue, they will therefore have the tendency to settle and reinvest their incomes in other activities.

Table 5.3. Redemption of Material

Nature	Original value	Life span	Annual redemption of fixed assets						
Year			1	2	3	4	5	6	7
Vehicle	506	10	50,6	50,6	50,6	50,6	50,6	50,6	50,6
Motos	70	10	7	7	7	7	7	7	7
Buildings	800	20	40	40	40	40	40	40	40
Office material	80	5	16	16	16	16	16		
TOTAL	1456		114	114	114	114	114	98	98

At the end of 7 years for which the project will last, the total redemption will be US $ 766000 (for one dollar at 600 FCFA) that is 459.600.000. The total cost of investments is US $ 12723000, in as much as the portion in FBCF is 6%, whereby 94% of the turnover at the end of seven years.

5.2.2 Value Added

The value added generated by the project is made up of taxes withdrawn/deducted by the state, from salaries paid, redemption of material and benefits. Presently, state tax is especially represented by the royalty perceived and which is the cost for renewing resources. Given the returns deducted from these activities it is possible and necessary to resort to local manpower in order to ensure the management and maintenance of exploitations.

Salaries will also be paid for a subsequent activity of carbonisation. Different sectors may earn incomes from this exploitation. These include: scourges, foremen, head Coleman transporters, sellers (urban wholesalers), and the diallo kerin (urban retailers). But from the time when the riverside populations take care of this speculation, they can with minimum assistance by professionals (especially the sourgas) get all the income from this activity.

Therefore, at the end of the project, there will be at the level of the populations a commitment for these income-generating activities. This will encourage the capacity building of action of associations and committees for the protection of nature.

5.3 Industrial Process

There are many possibilities of reducing the consumption of hydrocarbons in the industry by applying energy-saving devices. These devices are situated at two well-identified levels:

1) At the level of the procedures of protection of electric energy (SENELEC for example)
2) At the level of the use of the energy produced (SONACOS, ICS)

After the drawing up of procedures for energy protection and the energy report from industries of SENELEC, SONACOS and ICS, reduction options were identified in terms of deposits of energy savings.

With these said options, we now come to the alternative solutions which will permit the reduction of energy consumption and increase its yield. Certainly, investments should be implemented in order to reach these objectives of savings which reduces the emissions of greenhouse effect gas.

Table 5.4. Industrial Procedures (Recapitulative Analysis of Options)

Industries	Energy savings Electricity (Mwh)	 Oil (ton)	Total oil savings (ton)	Savings (10^9 CFA per year)	Savings	Investment (10^9 CFA)	Difference at the end of year 15
SENELEC	20328	6194	122800	0,47	9,4	2,5	6,9
SONACOS	60165	26864	402960	2,05	30,8	5,3	25,5
ICS	699	210	8197	0,01	0,6	0,15	0,5
TOTAL	81194	33268	533957	2,54	40,8	7,9	32,8

The implementation of these investments both for SENELEC and the ICS and SONACOS, which is 7,944 FCFA in all, will encourage a savings in petrol of 332668 tons of petrol for the first year whose material is imported in part.

Regarding the balance of trade, these investments in imported material is translated by an increase in deficit. But by implementing these equipment, the savings realised on the importation of petrol will contribute in mitigating this said deficit. Thus out of the 20 years of the life-span of equipment the nation will be able to save 40,8 billions of FCFA in foreign exchange. Not taking into account the maintenance expenditure relating to the putting in place of investments.

This type of project should permit a growth in the production of energy without too much effects on the environment. In effect, the objective of the PVD such as Senegal is not to reduce energy consumers but rather to rationally use the energy produced with a view to contributing to the stabilisation of greenhouse effects gas.

The objectives of the government include:

- ensuring a supply at low cost
- to accelerate the penetration of electricity (60% in the urban area and 15% in the rural area) from now to the year 2000

Therefore Senegal is conscious of the fact that the attainment of its objectives is through a better productivity of the electricity sector. Savings realised in SENELEC allow this company to put reliability into its production network and electric energy distribution. As for companies like SONACOS and ICS, they will further reinforce their positions at the level of the competitive market thanks to the improvement of their production and their productivity.
In these conditions, the savings realised could serve for the reconnection of more economic agents and contribute to the development of the localities concerned.

5.4 FINAL REMARKS

With the implementation of the different options, the recapitulation gives an overall investment of 92.013.200.000 FCFA (which is 150 millions of dollars). Out of the 20 years of the life span of the equipment, the nation will realise a savings in foreign exchange of 44 billion FCFA on the importation of petrol.

These options encourage the creation of permanent and temporary employment in both the urban as well as the rural areas. These employment, especially those created at the rural level permit the settlement of the populations . This also contributes to the creation of economic activities at the local level. These activities are permitted by the fact that these populations have electricity, basic social structures and drinking water among other things.

Regarding investments, we are assuming that the state finances 80% through a loan from the its partners, at concessional rates (for example 0,75%) over a duration of 40 years. Annual repayments will therefore be at 2.453.685.3336 FCFA with effect from the 11th. Year, the interest due is at a minimum of 552.079.2007 FCFA per annum, which is as compared to the expectations less than 1% of interests due and expected8.

In these conditions, the state could face this demand, with regards to the advantages which the nation will derive from it. For sure populations and enterprises involved in it will take part in the repayment of this debt, the state playing its role as facilitator.

The overall implementation of the three mitigation options presents an investment of 92 billions FCFA. In considering the life-span of equipment, evaluated at 15 years for the solar and SONACOS and 20 years for SENELEC and ICS, the gross savings realised are pegged at 44 billions of FCFA, including 40,8 at the industrial level.

There is indeed need to take into account the costs of exploitation and maintenance related to these new equipment to guarantee them an excellent use and usefulness. In these conditions, and bearing in mind that the industrial sector reinvests part of its benefits, one can reasonably say that this sector could improve its performances in its traditional borders of production and maintenance. This will encourage enterprises concerned to pursue their development which is in straight line in the process of economic and social development of Senegal.

Regarding solar energy, the investments realised are negligible. But they are necessary and take part in the development process of the Senegalese rural community. This same applies to projects related to the protection of forests and community reforestation. Thus the installation of new and renewable forms of energies like solar energy as well as the reforestation projects are perfectly in line with the 9th, Economic and Social Development Plan which is ongoing. This plan insists on the need to preserve the natural and forestry resources and to reinforce their potentialities. In this development strategy, the environment is identified as one of the most strategic sectors which will ensure sustainable development. This is why this present project combines sectoral approaches from a more global perspective of actions undertaken (industry, PME, rural and urban zones etc..) convinced about the strong interdependence between the environment, energy and development.

The different measures of mitigation options proposed here, will on the one hand compete with the acceleration of the electrification process of rural and village communities, and with sustainable economic development of these entities.

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