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BIOGAS

SENEGAL

The application of Biogas Technology to the treatment of industrial waste in Senegal

Report carried out on behalf of the United Nations Industrial Development Organization

January 1994
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CONTENT

1. THE ECONOMIC AND INDUSTRIAL POLICY FRAMEWORK FOR THE PROJECT IN SENEGAL

Senegal is a developing country, three fourths of which are situated in the Sahel zone, characterized by low rainfall and periodical drought.

Senegal has as all other African countries experienced a very significant development during the last 90 years and has now in 1993 a population of approx. 7.7 million. The annual growth of the population averaged 2.8% during the 1980s, and it is expected to be 3.0% per year in the 1990s. Thus, at the end of this century, the population is expected to reach 9.2 million.

The gross domestic product per inhabitant in 1992 amounted to around US$ 720. The development in GDP in Senegal has for a long period been connected to the development of the French economy. The GDP per capita is close to the end of the range for all middle-income developing countries.

However, this close monetary connection or relationship between the Franc in the CFA countries and the French Franc with fixed foreign exchange rate has in the beginning of January 1994 led to a devaluation of the Franc CFA by 50%. In other words, the development in the GDP has been too optimistic during recent years and the gross domestic product per capita is most properly significantly lower than the US$ 720.

Senegal's area comprises 200,000 km^2 of land of which significant parts are arid or semi-arid. The amount of cultivated agricultural land is estimated at 3.4 million hectares. However, this part of the land needs irrigation; water for it is in many regions scarce and often supplied from dams. Because of sandy soil characteristics especially in the Northern and Eastern part of Senegal, fertilizers which improve the soil structure are actively sought by the peasant population.

In the remaining part of Senegal, the soil is excellent. The vide range of natural resources allows a diversified agricultural production. Even though ground nuts and millet are the two most dominant and important agricultural products for the country, agricultural activities along the rivers (Senegal and Casamance) and in the river deltas such as tomato production, cotton, sugar, maize, bananas, pineapples, provide much of the export earnings for the country.

Unfortunately, the agricultural production begins to suffer because of poor structure of land and soil. The soil is degraded due to the pressure of the growing agricultural population living on the available resources of land, which begin to undermine the traditional methods of shifting cultivation.

The rapidly growing population in the rural areas gives some constraints both of ecological and socio-economic nature.

The ecological constraints are the general deterioration of the land, lack of rain in some areas, different kinds of diseases in the crops and the plants, as well as invasion by grasshoppers (locust).

The socio-economic constraints are numerous and in some cases very serious. Generally speaking, lack of finance among the farmers to buy seeds and get sufficient money to invest in technical applications in order to increase the harvest is a very significant problem. At the same time, the demographic development gives some problems to continue the traditional production methods. The population especially along the rivers beds in Senegal is furthermore facing general deforestation problems, which are partly a result of intensive need for fuel wood and the increasing problems related to institutional and management problems in the local agricultural and farmer organisations.

In other regions in Senegal, the agricultural base is being eroded through the deforestation which takes place due to the expansion of agriculture, through logging and the cutting of wood for fuel.

The cattle breeding in Senegal provides the life for more than 300,000 families in the rural area. While the actual number of cows has during the last 10 years been reduced from 280,000 to approximately 250,000, the number of sheep and goats have increased significantly in the same decade, from 300,000 to more than 600,000. As the goats and sheep contribute much more to the degradation and deforestation of the land compared to cows, this development in cattle breeding is very negative for the environment in the rural areas. The goats and sheep uproot the grass and eat new trees, leaving the soil open to erosion.

The industrial structure of the country is dominated by primary industry. Senegal has an important mining of phosphate primarily for exportation. Also the agricultural products like cotton, sugar, peanuts, vegetable oil and other agricultural products account for more than 50% of the export revenue. Besides that, the agricultural sector is the major generator of employment in Senegal.

The fishing industry in Senegal has witnessed rapid growth through the 1970s. In that period, the average annual amount of fish caught along the coast of Senegal and treated at the fish industries, primarily in Dakar and Ziguinchor, was approximately 350,000 tonnes per year. Due partly to changes in the climatic conditions and partly over-exploiting of the fish resources in the ocean along the coast line of Senegal, the amount of fish caught in Senegal has experienced a significant decrease. In 1990, the total catch of fish was only 140,000 tonnes. Even though the fish authorities in Senegal are positive, they do not expect that the amount of fish captured will increase in the near future.

However, the fishing sector is very important for Senegal. More than 100,000 people were employed in the fishing sector in the late 80'ties and the exportation of fish accounted for more than 25% of Senegal's export income.

The following fish are after treatment in Senegal exported mainly to Europe: Lobster, shrimp, sole, tuna-fish, cuttle-fish. Especially the tuna is a very important fish and almost all the tuna fish is canned and exported.

The dominating manufacturing industry is built up mainly around the transformation of the domestic raw materials and the above mentioned agricultural products.

The production of fertilisers from raw phosphate supplies the domestic market and accounts now for more than one fifth of exports. It is still the agro-industry that comprises sugar production, vegetable oil, beer production, fruit-and vegetable canneries which together with the fish industry dominate the industrial complex in Senegal.

The economic development in Senegal suffers from the fact that a large part of the country's economy is effected by a large number of subsidies to both production and consumption, which has had serious distortive effects on the economy. To some extent, this policy has been a success in terms of economic growth - between 1980 and 1990, the GDP of Senegal increased by about 2.5 - 3.0 percent per year, which is similar to the economic growth in France. But the rapid growth of the population, which increased by 3% per year, undermined the growth per capita and created an increasingly difficult problem of unemployment, which grew significantly, affecting above all the younger population. At the same time, Senegal has - together with the other F.CFA countries - for the last 3 years experienced poor development in the GDP. This poor development has as mentioned before led to the 50% devaluation of the Franc CFA.

This poor development seems to continue in the 1990s. A problem to be addressed is that the level of competition in the manufacturing industry is rather low. Even though the most important agro-industries are privately owned, the domestic market is protected behind solid custom walls. At the moment, there is no evidence that the Government intends to embark on a major privatisation programme and to lower tariffs, exposing the industry to more competition.

What the future industrial development will mean for the use of biogas technology for the treatment of waste is at present uncertain. In principle, the State can impose new and more environmentally friendly technology to a privately owned company when a production license is applied for. But experience until now has shown that the Government is very flexible with regard to environmental restrictions on private companies. The only exception is the sugar cane industry in the Northern part of the country. Due to the risk of serious pollution from this industry, people connected to the "Direction de l'Environnement" under the "Ministère de la Protection de la Nature" are monitoring the environmental impact from the sugar production very carefully.

2. THE INSTITUTIONAL AND LEGAL FRAMEWORK FOR ENVIRONMENTAL POLICY

2.1 Status Quo for Environmental Policy in Senegal

The Government of Senegal has since 1971 been dealing with the environmental problems and has seriously tried to enforce a sustainable Environmental Policy in Senegal. The first step for the protection of the environment was the set-up in 1971 of a national commission, "La Commission National de l'Environnement", to deal with the environmental problems. Under this organisation, the following subcommittees were established:

- la sous-commission de sauvegarde des sites naturels;
- la sous-commission de la fauna;
- la sous-commission de la flore;
- la sous-commission de la politique de l'Environnement;
- la sous-commission de l'éducation et de la propaganda.

One of the reasons for establishing this organisation was to present a country paper at a UN Conference in Stockholm in 1972 about the environmental problems in Senegal. However, the work made by the different subcommittees was so excellent that the Government decided to create an office in 1973, " Secrétariat d'Etat à la Protection de la Nature". This resort office was later extended to include the activities normally carried out by the "Direction des Eaux et Forêts" and the "Direction des Parcs Nationaux".

At a later stage, this office realized that there was a need for having some kind of cooperation with the "Ministère du Développement Industriel". The present environmental legislation was made in that period of three years. But facing the increasing problems during the 70'ties and the growing interest conflicts between various organizations, the "Secrétariat d'Etat à la Protection de la Nature" had to find some solution of the problems coursed by activities operating under the responsibility of the "Directions de l'Industrie, des Mines et de la Geólogie, Direction de l'Energie" and also the office for Artisan activities.

During the period from 1983 to 1990 with hårdly no activity from the "Direction de l'Environnement", this office in 1990 constituted the "Ministère de la

Protection de la Nature", together with the following institutions: "la Direction des Eaux", "Forêt et Chasse", "de Conservation des Sols et du Reboisement", "la Direction des Parcs Nationaux", la "Direction de l'Environnement".

After April 1991, the "Direction de l'Environnement" and "la Direction des Parcs Nationaux" were integrated in a new Ministry called "Ministrère du Tourisme et de l'Environnement". This change was made in order to coordinate various activities related to the development of the tourist sector.

Due to all the above mentioned organizational changes and various conflicts, it is a fact that the Environmental Policy in Senegal is still in its infant stage of development:

* Environmental consciousness is limited at both the political level and in the general public.

* The existing environmental legislation is outdated even though it was made in 1983 and insufficiently enforced.

* There is no independent ministry for environment nor an environmental agency, and very few staff in the ministries deal with environmental issues.

* There is little information or data available on levels of pollution and their impacts in Senegal, and little research is done, except for the research made by various donor agencies.

This background poses obvious constraints for the promotion of biogas technologies for the treatment of solid and liquid waste in Senegal. There is little political pressure on neither the municipal water and sewage utilities nor on the industries for the treatment of their solid and liquid wastes. The normal procedure is to dispose waste water directly into the rivers and the sea and to dispose solid waste on landfills unsorted and untreated.

With the exception of the sugar industry - which in many ways is one of the key industries in Senegal - the various industries are more or less unconcerned with regard to the polluting impact of their production process. The use of cleaner technologies does not yet enter the investment planning process as an option to be considered.

The mission in some cases experienced that the management is extremely cautious with regard to giving environmental consultants access to their premises. Only when it is clarified that the main purpose of the mission is to look into the possibility of using some of their industrial waste for production of biogas, the management generally speaking changes attitude and becomes more positive.

However, the situation is changing slowly. The environmental problems have become more transparent as they continue to intensify under the pressure of the growth of population and the economy.

Therefore, several environmental impact studies, strategies, and pilot projects in Senegal are being financed by international donors such as the UNDP and the EC and by bilateral donors such as France, Germany, and Sweden; these improve the information basis for environmental policy initiatives.

As regards the introduction of biogas technology for the treatment of organic industrial waste, the situation imposes a mixture of constraints and opportunities:

- On the one hand, although industrial managers are interested in cleaner technologies, no desperate need is felt as long as no governmental action is taken. The short term objectives are therefore that the cheapest solutions are the best ones, disregarding any environmental issue. This means that heavy subsidies will be needed to persuade managers to become pioneers in application of the biogas technology.

- On the other hand, however, the promotion of biogas will enter logically into the stream of initiatives by the international society and its environmental priorities. The managers are also open to any new technology from which the plant economy will benefit.

2.2 Institutional Framework for Environmental Policy in Senegal

As a logical consequence of the present stage of environmental policy in Senegal, also the public infrastructure for environmental administration is in its infancy:

* The main problems for the "Ministère de la Protection" and the "Direction de l'Environnemental" are the lack of finance for various studies and projects and lack of coordination between various ministries.

* The sectoral ministries neither have a sufficient mandate nor a central, regional or local entity capable of participating actively in environmental management.

* Lack of expertise and, in particular, of procedures for the systematic techno-economic evaluation of project opportunities lead to the acceptance of sub-optimal options for projects.

The *"Conseil National de l'Environnement"* was created in 1993 to ensure coordination between the activities of the "Ministère de la Protection de la Nature" and of the sectoral ministries. But it has not yet been effective in this task.

At the *local and regional administrative level* in the regions or the "Prefectures" of Senegal, there are no environmental administration or staff dealing with the local environmental problems, except the Dakar region.

Generally speaking, the number of well equipped *laboratories* is very limited in Senegal. However, there are laboratories which can provide sufficient capacity for the evaluation of physical and chemical properties in water, whereas the capacity for toxicological analysis and for the chemical analysis of biotasks has to be found at the University of Dakar or in France.

The introduction of biogas as a technology for the treatment of industrial waste would touch the field of interest of all the below mentioned ministries:

* The "Ministère de la Modernisation et de la Technologie" for working in the renewable energy sector.

* "L'Environnement" for being an environmental technology body with a rather broad cross-sectoral application.

* "L'Industrie" for its application in the agroindustry.

* "L'Energie" for being a renewable energy technology.

* The agroindustry for being a supplier of compost for farmers.

* The fishing industry for its use as substitution of other forms of fuel and its removal of the fish waste in the canned fish industry and the fish treatment industry.

The large number of potentially interested parties poses a potential coordination problem. In case of a biogas programme based on industrial waste, the "Ministère de la Protection de la Nature" will have to play a dominating role as the lead-counterpart for a biogas programme for waste treatment and therefore have an obligation of keep the other ministries well informed about the initiatives that are undertaken. But because of the broad interest one should expect the different ministries to provide active support to the programme.

2.3 Legal Framework

The present environmental law was initiated by a decision made by the Government in the beginning of January 1983. The basic content of the law according to the text is to set some kind of classification of the most polluting companies or enterprises in Senegal. With this law, the public interest or the State have the tools and some guidelines under which they can act or control various industries if there is a risk that production activities can have negative environmental impact on the nature and as such can be dangerous for the society and the country as a whole.

According to the law, the industries and their activities are divided in two categories depending on degree of pollution

In principle, however, the existing *primary legal framework* permits the authorities to comply with the environmental tasks demanded in a modern society although a few legal "lacunes" were identified:

- There is no general law making it obligatory to provide an integrated control of all types of pollution.

- Laws concerning the control of chemical products in general.

- Laws concerning the control of hazardous waste.

The law contains some weaknesses. There is a lack in the form of "decrets" and "reglements". The Government has not made sufficient use of the scope of manoeuvre provided by the primary legal framework to implement environmental policy priorities in the form of directives. Secondly, there are hardly any *environmental norms* (legal or otherwise).

The absence of stated environmental policy objectives and of norms for discharges and their enforcement by local and national authorities pose an obvious problem for the introduction of any anti-pollution technology, including biogas technology for waste treatment. In such a situation, the logical strategy is to focus on the implementation of a few demonstration projects for "win-win" pollution control technologies, i.e. technologies which not only yield environmental benefits to society but also financial benefits to the industrial investor. Biogas systems installed at the premises of industrial plants for the treatment of their organic waste fall into this category if economically viable solutions can be found.

2.4 Environmental Policy Priorities

At the moment, the Government does not have an active environmental policy with stated priorities. However, the Swedish Government has just financed a study in May 1992, "Vers un Plan National d'Actions pour l'Environnement".

In this study, there is an attempt to rank the different types of pollution as the most important listed by order of priority:

* Land pollution by pesticides, fertilizer and other agents.

* Pollution of underground water resources through nitrates.

* Pollution of the sea and of beaches (mercurium, uranium).

* Pollution of surface water by phosphates, faecal matter, chrome.

* Air pollution, above all in cities (SO_2, lead).

At the level of the communal authorities, the primary environmental concerns relate to the disposal of solid waste and of waste water.

It can be concluded that the promotion of biogas technology for the treatment of industrial waste matches the needs of environmental priorities in Senegal and especially in Dakar.

3. ENERGY POLICY IN SENEGAL

The issue of energy supply and consumption has for a long time drawn active political attention. Senegal faces two main energy problems. First, its almost entire dependence on imported oil for the "commercial" energy is a growing burden on the balance of payments. In 1991, net oil imports absorbed more than 50% of the merchandise export earnings. Unfortunately, the declining oil prices during recent years can not equalize the effect of the devaluation of the Franc CFA in January 1994. Secondly, over exploitation of the natural forest, which accounts for more than half of the country's energy supplies, is together with the present farming structure causing rapid deforestation, leading to growing scarcity and rising prices of fuel, wood, and charcoal.

The national energy policy for solving these problems, known as "RENES" ("Redeploiement Energetique du Sénégal") aims to halve internal consumption of petroleum products. This should be done by fulfilling the following three objectives:

* The *substitution of oil consumption* by introduction of further use of imported coal and other less costly imported fuels in the power sector and the cement industry.

* The *reduction of dependence on foreign sources of energy supply* through the promotion of domestic energy resources (hydropower, exploitation of peat and lignite resources in Senegal, promotion of renewable energy resources).

* The *promotion of energy savings* through the implementation of a national energy saving/energy efficiency programme.

Translation of RENES policy into specific operational programmes and projects will require the resolution of some important issues, as summarized below. It will also means that a considerable amount of future investments is needed as the energy sector moves from a cost based commercial energy supply system to one where a progressively larger share of the energy supply will be produced locally or from imported fuels which have a lower total cost but higher investment cost.

3.1 The Structure of the Energy Sector

Senegal's domestic energy resources are significant in relation to its energy needs and also reasonably diversified. They comprise a share of the hydropower potential of the Senegal and Gambia rivers (about 1,400 MW, with an average production capability of 7,500 GWh (1.9 million toe); limited petroleum resources which have not been well defined; a small natural gas deposit (40,000 toe); about 10 million dry tonnes (3.7 million toe) of peat, lignite possibilities and significant fuel wood potential (1.3 million toe supplied in 1991). The long term energy of dry biomass (agricultural residues), and of solar and wind resources, also appears to be significant. The development of all these resources could ultimately supply a good portion of Senegal's energy requirement. However, in short term their development will be restricted by considerations of location, heavy investment requirement, and institutional and political factors.

Hydropower:

The exploitation of the hydropower potential of Senegal and Gambia rivers is the responsibility of two multinational organizations.

1. The organization for Development of the Senegal River (OMVS), where members are Mali, Mauritania, and Senegal, and

2. The organization for Development of the Gambia river are Gambia, Guinea, Guinea-Bissau and Senegal (OMVG). Individual projects can proceed only with the agreement of the member countries which can cause delays.

Furthermore, for both projects the irrigation aspects are determining the economic justification, while the electricity production, at best, has a marginal improvement of the overall rate of return. This low return is largely due to the fact that the sites are 500-750 km from the main load centers in Western Senegal, requiring significant investment in transmission lines.

Oil and Gas

The petroleum resources have not yet been well defined. The Dome Flore field, with probable light oil reserves of 1.8 million toe (tonnes oil equivalent) is the only discovery to date. The Government is trying to make foreign companies interested in a possible joint exploitation venture with the national oil company, Petrosen.

However, there is a jurisdictional dispute over the area with Guinea-Bissau. The identification of further reserves will depend on the success of the exploitation efforts which the Government is trying to promote. A small natural gas deposit is already being used as fuel for the base load operation at the gas turbine at Cap des Biches, and should be sufficient for generating 90 GWh.

Petroleum Refinery

The decision of the shareholders (various multinational oil companies) to revamp and expand the capacity of the petroleum refinery from 900,000 tonnes to 1.2 million tonnes seems surprising in the light of the RENES programme to halve petroleum products consumption.

However, it seems that the investment plans for the oil refinery are apparently based on further export than the domestic projects. Due to the lack of oil refinery capacity in the neighbour countries such as Guinea, Gambia, Guinea-Bissau and Sierra Leone, these investment plans can be justified.

Peat

Various studies are under way to evaluate the feasibility of developing peat deposits found in depressions between dunes north of Dakar, called "Niayes". Potential applications include electricity generation, industrial or household fuel, or as an organic material for agricultural purposes.

Lignite

Lignite resources in Senegal have been reported from drilling for oil, water and phosphates, but virtually no samples are available for testing the amount and quality of the discovered lignite.

Fuel Wood

The natural forest in Senegal has been reduced by 30% during the last thirty years, and the present trends would lead to a decline of another 20% by the end of the century. The remaining fragile forest cover of the understocked and overpopulated western regions will soon be destroyed unless urgent action is taken.

The development objective in the wood fuel sector in the western regions of Senegal should be:

* To restructure the fuel wood sector around the major cities so that supply in medium term will come from managed forestry resources.

* To promote fuel wood conservation in the larger urban centres through the economic pricing of fuel wood, the provision of improved stoves and improvements in the distribution and utilization of modern fuels.

However, in order to fulfil these objectives there is a need for strengthening the forestry institutions.

Power Production

SENELEC, the national electricity company - a State-owned enterprise - has at present an annual consumption of fuel for the power stations of approximately 270,000 tonnes of oil, primarily heavy fuel oil.

There is no import or export of electricity in Senegal.
The installed public owned power capacity in Senegal is approximately 175 MW. 130 MW is installed in the capital and the remaining is installed in other urban centres. The actual maximum demand is estimated at 108 MW.

In SENELECs latest development plan, the management of SENELEC has proposed a very premature and excessive investment programme which will increase the total power capacity to 285 MW.

A minor amount of natural gas is available in Senegal and the power company has therefore in the beginning of the 1980s installed two gas turbines with a capacity of respectively 17 MW and 21 MW. However, the gas production has dropped significantly during recent years. Therefore, the power company primarily operates the two gas turbines only in peak-load periods, which also make sense since gas turbines generally speaking have a lower efficiency than steam turbines. However, sometime due to the shortage of gas, the gas turbines are operating with diesel as temporary fuel.

The industrial and the informal sector in Senegal which include all the commercial activities are responsible for more than 70% of SENELEC's annual demand of electricity. The households in Senegal consume less than 30% of the production of electricity. And only households in the urban and semiurban zones actually have access to electricity.

The power production in Senegal is primarily based on supply of electricity to the Dakar Region, and the cities of Saint Louis and Kaolack. The demand for electricity in these areas counts for more than 95% of the power production generated by the SENELEC.

The three regional centres which include Zinguinchor, Tamba-counda and Ourossoegui consume approximately 3% of SENELEC's production.

In the remote towns in the rural area of Senegal, SENELEC has installed small diesel generators. However, this electricity production here only counts for less than 1% of the total electricity production.

Even though the main two industries in Senegal, the sugar industry (CSS) and SONACOS, are connected to the main grid owned by SENELEC and have a substantial demand for electricity, these two industries have chosen to have their own power generation facilities. Less than 1% of SENELEC's annual production is consumed by these factories.

The actual production cost varies from the different power production units owned by SENELEC. At the power production plant in Dakar, the consumption of fuel is 210 g per produced KWh. In Saint Louis and Kaolack, the fuel consumption figures are 245 g/KWh and 230 g/Kwh, respectively. This variation reflects the different efficiency figures for the various plants owned by SENELEC.

If diesel is used instead of heavy fuel oil, the corresponding figure is 255 g/KWh for the plant in Dakar. This can be explained by the fact that the gas turbines operate with a lower efficiency when using diesel as a fuel.

As the price for electricity is one of the key parameters for application of the biogas technology, there is a need for looking further into the problems of tariff structure for electricity and the setting of the actual tariff.

At present, SENELEC is undertaking a detailed tariff study in order to achieve a more updated and more fair tariff for their different consumers in the future. Even though the national power company only pays a minor tax on the heavy fuel oil compared to other industrial consumers of heavy fuel oil and gas oil, the electricity prices seem to be at a relatively high level compared to similar prices in European countries.

The actual price level is depending of the annual electricity capacity need. The average price for ordinary consumers who only need low voltage (220-240 Volt) like households is 67.03 F. CFA per KWh.

The consumers in the informal and the commercial sector have according to the present tariff to pay 56.77 F. CFA per KWh.

The big industrial consumers, who do not have their own electricity production, have to pay 37.75 F. CFA per KWh when receiving at high tension and using own transformer.

SENELEC has calculated the average weighted tariff to 56.22 F. CFA per KWh.

For a possible future electricity generation based on biogas for power production, SENELEC will only pay 19.9 F. CFA/KWh and if the electricity was sold to SENELEC and supplied to the public grid. This sales price for electricity is a maximum price and is based on the substitution principle.

Furthermore, in order to pay this price, the power company asked for a guarantee for steady and reliable electricity supply to the public grid. If it was impossible to obtain this guarantee, the power company could not include this extra capacity in their load-planning and the price of sold electricity could be reduced significantly.

According to SENELEC, it is possible to get the high price for electricity if a biogas plant with power generation facilities can replace the whole or part of the actual electricity consumption for a specific industry. In other words, a biogas production will secure a reduction of the present electricity demand for a plant. This could be the case for several industries in the agro-industrial sector in Senegal.

On the other hand, the statement made by SENELEC about the prices for electricity produced in the industry sold and delivered to the public grid has to be considered very carefully.

At the visit at the sugar industry in the northern part of Senegal, (Compagnie Sucrière Sénégalaise, CSS) the Consultants were informed that according to a contract between SENELEC and CSS about sale of the surplus electricity produced, (in total 25 MWh per month) at the factory should be delivered to the public grid at a price of 47 FCFA per KWh. However, as SENELEC have not for a long time paid for electricity, CSS had stopped the supply of electricity.

3.2 Energy Prices in Senegal

As mentioned before, the need for imported fuels is a burden to the Balance of Payments of Senegal. The payment of the imported oil is accounted in US $.

Due to the 50% devaluation of the F.CFA on January 13, 1994 there is at present a great deal of uncertainty about future fuel prices. According to the "Ministère de l'Energie des Mines et de l'Industrie", there were several possible solutions of how the Senegalese Government should handle the problem that the price of imported fuels had overnight been doubled after the devaluation of the F. CFA.

Together with the Ministry of Finance, the "Direction de l'Energie" has elaborated several scenarios in order to estimate the future prices of imported fuels and the economic impacts of significantly higher domestic prices of fuels if the State revenue from custom taxes and value added taxes (VAT) should be unchanged. As no one could give a correct picture of the future prices for fuels, the Consultants have based on the present price structure tried to estimate the coming future prices of oil products. These estimations are made under the assumption that the present price structure will continue and the rate of VAT and other forms of taxation will be unchanged.

In the following table, the present prices and an estimation of future prices of various oil products in Senegal are given.

	Price before devaluation of F. CFA F CFA per ton	Price after devaluation of F. CFA F CFA per ton
Diesel oil	159,329	252,820
Diesel oil, SENELEC	131,383	222,356
Fuel oil, 180 CST	95,320	146,226
Fuel oil, 380 CST	89,556	123,635

According to the "Ministère de l'Energie des Mines et de l'Industrie", there are no actual plans for further incentives in the form of some kind subvention on fuels based on biomass, and even though the management was positive towards the idea of financial support of the application of the large scale biogas production based on industrial organic waste, the general opinion was that biogas as a fuel should be based on economic fuel prices. The Direction de l'Energie told that the subvention of LPG (gaz Butane) for household energy purposes over the coming years will be phasing out after a very successful subvention in favour of introducing improved gas stoves for the households of Senegal.

4. THE WASTE SECTOR IN RELATION TO BIOGAS TECHNOLOGY

4.1 General

The biogas sector in Senegal is developed only within specific sectors or related to specific companies. In fact, the current development is dominated by a single type of digester conceived and delivered by a French company, but with local agents and local subcontractors. As judged from the actual activities viewed and the persons met, the supporting activities seem to be fairly weak, although a number of institutions have worked with biogas.

The early biogas experience in Senegal is related to trials of small, very simple biogas systems based on the Ram Buhk Sing principles from India and later experience based on the Chinese type of digesters. Experiments and demonstration plants were made for example at CERER in Dakar, where abandoned examples of both Chinese and Indian type digesters can be seen. The Mission did not succeed in meeting persons from CERER or obtaining specific information of experience nor of current activities. It appeared as though all biogas activities at CERER had stopped a number of years back.

In the papers handed over to the Mission, also reference is made to a 30 m^3 demonstration plant with a Dual fuel motor and a generator to be installed at Sasal. However, as no specific results from this plant have been made available, it is not possible to evaluate the experience gained.

The current development of biogas technology in Senegal is almost completely related to the use of the "Transpaille" digester system, regardless of the type of waste or the setting.

In general, the system comprises a very simple digester in the form of an almost horizontally placed cylinder, through which the raw material passes by gravity. To make sure that straw, floating debris or other components do move through the digester together with the liquids, a pushing system has been introduced, driven either by a hydraulic hand pump or by motorized hydraulic systems.

The Transpaille is made of steel in a local factory for agricultural machinery, the SISMAR. Sizes between 5 and 40 m^3 have been encountered. The total number of plants produced in Senegal seem to be around 20 (see below).

4.2 Biogas in Relation to Primary Agricultural Activities

4.2.1 Waste Characteristics

In general, the agricultural waste available in the primary sector in Senegal tends to have a high solids content (i.e. 70-90% total solids) especially in the dry season of the year. Examples of this are:

- Rice husk and straw
- Straw from maize
- Cotton shells and cotton straw
- Maize "straw"

In the rural areas, these kinds of plant materials are available in large quantities during the time of harvest. A major part of them are left in the fields, but if required they could be collected to produce energy.

Also available is the dung or manure from cattle, sheep, and goats. However, this is in most cases spread over a large area of forage, which makes it difficult to utilise for biogas production. On a family level, it may be possible to collect small quantities of manure for own biogas production. The mission has not visited cattle farms so it is not clear to which extent concentrated production takes place in Senegal, where manure could be collected easily in large quantities to make biogas production feasible at an industrial level. However, it is not expected that many opportunities exist.

The main issue of using the dry agricultural products mentioned above is that in order to make a biogas production, a lot of water must be added. Even if this water is available for addition, the disposal of the liquids afterwards tends to become a problem. In the dry season, it may be possible to dry the fertilizer product by natural means, but in the rainy season this will not be possible, and a fairly wet fertilizer output will have to be spread in the fields or stored.

As a conclusion, the biogas technology does not seem to be an easily applicable technology for semi-large scale agricultural situations. However, due to the large needs for energy under these conditions, there are good reasons to do a dedicated work to develop types of plants, which can be applied.

4.2.2 Experience

At the family level, the SAED is currently making a pilot project among a number of families in the Delta Region near St Louis. A number of families have been given a 5 m^3 digester based on the Transpaille system including a small gasometer, a gasmeter, and a stove suited for biogas firing. The experience is still limited, but the families seem to be very fond of the solution. Especially the women seem happy, as they are able to engage a larger part of the family in the collection of feed material for the digester, than for traditional collection of fuel wood.

The preliminary results of the demonstration plants are:

- Digestors fed with a mixture of rice straw and cow manure, diluted with water.
- The gas yield has been recorded to be 3-10 m^3/week.
- A standard family of 10-12 persons would need around 1 m^3/day.
- The cost of the digestor installation would be approximately 1.5 million FCFA, when produced in series.

It is too early to draw any final conclusions on the economic viability of the system, but the main cost of course is related to the investment cost. However, even if the investment cost can be justified on a long term calculation, it seems very unlikely that the farmers will engage in private investments, considering the current level of income.

4.3 Municipal Waste

The solid waste collection and disposal is handled in Senegal by a former State owned company. The company SIAS is now partly privatized with the main shareholders being the State, the City of Dakar, and other public organizations. The only private shareholder is the French public cleansing company SITA, with a 7% stock.

In principle, the operation of the SIAS should cover all the country, but currently the operation is only active in the Dakar Region. There are, however, plans supported by the Japanese of introducing collection systems in ten major provincial towns and two religious cities. When asked about the content of the project, the representative of SIAS informed that no treatment or introduction of controlled landfilling is included in the project.

The present situation in Dakar is approximately as follows:

- The City of Dakar has entered into a contract with SIAS to cater for collection, scavenging (French: balayage), transfer and dumping of the household waste and most of the commercial waste. The contract has a value of 2.4 billion FCFA.

- SIAS has a total of some 1500 employees and 150 trucks and tractors with hangers.

- The industrial waste is to a large extent handled directly by the industries, which cater for their own transport of waste to the dump. The representative of SIAS estimated that only 7-10% of the industrial waste was collected by SIAS.

- The total quantity of waste collected amounts to some 3,200 m^3 or approx. 1,450 t/day, collected in an area of 550 km^2 from a population (unofficial) of 2.5 million inhabitants.

- Currently, no system is functioning as regards treatment of the waste before disposal. However, previously a composting system has existed, located near the existing solid waste dump, M'Bebeuss.

- A study was recently made of the quantities and types of industrial waste produced in Dakar. The organizations behind the study were INSA of Lyons in France, Ministry of Environment, and SIAS. The total quantity of industrial waste at the dump is estimated to account for some 50-70% of the total production.

By far the most urgent problem in the solid waste sector of Dakar seems to be the immense environmental problems at the landfill site.

- The landfill is situated at M'Beubeuss some 25 km from the centre of Dakar towards the Northwest.

- The landfill site covers an area of approximately 500 hectare, is uncontrolled and has not been equipped with any kind of pollution control measures from the beginning. In recent time, some monitoring wells have been made showing a significant pollution of the ground-water in the area and a heavy pollution load to the nearby lake of M'Beubeuss. However, it seems that the water resources at Thiaroye are not threatened.

- The SIAS representative quoted leakage of methane to be a large problem, which in fact comprises a significant risk of explosions.

- SIAS would like to close the landfill, but due to problems of location, they fear that a new one would have to be placed as far away as 60 km - leading to a significant increase in the cost of disposal.

- SIAS is selling smaller quantities of the old matured compost from the composting era. An indicative price is 4500 FCFA per tonne.

The solid waste handling in provincial towns:

No specific information was made available from SIAS about this issue. However, at Louga, there has been a project called Projet Environnemental Urbain de Louga. This project comprised experiments with composting of certain types of waste.

The aim of the project is three-fold:

. To produce compost partly for the vegetable gardeners, partly to facilitate the planting of a 20 m wide green belt around the town, in order to create some protection from the wind and the sand storms coming from the sparsely vegetated areas around the town.

- To clean up the town by collecting and treating the waste littered around in the town.

- To provide jobs and thus contribute to a reduction of the unemployment.

The project was supported by the French government and BRGM acted as consultants. The reports made available to the mission shoved the results of the use of the aerobic compost produced, the views of the vegetable gardeners, but no experience on the collection of the waste was included.

As part of the ongoing biogas project executed by SAED near St. Louis, a 5 m^3 "Transpaille" digester is about to be installed in a village in one of the more remote areas. It is the intention to feed this biogas reactor with solid waste collected in the village. However apart form this, there seems to be no Senegalese experience available concerning exploitation of biogas from municipal wastes.

4.4 Wastewater

4.4.1 Existing Situation and Waste Characteristics

The wastewater sector in Senegal comprises mainly the systems present in Dakar, except for some in relation to specific industries in other places.

The wastewater sector in the Dakar region is described in the report "Towards a National Plan of Action for the Environment".

The major part of Dakar is equipped with a sewerage system leading either directly to the sea or via a system of open canals to the sea.

The total quantities of pollution discharged to the sea have been estimated at:

BOD:	65 t/d
COD:	160 t/d
Total Nitrogen:	18 t/d
Total Phosphorus:	5 t/d

The industrial discharge is described to take place mainly in the harbour area of Dakar through five major outlets.

The total industrial pollution is thus in this context estimated at about one third of the total pollution load for BOD and phosphorus, but less for nitrogen. Seen from an environmental point of view, it thus seems most urgent to tackle the municipal loads. However, as shown in the section above, some of the industries have important discharges, when looked upon as concentrated loads. Some of these could reduce the load possible by introducing biogas treatment of certain waste or wastewater streams.

4.4.2 Experience with biogas in the waste water sector

The experience with treatment of waste water in general in Senegal is not very favourable at the municipal level.

For example, in Dakar a total of five treatment stations exist, but only one of these is operating, i.e. the station at Camberene.

The Camberene station is designed for about 100,000 Person Equivalents, but the current load is only approximately 25% of the capacity.

The plant is an activated sludge plant equipped with a digester to produce biogas from the primary and the secondary sludge produced. The digester is also only loaded to a small degree, and the real capacity of the system has hardly been demonstrated by the actual operation.

The report concludes:

- that the load on the plant can be increased at a minimal cost to increase the environmental effect of the investments already made.

- that the overall capacity of the plant can be increased to 500,000 PE (Person Equivalent) at a cost of approximately 90 million French Francs - an investment of less than 200 French Francs per PE, which seems fairly attractive.

In relation to biogas development it can be concluded that it is important to get this digestor operational. This can be done by increasing the load either by expanding the plant or by combining the sludge with other types of waste. The potential gas production from a plant of this size would be big enough to make a good economy if a generator system is installed.

4.5 The industrial sector

The biogas experience within industry includes a pilot project with a "Transpaille"digester installed in 1989 at the Thies abbattoir.

The Thies plant consists of:

- a 40 m^3 Transpaille digester fed with the paunch waste from the slaughtered cattle,
- two plastic gasometers,
- a motor/generator system to generate electricity (18 KVA),
- a wastewater treatment system based on a sedimentation tank, an aerobic pond and two ponds with macrophytes, which in turn are harvested and fed into the digester,

The technical experience with the system seems to be fairly good, but the economic results seem rather unsatisfactory. It is claimed that the reduced result is due to much lower loading than expected at design level. A comparison of the achieved results with the expected results is given in Table 4.

Item	Design Values	Actual Operation
Biomass input . Paunch waste . Manure	 76 t DS/year 4 t DS/year	 35-40 t DS/year
Yields . Biogas . Electricity	 13,000 m^3/year 12,700 KWH/year	 5,500-6,200 m^3/year 5,100-5,500 KWH/year
Compost produced	44 t DS/year	20-25 t DS/year
Economic Results . Construction cost . Operation and maintenance . Net result	 27 million FCFA 1.1 million FCFA/year Treatment cost of 3-600 FCFA/t carcasse	

The Mission has not heard of any other experience with biogas utilisation in the industrial sector in Senegal.

5. IDENTIFICATION OF INDUSTRIES WHERE BIOGAS-TECHNOLOGY MAY BE USED

5.1 Waste types identified

Evaluation of the industrial wastes of Dakar and their suitability for biogas production

Table 5.1.1 shows an analysis of the general composition of the waste collected in Dakar. Generally speaking, the waste contains a fairly high percentage of organic waste. It is worth noting that the waste contains very little metals - a sign that a high degree of recuperation takes place.

CATEGORIES	DAKAR	PIKINE	RUFISQUE
Organic waste	43 à 60	34 à 43	35
Textiles	2 à 9	2 à 5	6
Paper cardboard	6 à 24	4 à 7	6
Ferruginous metal	2 à 5	1 à 3	3
Non ferruginous metal	0	0	0
Plastic	2 à 7	2 à 4	5
Glass	1 à 3	0,5 à 2	1
Ceramic stoneware	0,5 à 6	1 à 4	2
Remainder	0,5 à 5	6 à 9	10

Table 5.1.1

In 1990, SIAS made an inventory of the types of waste collected by SIAS from the industries. It is estimated that SIAS has a monthly total collection of approximately 5,000 m^3 from a total of around 70 industries. Out of this amount, approximately 2,000 m^3 (20%) is registered as coming from a total of 24 agro-alimentary industries. However, it is not clear to which degree the waste is limited to production waste or whether it also includes general waste (paper, plastics, etc). For example, the fishing industry is quoted to contribute with a total of 996 t/month from 12 industries (i.e. half of the total agro-alimentary contribution). However, there is an indication in the report that the amount may comprise not only the industrial fish processing waste, but also the general waste from the large floating tuna fish factories (Armements), which unload their products and waste in the harbour.

Another source of information is a more recent, but unpublished survey made by the Ministry of Environment on the discharges of pollutants from different larger industries, Annex 1.

From the tables received it is possible to extract the industries, which seem to be of particular interest. These are shown in table below.

Table 5.1.2 Industrial waste of interest for biogas production

Name of industry	Production/ type of waste	Solid Wastes, t/day Total/Organic *	Wastewater m^3/day and degree of pollution **
SNCDS	Fish Canning Industry	32/32	400 H
SITRAF	Fruit juices, annanas+ mango	1.5/1.5	172 H
Armement DAK Peche	Fish waste + other	0.4/0.4	8 H
SOPICA Siguinchor	Fish Waste	8/8	65
SOBOA	Brewery		
CSS - Richard Toll	Sugar production	120/120	24,000 H
SEIB- Diourbel (Sonacos)	Vegetable oil refining	70/70	500
Sonacos Dakar	Vegetable oil refining	2 - bleaching soil	
Bakeries	Misproductions of cakes	4/4	
Abattoir de Dakar	Paunch waste	9/9	220 H

* "Organic" only meant as an expression for the origin of the waste. The true organic fraction measured as Volatile Solids will typically be 50-80% of the dry matter, which constitutes only a part of the above figures.

** Degree of pollution: H= High, M=Medium, L= Low

It is the general opinion of the Consultants that the above industries should have good possibilities of utilising the biogas technology either alone or in combination between several industries using a common biogas plant. In some cases, also industries may combine with agricultural operations to "dilute" difficult types of waste and to make an easy outlet for the slurry or the fertilizer produced.

However, the list above is not believed to be exhaustive. It is evident that many more industries will be on the list of potential candidates, once a thorough mapping of the biomass has taken place.

In order to illustrate the possibilities, some cases are analyzed further in the later sections of this chapter.

5.2 Sugar Plants

Senegal has a domestic sugar factory at Richard Toll based on sugar cane grown in the irrigated areas in the river basin of River Senegal.

The total production of the sugar factory is approximately 90,000 t of sugar per year from a total intake of approximately 500,000 tonnes of cane per year.

Energy system

The production process is a typical production based on cane. This means that the bagasse (the residue of the cane after extraction) is used as a fuel to supply the major part of the energy for the process, unlike the situation for sugar factories based on sugar beets. In fact, in the case of Richard Toll, there is a much larger availability of Bagasse than can be used for energy production for the factory itself.

The steam boilers and the generator system of the factory have a much larger capacity than needed for the production. Therefore, the CSS has made a contract with SENELEC to sell power to the public grid at a favourable rate of 47 FCFA per KWh.

During the campaign (6 months per year), the factory can supply up to 1 MW, and outside the campaign the factory can supply up to 5-6 MW. However, the actual supply has been terminated as the SENELEC did not pay for the electricity. A total debt of some 70 million FCFA is still not settled.

Waste Characteristics

The major waste components of the sugar factory are:

- The bagasse at a total volume of some 290,000 tonnes per year, out of which 70-80% is currently used for energy production.
- Sludge from the sedimentation of the sugar juice. This sludge is subject to a supplementary extraction of sugar and following this, it is transported to the fields as a soil conditioner.
- Residual water in an amount of 600,000 m^3 per year. This residual water is highly polluted with dissolved sugar and other organic components. For this reason, the residual water is pumped to a pond system some kilometres away from the factory for treatment. The system consists of an anaerobic pond followed by several facultative (aerobic/anaerobic ponds) algae ponds. At the point of discharge, the water is treated almost to European effluent standards.

The treated water is used for irrigation.

With regard to biogas technology, the sludge and the residual water could ideally be used as a source of energy. However, as there is surplus of bagasse, and the technical system is already made for utilisation of this source of energy, there is no economic justification to establish a biogas production based on these wastes.

5.3 Vegetable Oil Industry

The vegetable oil industry in Senegal is based mainly on ground nuts as the locally produced raw material. The total production of ground nut was some 600,000 tonnes in 1993. Apart from this, also raw oil from soya, rape, sunflower seeds, etc. is imported and refined in Senegal to balance out the need of the local market. This is mainly due to the ground nut oil being a more valuable product. It pays to substitute ground nuts by imported raw oil from Europe or elsewhere.

The industry is dominated by SONACOS (Société Nationale de Commercialisation des Oléagineaux du Sénégal), who is the only major industrial operator in the field. SONACOS has a total of four factories in Senegal, located in Dakar (by far the largest), Diourbel, Kaolack, and Ziguinchor.

The annual capacity of the production equipment for vegetable oil is approximately 120,000 tonnes of oil per year. The current level of production is some 80,000 tonnes. The total production of crude oil in Dakar is 60,000 tonnes, out of which some 55,000 are exported. The remainder is refined in Dakar along with approximately 50,000 tonnes of crude oil imported.

The products and by-products of the industry are:

- Vegetable oil, crude or refined
- Pellets sold as fodder (detoxified against aflatoxin)
- Shells from the ground nuts, used as a fuel for the factory in Dakar
- Soapy fatty acids (saponifié), used for production of soap

The waste products of the industry are:

- 2 t/day of bleaching soil with a content of approximately 0.2% oil.
- Saline wash water in a quantity of approximately 100 m^3/hr of sea water. This effluent is treated by gravity separation before being discharged to the sea.

The SONACOS has made a serious effort to minimize their dependency on conventional energy. They have installed three boilers fed by solid fuel (mainly ground nut shells, but other agricultural wastes is being tried out) and also a generator system producing a total of 2 million KWh/year. This amount is not sufficient to completely cover the annual demand for electricity, but close enough to create periods, where there is a surplus. During these hours, the factory is selling electricity to the grid (see section on Energy Policy). The plant is equipped with a very large storage volume (totally more than 15,000 m^3) for storage of ground nuts and shells. Some of the boilers are newly installed.

Evaluation of Biogas Potential

The potential exploitation of biogas technology in relation to the vegetable oil industry as described above is fairly limited:

- As long as there is an outlet for the feed stock produced from the pressed ground nuts, this will almost certainly be more economical to exploit. In cases where the "pressing cake" cannot be sold as feed stock, large quantities of gas may be produced from it due to the high oil content.

- The bleaching soil has a high specific gas production per tonne of waste, but the quantity is limited. However, experience, especially from Denmark, shows that adding bleaching soil to biogas rectors not only increases the gas production significantly, but also stabilises the process to a high degree. Thus the bleaching soil currently tipped at the landfill should be considered for utilisation in future biogas plants.

5.4 Industry for Conservation of Fish

5.4.1 The Fishing Industry

The fishing industry is one of the major export sectors of Senegal, but also a significant production is marketed in Senegal.

For the export, there are three major productions:

- The tuna fish industry, which produce canned tuna mostly
- Frozen fish
- Frozen or canned shrimp

With regard to the tuna fish industry, there are three canneries in Senegal, all located in Dakar, which receive the total catch from the Senegalese ships and a variable fraction of the tuna caught by other nationalities, primarily French and Spanish vessels. The total amount of tuna fish landed in Dakar in 1991 was around 30,000 tonnes, whereas the tonnage of tuna fish exported in 1991 was around 19,500 tonnes fairly evenly distributed over the year and with one of the three canneries (SNCDS) produ' ıg around half of the total tonnage. The two other share the remaining part evenly.

The frozen fish industry is much more diversified with approximately 55 units in Dakar, 2 in Ziguinchor, 2 in M'Bour near Thies and one in St Louis. The factory visited in Dakar, the Amt rger Casamance, has a production of approximately 10 tonnes per day of frozen fish, whereas a typical unit in the other cities shows a production of some 2-5 tonnes per day.

Fish Industry in Ziguinchor

Ziguinchor was visited with the aim of evaluating the potential for biogas production within the fish processing industry in the provinces.

Ziguinchor is situated on the shore of Cassamance in the mangrove areas. The fishing activities take place as "Pecherie Artisanale" from a total of some 2,000 traditional vessels, Pirogues.

Thus a significant shrimp production takes place. Most of the shrimp is processed without peeling and frozen directly, whereas some 30% is peeled before freezing. Also Sole is caught and processed to frozen fish.

The total production figures for the Cassamance region are given in Table 5.4.1.

Type of "Fish"	1991	1992
Fish	8,000	6,600
Shrimp	1,400	1,000
Molluscs	100	470
Total	9,500	8,070

Table 5.4.1

The decrease in production from 1991 to 1992 is to a large extent due to the rebellion in Cassamance.

The value of the fish products is estimated at around 2 billion FCFA.

5.4.2 Waste Characteristics

In both the case of tuna fish canning and for frozen fish industry, large amounts of organic waste are created in the primary production, such as fish skin, viscera, heads and traces of blood. Before reuse takes place, the fraction can be as high as 45% and in some cases even 60% of the total catch of fish received.

The waste can be divided in the semi-solid waste and waste that is washed away with the waste water. The semi-solid waste is normally sold to fish meal factories. Measurements carried out in Marocco have shown that in the case of canned sardines only app. 33% of the received fish ends in the final product and 33% is semi-solid waste, and 33% is washed out with the waste water.

Thus significant volumes of waste are involved. In Dakar two fish meal factories exist, the Afrique Azote and the Senegal Proteine. These two factories utilise a very large part of the primary semi-solid waste.

In the case of the frozen fish factory, Amerger Casamange in Dakar, it was estimated that the re-usable fraction sent to the fish meal factory was around 80% of the total primary production waste, leaving around one tonne of fish waste to be deposited at the landfill.

The market value of the primary production waste as a feed stock for the fish meal factory is around 7 FCFA per kilogramme for tuna fish waste and 3 FCFA for the other types of waste. The tuna fish waste is more valuable as oil can be extracted from it for use as a fuel for the fish meal factory.

A visit to one of the fish meal factories in Dakar, Afric Azote, disclosed that they currently produce a total of 5,000 tonnes of fish meal per year, corresponding to a total amount of fish waste of at least 25-30,000 tonnes per year.

The factory is currently operating at 50% capacity due to a lack of fish waste. The factory collects fish at all the major fish industries in Dakar. The fish meal is exported for example to Morocco or is sold locally at a value of 125 FCFA/kg.

Some special kinds of fish bones are not accepted by the fish meal factories, i.e. the bones of the "Seiche" (Zepia), a kind of octopus. This is due to the high content of calcium in the bone. A total of some 500-1,000 tonnes per year of this kind of waste is estimated to arise in Dakar alone.

Fish Industry in the Province

The fishing industry in the other cities of Senegal is much less important, but due to the fact that they can not dispose of their primary waste to the fish meal factories, the actual amounts of waste may still be very important.

At Siguinchor, two industries were visited, one producing primarily shrimp and one producing frozen Sole.

The production figures and estimates of the waste volumes are given in Table 5.4.2.

	Raw material		Prod-uct	Wast e	Waste-water m^3/d	Elec-tricity KWh/d
	t/year	t/day	t/d	t/d		
SOPICA Sole	3,360	12	5	5-6	70-80	3-4,000
SOSECH-AL Whole shrimp	1,500	5.5	3.6	0.45	N.A	4,800
Peeled shrimp			1.9	1.05	N.A	
Total	4,800	17.5	10.5	7	N.A.	8,500

Table 5.4.2

It is seen from the above figures that there is both a significant volume of waste and a high demand for energy. The above figures give no indication of the waste in the waste water.

Currently, both of the industries have arrangements with a contractor who removes the waste. The end disposal is most likely the river, where the fishermen claim that the waste "nourishes the fish and the shrimp".

The fee for having the waste removed from the factory is in the order of 3,500 FCFA per tonne.

Both the factories were interested in some kind of re-use of the waste. A plan has been considered together with the SONACOS establishment in Ziguinchor to produce fish meal by a simple process to sell to the farmers as a component for cattle feed.

The energy needed for the drying process can be delivered by SONACOS at almost no cost, due to a surplus of groundnut shells.

An analysis of the fish industry waste in Ziguinchor is given in Table 5.4.3.

Waste Product	Humidity before drying %	Humidity Dried product %	Fat %	Raw protein *** %
Shrimp	78 %	8.6	2.5	48
Sole	73 %	43 *		31
		4 **	2.8	70

* From the dryer

** Extra drying by the sun

*** For comparison, an analysis of the fish meal from Afric-Azote shows:

- 60-65% Protein
- 10% fat maximum
- 10% humidity
- 1% salt, and 1% sand.

Table 5.4.3

The analysis shows that both kinds of waste are high in protein and well suited to produce fish meal, if a processing plant was available. The value of the fish meal, which could be produced, is around 125 FCFA/kg at Dakar, or a total of 260,000 FCFA per day for a total of 2,100 kg/d from the two factories.

As a rough comparison, an amount of approximately 1,000 m^3/d of biogas could be produced from the waste. The value of equivalent to 650 litres of gasoil per day or approximately 162,500 FCFA (at oil price = 250 FCFA/-litre).

If electricity was produced, the value of the electricity would be approximately 2,150 kwh/d or 175,000 FCFA per day (80 FCFA/ KWh after price increase), plus a possibility of recovering heat at 80-85°C of a value up to 108,000 FCFA per day (at 250 FCFA/ litre).

The protein value of the fish waste is of course destroyed in the process, but a significant fertilizer value is left in the compost. If a proper mixture with other materials is made, such as cow manure from the abattoir, rice husk or ground nut shells, a very good fertilizer can be produced from the compost.

Thus the very preliminary analysis shows that the direct energy income is of the same order as the value of the fish meal. However, if the compost can be sold at any appreciable value, this will make a biogas solution more favourable. In Table 5.4.4, the results are given for a calculation of the economy of a biogas solution.

It is found that with an estimated selling price of compost of 30 FCFA/KG, a daily income of some 220,000 FCFA can be achieved by saving electricity and heat and selling the compost. This leads to a simple pay-back time of approximately 8 years if construction cost is set at 350 million FCFA. This construction price is believed to be realistic with the new exchange rate. Thus, with future rises of energy prices (possibly + 50-60%), the economic result is expected to be fairly good, i.e. pay-back time of 4-6 years.

	Day	Year
Waste volume	10 m^3	2500 m^3
Dry material 25%	2,5 t	
Volatile solids 80%	2,0 t	500 t
Biogas production	1000 m^3	250.000 m^3
Methane 65%	650 m^3	162.500 m^3
Produced amount of compost	3,0 t	750 t
Economic value of compost 30 FCFA/kg	90.000	22.500.000

Table 5.4.4 Ziguinchor Biogas Plant - Preliminary Calculation.

Daily production electricity based on 650 m^3 CH_4	2145 kWh
Daily production of heat	4290 kWh
Annual production (250 working days) electricity	536250 kWh
Annual production (250 working days) heat	1072500 kWh
Annual production (250 working days) heat (oil equivalent)	97 tonnes

Based on the following prices:

		Saved at plant	Sold
Electricity	FCFA/kWh	60	20
Oil	FCFA/t	150000	0
Compost	FCFA/t	5000	30000

Income in million FCFA per year:

	Saved	%	Sold	%	Total
Electricity	28,958	90	1,073	10	30,030
Heat	3,640	25	-		3,640
Compost	0,375	10	20,250	90	20,625
Total income					54,295

Annual operational cost including manpower and maintainance	10,000

Based on a standard plant with a reactor volume of 500 m^3 and a load of 4 kg VS/m^3/day the construction cost can be estimated to 350 million FCFA giving a simple payback period of 8 years.

5.5 Abattoir and other Agro-alimentary Industries

5.5.1 Waste Characteristics

A number of abattoirs exist in Senegal, several of them owned and run by the SERAS. One of the medium size ones at Thies, which has served as the demonstration site for the biogas technology of the "Transpaille" plant, see separate description in section 4.

The largest abattoir in Senegal is the one at Dakar, which commands almost 75% of the total number of cattle slaughtered in Senegal.

The waste emitted from the abattoirs comprises:

- Intestinal waste, comprising for example 300 kg/cow at a solids content of 15%
- Blood, which in most cases can not be used due to the muslim way of slaughtering
- Horns and hoofs
- Remainders of flesh

- Bones
- Wastewater in a quantity of approximately 1.5 litre per kg meat produced

Especially the intestinal waste, the blood, and the wastewater constitute serious sources of pollution. In the case of Dakar, the blood and the waste-water is discharged directly into the Bay of Han, where the problems with a pronounced eutrophication of the sea water are evident. The blood fraction not only represents a heavy polluter in terms of BOD, but also contains significant amounts of nitrogen - a necessary component for algae growth.

An estimate of the total volumes of waste from the Dakar Abattoir is shown in the table below.

Type of Waste	Annual amount	Daily amount (250 working days per year)
Production:		
Carcasse, tonnes	9,500	38
Number of heads slaughtered		
- cattle	55,000	220
- sheep/goats	190,000	760
- pigs	5,000	20
Solid Waste, tonnes		
- Total mass	2,300	9.2
- Dry matter	345	1.38
- Organic dry matter	276	1.10
Wastewater, m^3	55,000	220
Electricity used, KWh	1,000,000	3,000 (365 days per year)

The majority of the electricity is used to run the cold stores (85%), whereas only 1.7% of the electricity is used for heating of water (Boiling water for the slaughtering of pigs). The rest of the demand is for various equipment used at the abattoir.

The abattoir at Dakar is situated very close to the central fish market where also a significant volume of organic waste is present. The abattoir has fairly large open areas inside their premises, where a biogas plant could be placed.

A project has been proposed by SERAS to construct a biogas plant at the abattoir, to produce compost and to set up a commercial unit utilising the compost to grow seedlings for sale. A feasibility study has been made by the French company Agro Industrie Consultant for the seedlings project and the World Bank has been approached for financing of the biogas plant.

At an estimated cost of 250 million FCFA (at 100 FCFA = 2 FF), pay-back times of around 15 years are estimated for the abattoir waste alone, provided that a selling price of 30 FCFA can be achieved for the compost. With an increase in the energy prices of 50%, the pay-back time will drop to around 10 years. In the above calculations, no provision has been made for increased gas production due to addition of other industrial waste, i.e. bleaching soil and/or fish waste.

	Day	Year
Waste volume	9 m^3	2250 m^3
Dry material 15%	1,35 t	
Volatile solids 80%	1,08 t	270 t
Biogas production	324 m^3	81.000 m^3
Methane 65%	210 m^3	52.650 m^3
Produced amount of compost	2,2 t	550 t

Table 5.5.1 Abattoir Dakar - Biogas plant - Preliminary calculations.

Daily production electricity	695 kWh
Daily production of heat	1390 kWh
Annual productiucn electricity 250 working days	173745 kWh
Annual production heat	344490 kWh
Heat equivalent	31 tonnes oil

Based on the following prices

		Saved at plant	Sold
Electricity	FCFA/kWh	60	20
Oil	FCFA/t	150000	0
Compost	FCFA/t	5000	30000

Income in million FCFA per year

	Saved	%	Sold	%	Total
Electricity	9,382	90	0,347	10	9,730
Heat	2,359	50	-	*	2,359
Compost	0,275	10	14,850	90	15,125
Total income					27,213

* surplus heat cannot be sold

Annual operational cost including manpower and maintainance	10,000

Based on a standard plant with a reactor volume of 270 m^3 and a load of 4 kg VS/m^3/day the construction cost can be estimated to 250 million FCFA giving a simple payback period of 14,5 years.

5.6 Breweries and Distilleries

Breweries and distilleries are types of industries with significant amounts of organic waste and at the same time a high internal energy demand. In Senegal, there seems to be no distilleries operating at an industrial scale and only one brewery, the SOBOA.

SOBOA produces soft drinks and makes beer of the local mark "Stork" and "Flag". The soft drink production does not give rise to any amount of solid or semi-solid waste and the production of beer is of a fairly small scale, approximately 130,000 hectolitres per year, corresponding to around 1/25 of that of a medium scale European brewery.

The types of waste produced at SOBOA are the usual types for a brewery:

- Draff/spent grains from the preparation of the barley with malt

- Surplus yeast from the fermentation vessels

- Minor quantities of kieselguhr from the filtration processes

- Fairly large amounts of medium strength wastewater (BOD around 1,000-1,500 mg/l)

The draff waste/spent grains are used as fodder for cattle already, whereas the yeast is sold as a yeast suspension. A project for recovery of the yeast on an industrial scale is being considered. Likewise, it is being considered to mix the spent keiselguhr into the draff waste. If this is carried out, there will be no solid or semi solid production waste at the brewery.

This leaves only the liquid effluent to be considered. However, it was obvious from the meeting with SOBOA that they did not at present consider the wastewater to be a problem that needed much attention. The Mission was also informed that the brewery was in general positive about the ideas of producing biogas, but found that there was no economic benefit for them as a private industry. They quoted that the subject had been studied by ORSTOM about five years ago in a general study of biogas utilisation in the industrial sector. For the breweries this study had shown no advantages.

6. INFRASTRUCTURE FOR MANAGING BIOGAS PROJECTS IN SENEGAL

6.1 Public Organizations involved in Biogas Development

Among the public organisations involved in biogas development or having interests in the area are the relevant ministries and the relevant departments and services, the university and other educational institutions.

Among the ministries and services, the most relevant are:

. Ministère Chargé de la Modernisation et de la Technologie with Délégation des Affaires Scientifiques et Techniques, DAST as the focal point.

  DAST is currently coordinating several programmes for renewable energy technologies and also a programme for biotechnology and one for biomass.

  The DAST in general does not execute the practical activities by itself, but takes the coordinating role with regard to strategy, information dissemination, economic control (à supprimer), etc.

  The DAST has nominated the present coordinator of the biomass programme also to be the national coordinator for a possible new biogas programme.

. Ministère de l'Environnement et de la Protection de la Nature. The Ministry has several roles to play in this context, but has not yet had the necessary resources to play a very active role.

  The key roles to play for the Ministry within the biogas sector comprise:

  - Regulation of solid waste collection, treatment and disposal activities.

  - Setting of guidelines for water pollution.

- Elaboration of environmental guidelines for industrial activities and approval procedures.

- Approval of specific industries and monitoring of their performance in relation to the stated approval criteria. This function is probably a temporary one, as it will be turned over to more local bodies, once they achieve the capability and capacity for this.

. Ministère de l'Industrie et des Mines, which has obvious interests in development of more environmental technologies.

. Direction de l'Energie, due to the interest in a general energy policy and in particular the interest in increasing the use of renewable energy systems.

Until recently, also many large companies covering a sector were publicly owned such as SERAS, SIAS, SAED etc. This is changing now, where several of these organisations are being privatised. In the present context, all of these companies are considered as semi-private and treated as such, regardless of the current formal structure. Anyway, these organisations have a way of functioning and a basic philosophy approaching very much that of private companies.

6.2 Private and Semi-private Organisations involved in Biogas Development

The private and semi private can be divided into three categories:

1. The semi-private companies having another main field of activity, but having a certain interest in biogas technology, because they have a waste problem and/or they have an interest in the energy recovery potential.

   Such industries comprise:

SERAS, (Société d'Exploitation des Ressources Animales du Sénégal), which raise cattle, run the abattoirs, and produce hides for export.

SIAS, which run the waste collection system in the Dakar region. The SIAS therefore not only handle large quantities of waste, but can also provide important information about industrial waste collected by other organisations.

SAED, Société d'Amenagement d'Exploitation du Delta having an interest in the biogas technology as potential outlet for certain waste products (mainly dry agricultural wastes) and as a potential technology for energy supply in villages in the rural areas.

SODAGRI, Société du Développement Agricole et Agroindustrielle, which run several agricultural production units (irrigation schemes, rice mills, maize mills, cattle farms, etc.), which on the one hand have large volumes of agricultural waste and have a high demand for energy, partly for production partly for electrification of villages.

SENELEC, as the power company, which will have to buy any surplus electricity produced.

ISRA, Institut Sénégalais de Recherche Agricole, which among other things works with research in the use of compost for vegetable gardeners and nurseries. ISRA may be able to coordinate the marketing of the compost.

2. Private enterprises, which have a role to play in the development of the technology and as suppliers of equipment.

Here, the most prominent example seems to be SISMAR, Société industrielle sahélienne de Mécanique, de Matériels Agricoles et des Representations, which can produce almost anything on request within the field of steel and large machinery components.

The above mentioned industries were the only ones specifically identified during the mission. However, it is most likely that a closer study will reveal several more enterprises with a role to play.

3. Industrial enterprises being potential owners and/or users of biogas plants, either because they have a waste suitable for treatment or because they can use the energy. Examples of such industries are given in Chapter 5.

6.3 Education and Training

Here, the main actors seem to be:

- CERER (Centre d'études et de recherches sur des énergies renouvelables which is an organisation related to the scientifical and technical faculty.

- ENSUT, Ecole Nationale Supérieur Universitaire de Technologie, has a research laboratory for biotechnology.

6.4 International Organisations

Among the international organisations with an interest in biogas technology can be mentioned:

- CRAT, Centre Regional Africain de Technologie, which is a UN supported organisation for development of technology. The organisation has access to some funds, but act to a large extent as a mediator for dissemination of experience among its member countries (between which Senegal and Morocco are found, but not Tunesia).

- CIRAD, Centre de Cooperation en Recherche Agronomique pour le Developpement, which is the French Government organisation, which has supported the development of the Transpaille digester system, and which is considering support for an installation on the abattoir at Dakar and large abattoirs in other African countries (possibly in cooperation with the World Bank). Also CIRAD has sponsored studies of the use of compost for plant nurseries.

base access, library, etc). ORSTOM has also previously supported research projects on biogas utilisation in Senegal.

6.5 Barriers

Among the most important barriers for a promotion of large scale biogas digesters to treat industrial wastes are:

- The limited number of industries with large amounts of organic waste.
- The lack of a strong environmental "pressure" on the industries.
- The difficulties in actually being paid for electricity delivered to the public grid.
- A fairly scattered research in the field of biogas.

7. PROPOSED PROJECTS

7.1 Conclusion on the Potential for using Large-scale Biogas Installations within the Industrial Sector in Senegal

According to the information received, there has not recently been performed a general study of the amounts of biomass available in Senegal, which can support specific conclusions on the potential amounts of biogas, that could be produced. However, based on the above analysis of the various types of industries visited, the following conclusions can be drawn:

- The biogas production and utilisation at a large scale industrial level is at present non-existent in Senegal.

- The industrial sectors having large amounts of biomass available for a biogas production are in general not very large in Senegal and seem to be dominated either by very large units or by a large number of small units. For example the sugar factory at Richard Toll is the only sugar factory in Senegal, and the vegetable oil industry is dominated by one company, the SONACOS.

- The very large units having a high demand for energy and at the same time a high availability of biomass have already done a professional job of utilising this potential for internal production of steam and electricity for internal use and sometimes for sale to SENELEC. The solid, dry waste products are typically combusted in some kind of fluid bed furnace to produce steam for generation of electricity. Process steam is often supplied from "take-out" turbines making a very flexible and efficient energy production possible. The sugar factory and SONACOS are examples of industries which base their energy supply on dry biomass, bagasse and groundnut shells, respectively.

- Among the agro-alimentary industries having a primary, organic production waste, many industries have developed internal systems for re-use of the waste or made alliances with special recovery industries, which take over the major part of the waste and use it to produce animal feed stock, either for local use or for export.

Examples of such solutions are:

- Export of fodder pellets made from remainders of the ground nuts after extraction of oil,
- Brewery spent grains used for animal feed,
- Fish meal production from the fish waste from various canning and freezing plants, including of the exploitation of the residual oil in tuna fish waste to produce heat for the process

. Even though the potential is not very big for biogas utilisation, there are cases where the establishment of biogas units for treatment of semi-solid and liquid waste from industrial activities seem to be very feasible. Often the best possibilities arise if some form of co-treatment between several types of industrial waste is used. Examples of this are:

- Introduction of a biogas plant at the abattoir of Dakar to treat paunch waste along with special kinds of waste available from the fish industry and the vegetable oil industry.
- Introduction of local biogas plants in areas, where the re-use industry is not available, such as treatment of fish waste at Ziguinchor.

. In the calculation of the economic result of biogas production, it seems that the sales price level of the compost becomes a very significant factor. Selling prices of 30-45 FCFA per kg have been quoted. In the example of the abattoir of Dakar, some 50% of the income of the plant can be attributed to the selling of compost if the highest value can be used, leading to a very profitable operation. On the other hand, if no value can be attached to the compost, the economic result comes out very negative for the biogas installation if only the energy value can be considered.

. The political and administrative pressure exerted on the industries with regard to improvement of the external environment has not yet reached a level, where it can be seen as a promoting factor for the introduction of biogas technology as "the least costly method of treatment". Biogas installations within industries therefore, for the time being, have to be fully justified by a positive economy by themselves.

- There are obvious barriers for the introduction of the technology with regard to selling price of electricity sold to SENELEC, tariff structure and payment for the electricity delivered.

- The biogas activities in Senegal seem to be fairly scattered with the major activities related to rural areas and agricultural institutions. The activities at the university institutes seem to be totally dependant on financing on a project-to-project basis and therefore seem to have difficulties in maintaining a steady development. However, there are institutes which possess knowledge both on process issues and on some of the more technical aspects.

- When seen in a more general development perspective, it would be of high priority for Senegal to develop systems, which could provide a cheaper source of electricity supply for villages or agricultural complexes in the more remote areas. Most often the biomass source available here consists of almost dry residues of plant material, which on the other hand are available in large quantities.
  Whether biogas production can be developed to suit these demands in a competitive way will depend on a future technical development both within the biogas technology and within the various competing technologies, such as gasification with direct use for motor/generator systems.
  However, if an industrial biogas programme should be established there would be good reasons to investigate this subject further.

7.2 Considerations on a Biogas Programme

Due to the fact that the industrial enterprises having a biogas potential seem to be limited in total number and scattered with regard to type of industry and geographical location, it would not seem to be justified to establish a programme for industrial biogas utilisation alone. However, if donor support could be established for a joint programme of biogas development to cover industrial use and agricultural use as well as rural application, this would seem feasible.

A biogas programme of this kind could undertake activities like:

- A review of the total biomass available and suitable for biogas production.

- Support to establishment of a limited number of demonstration biogas plants, partly in industries, partly in relation to agricultural production units. Two examples of industrial projects are mentioned below and described further in Section 5.

- Further test and development of reactor types suitable for conversion of dry agricultural waste into biogas.

- Process and laboratory assistance to ongoing biogas activities.

- Development of local knowhow and capabilities both with regard to technical solutions and with regard to evaluation of the feasibility of various types of energy conversion systems, with an emphasis on biogas technology.

- Close evaluation of the issue of the compost value and establishment of marketing routes for such products, in order to demonstrate the feasibility to both biogas producers and end users

With regard to the organisational set-up the following steps should be taken:

- Establishment of a biogas coordination committee responsible for coordination of the programme.

- Establishment of a limited secretariat responsible for the day-to-day execution of the programme and especially monitoring and control of the activities as well as dissemination of results through a newsletter, arrangements of symposia, etc.

Apart from the technical assistance needed in relation to specific projects, it is proposed that a pool of resources is attached to the programme to allow for ad hoc assistance to be incorporated in the project activities. Part of this assistance should be devoted to programme reviews and evaluations, part of it to specific technical issues.

With regard to the secretariat, it seems necessary to establish this as an independent unit with own logistic facilities as the existing organisations seem to be very strained in this respect. For example the unit for coordination of new technologies, DAST, under the Ministry of Modernisation is only equipped with one telephone line for more than fifty people and also transportation is a scarce resource.

7.3 Proposed Demonstration Project: Abattoir de Dakar

It is proposed to give high priority to the establishment of a biogas unit at the abattoir in Dakar.

The main characteristics of such a project will be:

- That it relieves the bay of a heavy pollution emission.
- That it will be reasonably economic in itself.
- That it can be combined with treatment of other kinds of waste (fish waste, bleaching soil, etc.) to improve the economy.
- That it can serve as a demonstration project for several other large cities in Sahelian Africa.
- There is a large need for organic fertilizer in the Region of Dakar and near the abattoir in particular.
- The digester size will be in the order of 300-500 m^3 depending on the amount of other waste added.

The situation at the abattoir and the economy of the plant is evaluated further in Section 5.5.

7.4 Proposed Demonstration Project: Fish Canning Industries at Ziguinchor

It is proposed to look further into the possibility for establishing a demonstration plant to treat fish waste in Ziguinchor. The characteristics of the project are:

- The amount of fish waste is reasonably big compared to other regions in Senegal.
- Additional amounts of organic waste may be added from the abattoir of Ziguinchor if found desirable, in order to dilute the fish waste or to make a more valuable fertiliser.
- The present method of disposal is dumping at sea with unknown impact.
- Currently, no alternative treatment method is available at Ziguinchor, although a small production of fish meal is being considered.

The project setting is described in section 5.4

7.5 Proposed Demonstration Project: Renovation of the Camberene water treatment station

As pointed out in section 3.4.2 an anaerobic digester is placed at the camberene water treatment system. This digestor is for the moment running at 25% of capacity.

It is suggested that one of 2 options is selected in order to increase the use of this digestor and evaluate the results for future use of anaerobic digestors in water treatment plants.

<u>Option 1</u>

Expand the overall capacity of plant from 100,000 PE (person equivalent) to 500,000 PE cost app. US $ 16 mil.

Option 2

Codigestion the sludge with other organic industrial waste cost limited to transport of this waste and limited renovation of plant and operation system cost app. US $ 50,000.

Estimation des déchets solides en tonnes/an

INDUSTRIE	DECHETS SOLIDES en tonnes/an		DECHETS LIQUIDES m³	
	Total	% organique	Total	%organique
NIPPON SEN	64	64	180	180
SOTEXKA	162	162	9072	2760*
SOPICA	1944	1944	15750	15750
BISCUTERIE WEHBE	60	0	144	144
MOULINS SENTENAC	12	12	365	365
LES GRANDS MOULINS	146	146	2920	2920*
SIPOA	*	*		
SISPA	1095	1095	182 500	1820
RUFSAC	960	10	0	0
CSS	15 000	15 000	110425000	3000000
COMPLEXE AVICOLE DE M'BAO	26	26	116	116
COTONNIERE DU CAP-VERT	40	40	51100	51100
NESTLE	*624	624	40000	40000
SNCDS	8000*	8000*	100000	100000
SITRAF	400	400	43000	43000
SOTIBA	624	624	30000	30000
SEIB	17300	17300	122520	122520
SIPASEN	0	0	0	0
SODEFITEX	80	80	2500	2500
XAMAL	3	3	100	100
ARMEMENT DAKAR PECHE	100	100	2016	2016

SOBOA

INDUSTRIE	DECHETS SOLIDES	DECHETS LIQUIDES	DECHETS GAZEUX	SOUS -PRODUITS
Delta 2000 agro industrie	Balle de riz			Son de riz

INDUSTRIE	DECHETS SOLIDES	DECHETS LIQUIDES	DECHETS GAZEUX	SOUS -PRODUITS
SEIB	terres décolorantes raffinage, cendre chaudière, rebroyés polyéthylène : décharge commune Diourbel	toutes eaux de lavage usine avec mélange de graisse	Gaz de 4 cheminées	pâtes de neutralisation raffinage
SIPASEN				
CCIS	sacs vides déchirés, camion de poubelle/15 jours			
SEIGNEURIE AFRIC	papier-carton-sac papier, boîte cabossée ->SIAS			
SODEFITEX		2500m3		
COSELECA				
NDAAGOU				
XAMAL	Rognures de papier	15m3 par mois		
SNP	Déchets plastiques			
PROCHIMAT		Eaux usées des blocs sociaux		
ARMEMENT DAK PECHE	Odures déchets poissons			
ICS		200m3/h	Gaz de combustion plus vapeur d'eau	
ICS Darou	Gypse	30M3/h	Vapeur d'eau fluorés Anydride sulfureux (SO_2)	Gypse- jus flucs
Société nouvelle des salins du Sine Saloum				
Sopica	Peaux de sôles, tripes, écailles, carapaces et têtes de crevettes	750m3/mois	Fréon F12 et F22	

INDUSTRIE	DECHETS SOLIDES	DECHETS LIQUIDES	DECHETS GAZEUX	SOUS -PRODUITS
NIPPON SEN	Brisure de craie	Eaux de toilette		
SOTEXKA	Celluloses organiques		Fumées de chaudières	Déchets de coton
SOPICA	Peaux de sôles, Tripes, écailles, Carapaces et têtes de crevettes		Fréon	
SIPAO				
BISCUTERIE WEHBE	Polyethylène Aggloméré			
SAF	Terre, Sable		Fumée générateur vapeur combustible fuel 180	Glycérinerie
MOULINS SENTENAC	Balayures			Issues de céréales
SS PHOSPHATES DE THIES			Fumées de combustion	Sous forme de fines
DAKAR-MARINE	Ordure ménagère/ferraille/ sable			
SIEMEX	Chutes/ Mal formations			
LES GRANDS MOULINS	Poussières de blé			Son issu des blés
SENAC	Amiante et ciment			
SIPOA	Cartons laize aluminium futs en carton	40 litres environ		
SISPA	Scoris de poisson et crevettes	500m3		
RUFSAC	Papier	Encre		
CSS	Ecumes	110425000m3	Fumées de chaudières	Bagasse
COMPLEXE AVICOLE DE M'BAO	Coquille d'oeufs à couver-poussins morts nés-papier			

INDUSTRIE	DECHETS SOLIDES	DECHETS LIQUIDES	DECHETS GAZEUX	SOUS -PRODUITS
COTONNIERE DU CAP-VERT	Déchets coton		Groupe électrogène 125KVA	
SENELEC	Cendres, sédiments, vanadioum, asphaltènes		CO_2, SO_2, SO_3	Boues huileuses(dérivés du mazout)
SAR		1600 m3	H_2 et CH_4 -> CO_2 et H_2O	
NESTLE	cartons, fer blanc, papier, toile plastique	Eau de nettoyage : 40 000 m3/an	Fumées de combustion de fuel 1500 dans 2 chaudières	Fût d'huile de beurre, papier d'emballage de lait
SNCDS	8.000 t d'arretes, viscères, peau et traces sanguines	100 000 m3 d'eau+sang	Gaz de combustion de 2 chaudières	8.000 t de têtes, peau, queues arretes et parties sanguines
SITRAF	pulpes, écorces et noyaux de fruit	eaux usées riches en nutrients		pulpe de fruit pour confiture et alimentation bétail
SOTIBA	2 camions/semaine d'ordures	300 000 m3/an eaux colorés et résidus de produits chimiques et colorants dans Baie de Hann	Gaz de 7 chaudières de 53 t/h	
SRH	terre activée à Mbeubeuss	200 m3/mois	Gaz d 1 chaudière	300 l/j solvant utilisé comme combustible