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BIOGAS

TUNISIA

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

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

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1. The Economic and Industrial Policy Framework for the Project in Tunisia

Tunisia has a population of 8 million and a land area of 164,000 km^2 of which two thirds are arid or semi-arid. A large part of agricultural land needs irrigation; water for it is scarce and often supplied from dams.

In 1992 gross domestic product per inhabitant amounted to around US$ 1050 (1.00 TD = $US 1.03). Agriculture provides employment to a quarter of the workforce and accounts for about 20 percent of GDP. The industrial structure is dominated by primary industry and generates about 30% of GDP. The manufacturing industry is built up mainly around the transformation of the domestic raw materials. The principal industrial activities are the extraction industries, phosphate processing industries, iron production, petroleum industries, textiles and agro-industries. The latter comprise sugar plants, olive oil, fish-, fruit- and vegetable canneries. The main export sectors are crude oil, olive oil, fruit and fish products, textile products, apparels, and leather products. In addition to the fertilizer industry, heavy industry is found in the form of one oil refinery, cement plants and an iron and steel complex, chemical industries.

The Tunisian econon y is undergoing a process of restructuring. The problem which is being addressed is that the level of competition in manufacturing industry is rather low. The state owns an important part of industry including the most important agro-industries, while the private industry serving the domestic market used to be protected behind solid tariff walls. The state aims at improving the competitiveness and the export orientation of the industry by moving away from protection and direct state intervention. The Government is liberalizing prices, lowering tariffs, embarking on a major privatisation programme, and the dinar became freely convertible for commercial and trading operations at the beginning of 1993. A new unified investment code to be adopted in 1994 will generalize the conditions for industry across sectors and for investors.

2. The Institutional and Legal Framework for Environmental Policy

2.1 Status Quo for Environmental Policy in Tunisia

Environmental concerns have become an important part of the policy agenda in Tunisia:

* Environmental reforms are actively promoted by the Government. The President is a former Minister of Interior which used to be in charge of environment, the VIIème Plan de Développement Economique et Social 1992-96 underlines the need to align economic growth with environmental objec-tives, strong NGOs are active in the environmental field and the media give good coverage of environmental issues

* The Government participated actively in preparation of the Rio Conference and has signed the relevant international agreements, inter alia, the Montreal Protocol

* A potentially efficient structure has been created for environmental policy formulation (MEAT) and monitoring (ANPE)

* Strict environmental norms are being adopted for pollutant discharges and a system of fines has been put into place

* A fund has been set up in 1993-94 to cofinance environmental projects at low interest rates; and the investment code gives economic and financial incentives to environmental investments

* Environmental impact studies, strategies and pilot projects in Tunisia are being financed by international donors such as the World Bank, UNDP and the EC and by bilateral donors such as France, Germany, the USA and Sweden.

The national strategy and policy priorities are outlined in the "Rapport National sur l'Environnement et le Développement Durable" published by MEAT in January 1993.

Whereas the institutional and legal principles of environmental policy are defined in a generally coherent way, the practical application of the policy is in its infant stages. There are examples of industries being closed for environmental reasons, but on the whole the enforcement of the norms still lags behind the statement of principles. As yet, few investments in environmental improvements have been made by industries and there is still relatively little information available on levels of pollution and their impacts in Tunisia.

2.2 The Legal and Regulatory Framework for Environmental Policy in Tunisia

2.2.1 Laws and Decrees

Tunisia does not have an environmental law ("code de l'Environnement") which in an integrated and coherent manner covers the environment. Such an integrated environmental law is under preparation. In the meantime, the legal basis for action is found in a series of different sectoral laws and decrees. Three principal areas are covered by the *primary legislation*:

* Protection of the natural environment: land, subsurfaces, continental waters, maritime environment, air, fauna (in particular by the Code Forestier 1966/88, Code des Eaux 1975, La Loi de Protection des Terres Agricoles 1983)

* Protection of human establishments: construction, archeological monuments, national parks (in particular Code de l'Urbanisme)

* Fight against pollution: wastes, dangerous establishments, chemical and dangerous substances, noise, smell

At the level of the *secondary legal framework* there is some concern about the level of discretion for public authorities in the application of the environmental rules, as the verb "pouvoir" ("can") is often used in the legal texts on administrative action instead of "devoir" ("should") or other verbs that fix an obligation [1]. Intervention by authorities against breakage of rules used to be slow or lenient; however, environmental law enforcement has become much stricter over the last two years.

2.2.2 Norms

Standards for emission and effluent charges have been elaborated by the Tunisian Government by adapting standards from various European countries to the conditions in Tunisia. The existing standards are quite severe, with levels corresponding to the strictest found in Europe. The emission and effluent standards for water are comprehensive [2] and well applied, whereas those for air and solid wastes still need further elaboration. There are no technology based standards for the polluting industrial sectors.

2.2.3 Economic incentives and market based measures

Tunisia is one of the few developing countries that has initiated a system of fiscal and financial incentives to stimulate industries to invest in pollution control facilities.

The "pollueur-payeur" and "internationalisation des couts écologiques" principles are well recognised as a guiding tool for tariff and taxation policies. Inter alia, it is applied in the tariffs for water where the charge varies with the quantity of water that is consumed by the industrial user.

To alleviate the cost to the national industry of compliance with the strict norms, the Government has set up a *Pollution Fund* to assist industries to adopt measures to keep within the limits set by the discharge standards. In addition, incentives take the form of:

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[1] Discretionary flexibility in the application of administration is needed to ensure proper trade-offs to be made between the imperatives of economic development and environmental concerns, but when these are generalised and superimposed on financial and staff shortages enforcement may become too weak.

[2] The pollution standards were fixed on the basis of point sources not taking into consideration the total volume of emissions.

* Exemptions from import duties and tariffs on raw materials, equipment and imported products necessary for reducing and combating pollution emissions

* Tax exemptions on materials, equipment and products that are needed for the adoption of pollution control methods

* Preferential financing by the Central Bank of Tunisia for investments that encourage the use of cleaner production methods

2.3 Institutional Framework for Environmental Policy in Tunisia

2.3.1 Situation

The adoption of ambitious targets for environmental policy has been complemented over the last five years by a substantial organisational restructuring of the institutional framework for policy definition, implementation and monitoring. The institutional reforms have been driven by two aims - to improve coordination of initiatives and to promote consensus building around environmental policy. The achievements at the "macro" level in terms of finding a balance between sectoral, horizontal, centralised and regionalized structures are very positive. But their effectiveness will depend "internally" on the attitude of operators at the micro-level and "externally" on the scope of the financial and human resources that are made available.

2.3.2 The Ministère de l'Environnement and its institutions

The *"Ministère de l'Environnement et de l'Aménagement Territoire" (MEAT)* is the focal institution for the environmental efforts since its creation in 1991. MEAT is in charge of the definition of national strategies and policies in the field of environment and its officials deal directly with the "Cellule d'Environnement" of the sectoral ministries. Some of the staff of these were in fact transferred to MEAT at its creation [3]. In particular, MEAT is responsible for:

* The implementation of institutional and legal measures for the protection of the environment

* The integration of environmental matters in the national economic and social development plans

* The definition of national contingency planning for actions in case of major pollution accidents

* Coordination of actions

MEAT has a staff of 40 working in six "directions":

* Environnement Industriel
* Conservation de la Nature et Milieu Rural
* Environnement Urbain
* Aménagement du Territoire
* Législation et Affaires Juridiques
* Affaires Administratives et Financières

The creation of MEAT did not prove sufficient to break the sectoral approach to environmental polivy. Therefore, the Government, at the end of 1993, decided to create *"La Commission Nationale pour le Développement Durable"* as the key institutional instrument to promote national political and administrative consensus around environmental policy. The Commission is headed by the Prime Minister and composed of 11 ministers, 2 members of Parliament, 1 representative from each of the main economic groups (labour, agriculture, employers), and two NGOs. The Commission will provide overall political guidance for the definition of environmental policies

[3] Originally, environmental policy was sectoralized with the industries having small environmental departments to deal with environmental issues related to their field of intervention. The creation of ANPE in 1986 represented the first institutionalised attempt to improve coordination of environmental actions.

and publish an annual report to the Prime Minister on its activities. It is assisted in its work by a Technical Committee, which in turn can create sub-committees for specialised work. MEAT is the permanent secretariat of the technical committee.

For the implementation of its policies, MEAT has two agencies under its jurisdiction: *"L'ANPE"* created in 1986 and *"L'ONAS"* created in 1974.

The *"Agence Nationale de Protection de l'Environnement" (ANPE)* is reponsible for the implementation of environmental policy initiatives, the monitoring of the compliance with environmental standards and the initiation of coercive action against violations[4]. ANPE has a staff of 50 persons and is composed of several departments including "Le Département des Etudes et des grandes Projets", Le Département de Sensibilisation d'Information et de Communication, Le Département d'Interventions de Dépollution.

According to law, entrepreneurs of major industrial, touristic, agricultural and commercial projects are to present environmental impact studies to ANPE for its evaluation. ANPE licenses the consultants for these studies and assists in the drafting of TOR for the studies. ANPE monitors the compliance with standards for pollutant emissions, issues fines for violations, ranging from 10,000 to 50,000 TD, concludes contracts with polluters for programmes towards the reduction of emissions and orders closure of industries that cannot comply with environmental standards.

"L'Office National de l'Assainissement d'Eau (L'ONAS)" is reponsible for the implementation of water projects in Tunisia. Although the municipalities are responsible for assuring the water and sewage infrastructure in their regions, its creation proved necessary due to the limited technical expertise available in the muncipalities for the proper preparation and monitoring of

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[4]Before the creation of the MEAT it was referred to as the Ministry of Interior.

the sewage projects. ONAS has a staff of 2500 and enjoys a good reputation for its technical qualifications as well as its project management skills.

2.3.3 The Ministère de l'Agriculture

With the protection of natural resources being the most important environmental concern, the Ministry of Agriculture plays an important role in promoting improved land practices and soil concervation methods.

2.3.4 Ministère de l'Economie Nationale (MEN) and its institutions

The MEN is in charge of defining and implementing the economical development policies related to the industrial sector, commerce, energy and mining. The MEN is composed of different departments of which the most important are:

* *"La Direction Générale de l'Industrie"* which manages the activities related to the industrial sector in its large diversity

* *"La Direction Générale de l'Energie"* concerned with petroleum exploration and production, the power, natural gas and oil product subsectors, and the rational use of energy

* *"La Direction Générale des Mines"* concerned with mining and extractive activities

The "*Institut National des Normes et de la Propriete Intellectuel*" (INNORPI) deals with all actions concerning standards, quality assurance, and the protection of intellectual property rights. In particular, it helps concerned institutions and enterprises with the technical elaboration of standards and to verify the draft standards that are proposed to the Ministry of Economy for their adoption.

2.3.5 SERS

The *Secrétariat d'Etat de la Recherche et du Développement Technologique (SERS)"* SERS was created in 1991 as the coordinating institution for R&D projects in Tunisia. It is placed under the Office of the Prime Minister and allocates the national R&D budget among the project proposals proposed by ministries for funding. The selected R&D programmes are usually submitted to call for tenders.

2.3.6 Institutions at local level

At the *local administrative level*, one finds some twenty *"Governerats"* and below these 246 *"Municipalités"*. MEAT is supposed to work out a "Programme Regional Environnement pour le Développement" (PRED) for each Governerat and a "Programme Environnement Communal" (PEM) for the municipalities. The PRED is monitored by a "Comité Régional" nominated by the "Conseil Régional" and presided by the "Gouverneur" at its meetings. The "Loi Organique des Communes" (1975/85) entrusts the "Président du Conseil Municipal" the competence to protect the municipal environment. Each "municipalité" is supposed to have a technical unit for the protection of environment staffed with administrators and technicians with expertise in the different technical areas needed for the task. The municipalities monitor the compliance of local industries with emission standards[6] .

The major municipalities, such as Tunis, have well qualified staff for this task, in the smaller municipalities the staff and the financial resources are insufficient. Environmental matters in the municipality of Tunis, for example, are handled by the "Direction Hygiene et de la Protection de l'Environnement" and by the "Direction de la Proprete". The latter with a staff of 3000 takes care of the collection of waste. The "Sous-Direction de l'En-

[6]Ensuring compliance with the set standards is the responsibility of INNORPI and ANPE. This is done by systematic as well as ad hoc inspection by ANPE's inspectors mainly for water and solid waste emissions. But the checks are normally undertaken at the request of the municipality under whose jurisdiction the industries suspected of exceeding the limits imposed by the standards fall within.

vironnement" is composed of three units fighting against noise-pollution (unité physique), air pollution (unité chimique) and insects (unité biologique). "Sous-Direction Hygiène" is responsible for food control in the local markets.

The *Ministère de l'Agriculture* undertakes its environmental activities through its "Commissariat Régional pour le Développement Agricole" under the supervision of the Ministère de l'Environnment.

2.3.7 Research Laboratories and Technical Support

Numerous well equipped *laboratories* are found in Tunisia. They provide sufficient capacity to undertake sampling and analytical measurements for the evaluation of physical and chemical properties in water and solid wastes.

3. Environmental Policy Priorities

3.1 Key priorities and pollution

Management of natural resources (land and water) is the first priority of official environmental policy in Tunesia. The second priority is to ensure that pollution does not exceed the levels fixed by the norms. The third priority is improvement of the quality of life in rural and urban areas.

According to the "Rapport National sur l-Environnement et le Développement Durable", the most polluting industrial sectors are:

* The chemical industries, in particular the phosphate producers

* The tanneries which send about 900,000 m^3 of wastewater into the sea containing chrome, sulphur, cyanid, etc.

* The agro-industrial industry, in particular the olive oil industry which leads to an annual production of about 275,000 tons of "margines", and chicken farms which have to dispose of 500,000 tons of chicken manure per year

* The cement plants which give rise to dust problems

* The mining sector of Gafsa which gives rise to dust problems and to waste containing heavy metals

* The small scale industry which sends untreated water into lakes and rivers

* The annual 4 tons of mercury from the paper production at Kasserine, the daily 9 tons of dust containing ferrooxydes produced by the steel industry at Fouledh and the pollution from the annual consumption of 30,000 tons of detergents

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

Among the agroindustrial waste the "margines" from olive production and the wastewater from the fruit and vegetable conserves industries give rise to special concerns. During the annual "campaign", the organic waste from the "margines" is equivalent to the household waste from 4 million inhabitants; whereas the fruit and vegetable conserves industry have an annnual wastewater production of 20 million m^3 with a high content of organic matter.

3.2 Environmental Programmes

Tunisia has organised its environmental actions around three programmes:

* The *"Yellow Hand Project"* with the aim at combatting desertification, particularly in areas that are at high risk. The project consists of a host of preventive measures which include the strategic irrigation of farm land, the building of long distance canals to ensure a wider and more effective distribution of the water resources, the development of solar energy for the pumping of water and the stepping up of reforestation among others.

* The *"Green Hand Project"* aims to preserve biodiversity

* The *"Blue hand project"* aims to ensure compliance between economic growth and environmental objectives (tourism and industry)

In addition, at a more specific level one finds the solid waste programme "Programme Nationale de la Gestion des Dechets Solides" (PRONAGDES), the water treatment programme "Programme de l'Assainissment" managed by l'ONAS with an annual budget of 50 million DT, the "Programme de Sensibiliation" and the "Programme d'Education Environnementale" administered by the Ministère d'Education.

3.3 The Treatment of Liquid Waste in Tunisia

The treatment of urban water has been and continues to be one of the most important environmental policy priorities in Tunesia. At present 75% of the wastewater from urban households is treated, and 25% of the total wastewater is treated and reused in agriculture.

The "Code des Eaux" (1975) provides the general legal umbrella for the legal dispositions that concern the treatment of urban and individual wastewater (more precisely defined by a decree from 1985 and by norms for discharges in the recipient environment).

Since the creation of l'ONAS in 1975 and the clear assignment to this institution of the responsibility for the treatment of wastewater, Tunisia has undertaken great efforts to reduce the amount of liquid waste.

3.4 The Treatment of Solid Waste in Tunisia

Contrary to the situation for water treatment, the institutional responsibilities for the treatment of solid wastes has not been centralised in an organistion such as ONAS. The municipalities take care of the collection of household wastes.

Solid waste is usually deposited without treatment in Tunisia. In order to rectify this situation, the Government in 1993 adopted a programme for the treatment of solid waste, called *PRONAGDES (Programme national de gestion des déchets solides)* covering the three areas of household waste, industrial waste and special waste (hospitals, slaughterhouses, chicken waste, batteries).The annual amounts of these wastes are given in Table I.

Tabel I: Volume of Solid Waste in Tunisia	
	per year
Household waste	1,200,000 tons
Chicken farm waste	500,000 tons
Mining waste:	
- Gafsa	10,000,000 m^3
- Sfax	1,000,000 m^3
- Gabés	3,250,000 m^3
Hospital waste	2,000 tons
Batteries	330,000 units
Tires	25,000 tons
Industrial organic waste	?

The household waste is characterized by a relatively high humidity content which makes it rather expensive to incenerate the waste. In addition, Tunesian soil is poor in organic matter and compost is wanted.

Therefore, no incineration plants have been built. Partial composting of household waste is done only at a pilot scale plant at one of the two landfills in Tunis. The compost is sold by the municipality at the arbitrarily fixed price of 20 TD per ton to STEC which markets it at 140 DT per ton after special treatment.

Tabel II Composition of Unsorted Household Waste in Tunis	
Annual Average in weight %	
vegetable matter	62.5
paper	6.2
glass	0.3
metals	1.2
textile and plastic	1.8
rubber	0.3
bones	0.3
inert matter	27.3

The Government will set up 23 controlled landfills. The cost per ton of treating solid waste is estimated at 4 DT for a controlled landfill site and at 25 DT for treatment in a biogas plant. Nevertheless, the Ministry of Environment intends to include the option for the production of biogas from solid household waste in the next three sanitary landfill projects to be set up at Sousse, Hammamet and Raoued. These cities are located in tourist zones and the intention is to treat household waste and waste from markets together with sludge from water treatment plants operated by l'ONAS. Because of the cost increase due to the inclusion of the biogas option, these projects will not be managed by the municipalities but by MEAT itself. These projects are still at the prefeasibility stage and finance is still sought for their implementation.

A first attempt at creating a collective treatment for industries is being made at Ben Arous where 900 industrial enterprises will be attached to the treatment stations of SOD Méliane for the selective treatment of wastewater according to their content of BOD, COD and in terms of heavy metals or dangerous substances.

4. Energy Policy in Tunisia

4.1 Energy situation and policy

The issue of energy supply and consumption has for a long time drawn active political attention. During the 1980s primary energy demand grew at an annual rate of 5% per year from an annual demand of 3 mtoe in 1981 to 5 mtoe in 1991. Commercial final energy demand in 1990 amounted to 3.5 mtoe of which 77% was covered by petroleum products, 11% by natural gas, 11% by electricity and the remaining 1% by coal. Industry, with 42% of final energy demand, is the most important consumer, transport accounts for 32%, household demand for 13%, public sector for 8% and agriculture 5%. In 1991 the electrification rate reached 81%, in cities 100% and in rural areas 47%.

In the face of stagnating national production the relative importance of the hydrocarbon sector in the economy fell during the decade. The production of crude oil amounted to 5.1 mtoe and of associated natural gas 2 mtoe in 1991 accounting for 8% of GDP and for 6% of exports[6]. Unless new discoveries are made it is expected that Tunisia will become a net importer of energy products in 1997.

In the light of this, the rational use of energy - the promotion of energy savings and the use of new and renewable energy sources - has become an important objective of national energy policy. The objective was institutionalized through the creation of the *"Agence pour la Maitrise de l'Energie (AME)"* in 1986 and the adoption in 1990 of the "Loi relative a la maitrise de l'Energie".

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[6] In addition to its associated gas production, Tunisia receives its gas supply from royalties paid in kind for the transport of Algerian natural gas through its territory.

The 1990 law confirms the status of AME as the key agency res-ponsible for promoting a rational use of energy, putting it in charge of, inter alia, (i) energy demand studies, (ii) defining energy saving investment projects that are applicable for financial support, (iii) to manage the obligatory energy audits for energy intensive industries, (iv) to pronounce itself on energy aspects of new energy intensive projects, (v) to assist the scientific and technical development of energy sav-ing technology, and (vi) the realisation of demonstration projects in the field of energy saving and renewable energy.

4.2 Energy prices

Since the beginning of the 1980s Tunisia has slowly increased its internal energy prices to international levels. On average, taxation has brought consumer prices above opportunity costs, although e.g. kerosene remains to be subsidised for social reasons. Due to the taxation of fuels for residential as well as industrial consumers, consumers who make investments in energy saving technologies, e.g. biogas plants can make savings that are higher than the economic savings to society (if environmental impact of e.g. CO_2 is not included in the calculation). In January 1994 prices were:

* *Power tariffs* reflect differences in the cost of supply and include differentiated day and night tariffs. High voltage consumers pay 34 mill/kWh in day tariff, 74 mill/kWh for peak load tariff and 26 mill/kWh for night tariff, (UScents 33, 72 and 25) medium voltage ordinary consumers pay 56 mill/kWh, and households pay 59 mill for the first 50 kWh per month and 76 mill for concumption above that level

* *Gas oil* cost 310 TD/cu.m. (US cents 30 per litre)

* *Heavy fuel* cost DT 106/tonne (US$ 100)

* *LPG in bulk* cost 292 TD/tonne (US$ 285)

4.3 Policies for cogeneration

The state owned national power company STEG has the monopoly for the transmission and the distribution of electricity. A few firms cogenerate steam and electricity for their own energy demand. Some firms from inter alia the textile industry sell surplus power production to STEG which acquires 18% of its power in this way.

STEG is supposed to base its tariffs for purchased power on the "avoided cost" principle, that is, on its marginal costs.

4.4 Promotion of energy savings

The key actions to promote energy savings defined by the 1990 law include obligatory energy audits of major energy consumers. The audits are undertaken by engineering consulting firms licensed for this task by AME. Based on the results of the audit, the firm signs a contract with AME for an energy saving programme ("contrat-programme"). After a two year period a follow-up audit is made to verify the energy efficiency status of the firm. In order to assist the industries in their implementation of energy savings, AME can provide financial support to cover some of the costs. Finally, AME maintains a data base on energy saving technology to be used by the firms and by the engineering consulting firms.

4.5 Promotion of renewable energy

ETAP was the first company who was in charge of renewable energy development, particularly the biogas.

AME has tested different renewable energy technologies and applications on the national market such as photovoltaic systems (PV) for the electrification of isolated rural communities, solar water heaters, wind mills for water pumping and for electricity production, improved fuel wood stoves and biogas systems to cover the domestic energy demand of small farmers that have at least five cows.

The *Institut National de la Récherche Scientifique et Technologique (l'INRST)* has been the key institution for the local technological gdevelopment effort in the field of renewable energy.

Based on these experiences the order of priority for AME's future effort is as follows:

* PV-systems for electrification of rural households and institutions not connected to the public grid (some 10,000 PV-units are expected to be installed during the 8th plan)

* Solar heating systems (the state will make a specific effort to install these in public buildings)

* Biogas in rural areas

* Improved fuel wood stoves.

The creation of a "Fonds National d'Aide au Développement des Energies Renouvelables" has been under discussion for more than a year. The fund, to be financed by a taxation of fuel consumption of any kind and amounting to 0.001 DT/litre, would have around 4 million DT/year at its disposal. But so far donor funds remain the main source of financing for renewable energy projects.

5. Infrastructure for Managing Biogas Projects

5.1 Status quo for biogas projects in Tunisia

Tunisia has since the 1980s experimented with biogas systems in a wide range of sectors and for a variety of applications. As a result, a number of different Tunesian institutions possess experience with biogas for relevant applications in Tunisia at the research, pilot or demonstration levels.

5.1.1 Biogas for energy

The first pilot biogas plants were installed in 1982. The biogas activities received new impetus through the GTZ's "programme spécial de l'énergie" which started in 1987. So far some 50 biogas digesters have been installed at farms in Tunisia. The main objective of these biogas activities was to avoid deforestation by replacing the consumption of fuel wood and to save the consumption of LPG and of kerosene.

The cost of a 10 m^3 biodigestor is around 400 DT provided that the beneficiary provided the manpower free of charge. The digesters are capable of producing around 300 m^3 per year. One cubic meter of biogas has the cooking potential of 2.7 kg wood and thus is a viable solution when the waste of as few as 6-10 cows treated.

AME/GTZ's biogas programme has shown that simple small biogas digesters can work in Tunisia. But until now the programme for the promotion of biogas in rural areas has not attempted to include local biotechnologists in its R&D efforts (what happens inside the biogas digesters is a black-box to the engi-neers involved), nor has it been able to set-up a structure which can give technical advise and follow-up to local farmers willing to invest in biogas digesters that live outside the narrow regions where demonstration plants have been installed.

5.1.2 Biogas for treatment of agroindustrial waste

The efforts in this area have concentrated on the two major sources of organic pollution - chicken waste and liquid olive oil waste, the socalled "margines".

In 1986 ETAP (Entreprise Tunisienne d'Activités Pétrolières) carried out the *"Valorisation énergétiques des fientes de volaille de la SOCELTA pour la production du methane" project* [8]. In this project, an attempt was made to set-up an industrial scale biogas reactor to treat chicken manure at the SOCELTA chicken farm at Tabarka. At the laboratories at l'INAT and at l'ENIT the technology was first tested at a pilot scale. The plant never came to operate successfully and the project was discontinued.

In 1993 the activity has been taken up once more. An egg producing society near Sfax established a 1 m^3 pilot digester and in cooperation with Centre de Biotechnologie de Sfax (CBS) has done some experiments in treatment of

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[8]Until the creation of AME ETAP was the lead agency for the development and promotion of renewable energy.

their chicken manure. The reactor has only run intermittently and is currently not in operation. Experimentation has focused upon optimization of the carbon to nitrogen ratio for best biogas production and waste treatment. Currently the chicken waste is sold as high nitrogen fertilizer and the demand is good. Anaerobic digestion of the waste does not decrease the relative nitrogen content of fertilizer, as composting does, but in fact ensures that the nitrogen is in a most assimilable from for the crops and is a lesser danger as a water pollutant.

Margines is a difficult waste. It has a very high organic content and is thus difficult to treat other than by anaerobic methods. However the content of polyphenols inhibits anerobic digestion when the waste is treated alone. The Sfax laboratory has done some work on this subject (see par. 5.4); and the GTZ Sonderenergieprogram in Tunisia has published an international call for tender for a pilot plant to treat margines.

5.1.3 Biogas for treatment of household waste

As a part of a national research program (INRST) on utilization of household solid waste (HSW) a pilot composting plant treating 5 tons waste per hour and a 5.6 m^3 pilot scale anaerobic digestor were built. The composting plant is in full operation treating up to 40 tons per day and selling the composted waste to a firm for 20 TD/ton, which makes additions, packages the compost and sells it for a price more than 15 times higher. However, the digestor has never operated. It is fully stirred system, stirring performed by a recirculation pump, equipped with a waste-premixing tank and a gas holder. The size of the reactor makes it very suitable for many types of studies and the original plans included diluting the HSW, after classification and maceration at the composting plant, with industrial wastewater. This is a good example of codigestion. However, the reactor was never started, and the INRST is planned to undertake research on this plant.

5.1.4 Biogas for wastewater treatment

The large, 100,000 m^3/day, municipal wastewater treatment plant at Tunis and some treatement plants in other larger cities have anaerobic digestors for sludge stabilization. ONAS representatives described that the reactors operate normally and that at Tunis the gas is utilized for electricity production. The engineers and technicians at these sites are probably the most experienced biogas plant operators in Tunisia and represent a valuable human resource for future Tunisian biogas programs.

5.2 Laboratories involved in biogas research

The *Centre de Biotechnologie de Sfax* is an extremely well equipped and capable research institute. The Centre has a staff of $\approx$50 of which 8 conduct biogas research. Current projects include work on potato viruses, glucose and fructose syrup production, microbial pesticides and research on anerobic digestion of chicken manure and margines. Their research in the treatment of margines has focussed treatment in fixed-film bioreactors and on finding ways of transforming the polyphenols before biogas treatment and some promising results have been atttained. Detailed discussions were undertaken with the staff regarding suggested lines for further research, especially with respect to treatment of les margines.

The *Institut National de Recherche Scientifique et Technique, (I.N.R.S.T.)* under SERS plays an important role in the formulation of policies and priorities for R&D projects and undertakes research in various areas[9]. I.N.R.S.T. is responsible for the pilot-scale research reactor at the pilot composting plant in Tunis. The main research center of located approx. 75 km south of Tunis. Management is well aware of the potential of biogas technology but the institute has little experience in the area. However, they have had significant experience with other alternative energy sources, *e.g.* solar electric cells and solar water heaters and the infrastructure for a biogas research project probably exists here.

INAT is inter alia involved in research on the handling of waste from the chicken farms, and has in this connection looked into the application of biogas systems.

[9]Excellent examples of their strategy/perspective work are the papers "Gestion et traitement des dechets domestiques. Sitution actuelle et perspectives" from October 1992

6. The Market for Biogas Technology in Tunisia

6.1 Criteria for the selection of biogas projects

There are basically three markets and three different clients for the application of biogas in Tunesia:

* Treatment of *agroindustrial waste* where the potential clients are public or private agro-industries (6.3.1 to 6.3.4)

* Treatment of *agricultural waste*, where the potential clients are the private large scale rural enterprises (6.3.5)[10]

* Treatment of *urban wastewater and solid waste*, where the clients are state and municipal waste treatment utilities (6.3.6 to 6.3.7).

Which of these represent priority targets for a programme for the promotion of biogas technology depends on basically two parameters: (i) the size of the market in terms of organic material that can be treated for the particular application and (ii) the economic and financial viability of biogas compared to competing technologies for treatment.

Experience has shown that the best biogas output per ton of organic matter and a stable and robust system is achieved when different types of waste are mixed in the reactor - e.g. household waste, waste from slaughterhouses, bleaching soil from eating oil production and other high solids wastes containing fats or oils. Therefore, ideal sites are those where organic matter of different origins can be treated. Due to the cost of transport the suppliers of a waste such as manure, which has a relatively low biogas potential per ton, should be within a radius of 10 kms from the plant. Other wastes which are economical to transport longer distances are for specialised wastes where the supplier pays a relatively high price per ton for treatment, such as organic chemical wastes.

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[10] The small scale biogas systems mentioned under 5.1.1 for energy applications of small independent farmers clearly falls outside the TOR of ther study.

6.2 Estimation of the Amounts of Organic Waste found in Tunisia

Table 3 in the annex provides an estimate of the amount of organic waste that can be treated in biogas plants. From this it can be seen that the largest single source for biogas production is municipal solid waste. These wastes are highly amenable to treatment (treatment of these wastes alone is entirely serviceable), have high solids content and so give lots of biogas and are excellent as a base reactor feed in codigestion situations with difficult wastes, such as les margines, organic chemical wastes or chicken manure (a high nitrogen waste). The digested material produces an excellent soil conditioner with both significant organic fiber and high-nitrogen content.

6.3 Identification of Priority Industries for the Installment of Biogas Systems

6.3.1 Sugar plants and destilleries

Sugar production in Tunisia is produced from domestically produced beets and from imported raw materials. The former, which generates organic waste of interest, is a seasonal activity which usually lasts three to four months. The best use of a biogas plant is combined with a distillery or yeast factory which operate year round. This is the situation at the the sugar plants at Beja and Jendouba, both approx. 150 km west of Tunis.

During the campaign (about 4 months/year) the sugar plant at Beja produces 70 m^3 wastewater per hour giving 3.5 tons COD daily. In addition, a local factory producing yeast from molasses makes 30 tons COD daily for about 300/year. Averaged over the 300 days this waste has the potential for the production of over 10000 m^3 methane daily giving an electricity generating capacity of 1.25 MW and a heating capacity of 2.5 MW. Most of the water would be recoverable for reuse in the plant.

At present the plant at Beja treats its wastewater in anaerobic/aerobic lagoons systems which allow 85% of this methane to be released to the atmosphere.

Presently, the much larger plant at Jendouba is not treating their wastewater. They possess a large activated sludge treatment system (10000 m^3) but it has not been active for several years.

At all these plants beet pulp is sold for cattle fodder and so is not considered in the analysis.

6.3.2 Fish conserves industry

The plant visited during the field trip to Tunisia was a plant which froze fresh fish products, mainly octupus, squid and shrimps destined for shipment to foreign markets. In this type of process the waste was insufficient to justify investment in a dedicated biogas reactor at the plant but the waste would be of interest and is of good quality (*i.e.* high solids content and readily biodegradable) for a codigesting biogas reactor installed at a, *e.g.*, landfill.

6.3.3 Slaughterhouses

The waste from the approximately 1000 slaughterhouses in the country is receiving priority attention under the PRONAGDES programme. The largest slaughterhouse is found in Tunis and is the the only slaughterhouse "agréé" by the CEE. However, it is operating at about 3% of total capacity because of the competition from the small slaughterhouses, the socalled "tueries". As long as the municipality allows these to continue it will be difficult to justify investments in biogas plants at the large slaughterhouses. The use will be too irregular. However, as in the case of the fish processing factories, the wastes are of high quality for biogas production and their collection and transportation to a centralized plant is economically justifiable.

6.3.4 Dairy industry

A small dairy farm/cheese factory was visited. Dairy wastewaters are highly degradable and possibilities for treatment, in-house utilization of the biogas and reuse of the treated water exists at factories of appropriate size. Waste solids and whey from dairies are usually in high demand as animal feeds and, though very good as biogas substrate, are rarely available.

The private dairyman and cheese maker visited has built two anaerobic digestors at his farm near Sfax. Both reactors, 50 and 12 m^3, are in-ground STR (stirred tank reactors) units. The reactors treat manure from approx. 400 dairy cows and calves ($\approx$4 tons/day) and the treated material was then used as fertilizer on adjacent fields growing fodder for the cattle. During their, unfortunately short, operating history the reactors produced less than one reactor volume of biogas per day. The gas was burned for production of hot water at the small cheese factory on the farm and accounted for virtually all of the heating costs. However, the reactors are only equipped with manual stirrers which were operated only occasionally and eventually a layer of solid material collected on the surface of the digester contents. Since that time the "cake layer" has disturbed feeding and removal of digested material and optimal operation has not been possible. This is a common problem in small, manually operated digesters.

6.3.5 Vegetable and fruits conserves industry

This mission did not visit any vegetable industries. But some studies, inter alia undertaken by UNIDO have looked into the possibilities of using biogas. A present UNIDO study on the rehabilitation of the agroindustry may provide details of use for an evaluation of the potential[11].

Ths pulp of the tomato is already used for ensilage. But the 20 million cu.m. of wastewater from the conserves industry contains a substantial amount of organic waste and is an amenable wastewater for treatment in high-rate UASB (upflow anaerobic sludge blanket) biogas reactors where over 95% of the COD present would be convertible to methane (1 ton COD giving 400 m^3 methane).

6.3.6 Olive oil production - treatment of "margines"

The use of biogas for the treatment of the "margines" from the oilive oil industry is faced by three challenges:

* The production of olive oil is a seasonsal activity. Therefore, the use of biogas presupposes that other organic matter can be found nearby to be

[11]Mr. Paul Widemann is in charge of this study in Vienna.

used during the off-season and as supplementary material during the season. In first light this is a problem. However, given the recalcitrant and toxic nature of les margines the only feasible treatment scheme for margines is in a codigestion situation.

* The olive oil industry consists of 1300 different plants. Therefore, collective biogas plants have to be set up which presupposes that the plants are loated near to each other. In fact, olive oil plants are usually located in the same quarter and about 80% of the total production takes place in non-artisanal plants. Les margines are very high strength wastes and have high biogas potential, so transport to centralized plants is justifiable. As olive oil production occurs in rural areas, treatment in a central plant which treats, *e.g.*, manure as its base substrate would be practical.

The competing alternative technology for the treatment of the "margines" is the solar drying of the margines in collection ponds and the subsequent burning of the dried matter. This technique, which is used in Spain, France and Greece is (i) relatively expensive, (ii) provides no "valorisation" of the organic matter in the "margines" and is far from ideal from the environmental point of view, in part due to the fact that there is nearly always leakage from such ponds into ground and surface waters.

6.3.7 Chicken manure

The 5-600,000 tons/year of chicken manure from the chicken farms has potentially interesting applications as fertiliser after drying and as animal feed after treatment in a (preferably thermophilic) biogas plant. Both applications take place in Tunisia but the chicken farms remain with a surplus manure (a wetter fraction) which they have difficulty to get rid of. This poses health problems for the animals and a smell problem for the neighbourhood. These wastes are of good quality for codigestion applications, especially in combination with low nitrogen wastes, such as HSW, manure or market waste, where the nitrogen content of the chicken manure is fully recovered in the digested material and due to the fact that the chicken waste has a high biogas potential.

Research on finding new applications are undertaken by inter alie l'UNAT. The SFAX laboratory is testing the use of biogas for the treatment of the manure, but as yet no cost-benefit comparisons exist.

6.3.8 Treatment of household solid waste

The production of housewaste collected by the municipalities amounts to about 1.2 million tons per year [12].

In this area, biogas competes with three alternatives:

- *The controlled landfill.* This is a well tested and cheap technology with costs per received ton of waste of about 5 DT. Compared to biogas the negative aspect is that environmental problems in terms of methane gas emission, occur, no "valorisation" of waste takes place, land requirements are high and the potential for undetected leakage into ground water from deep in the landfill is always present.

- *The controlled landfill with composting of the organic fraction.* This operation is more expensive (both with regard to investment and with regard to manpower requirements) and complex - there is a need to sort waste preferably already at the source level. The cost of production of the compost is rather high - at the pilot project at the "Henchir El Yahoudia" landfill in Tunis the cost amounted to 100 DT per ton. The compost is of similar quality (nitrogen content is lower but the initial product is more dry) as in the case of a biogas plant, but no use is made of the energy content. Other associated problems are as described above.

- *The controlled landfill with incineration of waste.* Incineration on a larger scale is not seriously under consideration due to the high water content of household waste in Tunisia and the demand for soil conditioners.

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[12] The production of housewaste per day and per person amounts to about 0.5 kg on average.

6.3.9 Treatment of domestic/municipal wastewater

The *activated sludge technique (AST, an aerobic technique) and aerobic lagooning* are the main methods used for wastewater treatment in Tunisia. Compared to biogas, AST is extremely energy intensive. In developed countries AST plants are often the largest single electricity consumers in urban areas. All aerobic wastetreatment processes produce between five to ten times as much waste sludge as anaerobic processes do. Though utilizeable as feed for anaerobic digestion and biogas production, waste sludge is a relatively poor substrate compared to the original material and represents a large solid waste problem. This is because the readily attackable material in the wastewater is converted to microbial cells which are very difficult to degrade. The biological process control of AST plants is at least as complex as that of anaerobic digestors.

Aerobic lagooning is a low technology, economical and simple wastewater treatment system where land costs are not prohibitive and environmental contamination can be tolerated, for example in rural areas. The method, however, is very land intensive and often not a viable solution in urban areas. Other disadvantages include the ever present possibility of environmental contamination. This can occur via infiltration of groundwater, spill-over or overloading to surface waters, and in cases where the lagoons are overloaded, atmospheric contamination due to uncontrolled release of methane, odor problems, and spreading of disease causing organisms via animal and insect vectors.

Today there are several full-scale anaerobic municipal wastewater treatments plants in operation. These plants are of the UASB type. COD removal averages 75% in the initial 6-8 hour treatment and is coupled to anaerobic digestors for treatment of the relatively small quantities of waste sludge produced. Final COD removal in such systems approaches 85%.

Virtually the only restriction on these processes is that the wastewater should have an average temperature near 20°C for the UASB step. The small size of the anaerobic digestors for waste sludge destruction and the biogas produced during the process grant fossil-fuel-free artificial heating and electricity. UASB technology for municipal wastewater treatment would not be practical in Northern Europe but represents absolutely no restriction in Tunisia where the climate is much warmer.

Such anaerobic wastewater treatment processes are much less costly to operate than AST reactors and have similar construction costs. For final polishing to modern wastewater standards an aerobic step is required, but the size and cost of operation are greatly reduced (approx. by a factor 5) compared to conventional AST plants.

7. Project Proposal

7.1 Background: The market for biogas development in Tunisia

A number of factors favour the promotion of biogas as a technology for the treatment for organic waste in Tunesia:

* The *combination of (i) high environmental policy ambitions and standards, (ii) a good basic structure for the implementation of environmental policies, (iii) incentive schemes for environmental investments and (iv) "virgin" territory for environmental investments* provide a fertile ground for the promotion of biogas technologies for waste treatment. The necessary investments in waste treatment have not yet been made and biogas technology can be taken into account as an option within a wide area of application.

* The promotion of biogas technology for the treatment of industrial waste matches the needs of *environmental priorities* in Tunisia.

* What the *privatisation process* will mean for the use of biogas technology for the treatment of waste is as yet uncertain. In principle, the state can order a state company to employ a new technology at any time, whereas normally this obligation is imposed on a private company only when a production license is applied for. But experience has shown that most Governments are more likely to impose environmental restrictions on private companies.

* The *energy policy* in the country favours the introduction of biogas for waste treatment:
  High energy prices improve the financial value of biogas investments for industries that can make use of the biogas production obtained from the treatment of its waste to cover some of the demand for heat and power.
  - The AME actively promotes biogas systems in its overall renewable energy programme
  - The project will reinforce the energy saving initiatives launched in the country.
  - STEG is already used to purchase power from autogenerators

* There is a *good market for compost and other fertiliser products from biogas production.* Because of sandy soil characteristics, the soil is short of organic matter and fertilizers which improve the soil structure are actively sought by the peasant population.

* A basic *infrastructure for research, project planning and implementation of biogas projects* is already in place. Biogas has been tested in several sectors for various applications. As a result valuable experience and know-how with biogas systems has been acquired by several institutions.

7.2 Justification for the project

While the overall environment for biogas in Tunesia is favourable by international comparison, the technology continues to be expensive and insufficiently proven in Tunisia. Biogas technology is not yet an "off the shelf-technology" due to the highly variable characteristics of different types of wastes treated.

However, the anaerobic waste treatment is being succesfully applied in many other countries, both in the public and private sectors. Thousands of anaerobic reactors of many types are in operation worldwide with their accompanying enviromental and economic benefits. Tunisia is considered by the United Nations as a "threshold country" and possess all the potential technology and know-how, in terms of educated technicai persons, for an expandable and sustainable biogas technology.

7.3 Demonstration Projects

Two suggested demonstration projects are described. The first, for treatment of both olive oil wastewater and chicken manure, is a demonstration of the codigestion process which addresses the two single most serious environemntal problems of Tunisia. The technology described can in the future be applied to the treatment of any solid, semisolid or high strength liquid wastes. The second is a wastewater treatment project which will have application for all agro-industrial (sugar, fish, fruit and vegetable canning wastewater) and hard industrial (biodegradable organic chemicals and solvents) wastewaters.

7.3.1 "Les Margines" (olive oil wastewater) and chicken waste

Any responsible demonstration project for Tunisia will include a project for treatment of "les margines", olive oil wastewater. Les margines are currently the most damaging environmental waste problem in the country and, in their own right, are difficult wastes to treat. They are concentrated wastewaters containing a high fraction of recalcitrant and toxic organic chemicals, *i.e.* poly- and monophenols.

The waste is a liquid, contains little undissolved organic matter and normally has a COD content of between 100 and 150 kg/m^3. The COD is composed of approx. one third each of soluble sugars, suspended oils and fats, and dissolved phenols and polyphenols. The *p*H is between 5 and 6.

A review of the literature, discussions with the staff of Centre de Biotechnologie de Sfax and the experience of the DTI team show that the most viable solution given today's technology is treatment of les margines via codigestion. Codigestion is the practice of treating solid wastes, semisolids and high strength wastewaters in mixtures in anaerobic digestors. Treating several wastes simultaneously gives a robustness to the biological process via a numerous, well adapted and diverse microbial population. Treatment of many wastes types simultaneously also allows for dilution of toxic and recalcitrant wastes, such as les margines. The presence of solids and semisolids also gives biophysical protection from toxic chemicals to the microbial populationvia the opportunity for surface attachment, and access to surface bound substrates which are often more easily degradable compared to when they are free in solution. Additionally, a codigestion process eases handling of seasonal wastes, *i.e.* as the production of a particular waste ends as a course of the agricultural season, production and treatment of another seasonal waste can begin.

In such a treatment system, because of their toxicity and recalcitrance, les margines would initially account for a relatively small fraction of the reactor feed. However, within a matter of days or weeks it would be possible to increase the input of les margines until they represent a major fraction of the waste treated. Also important to the process will be the choice of starting inoculum for the reactor.

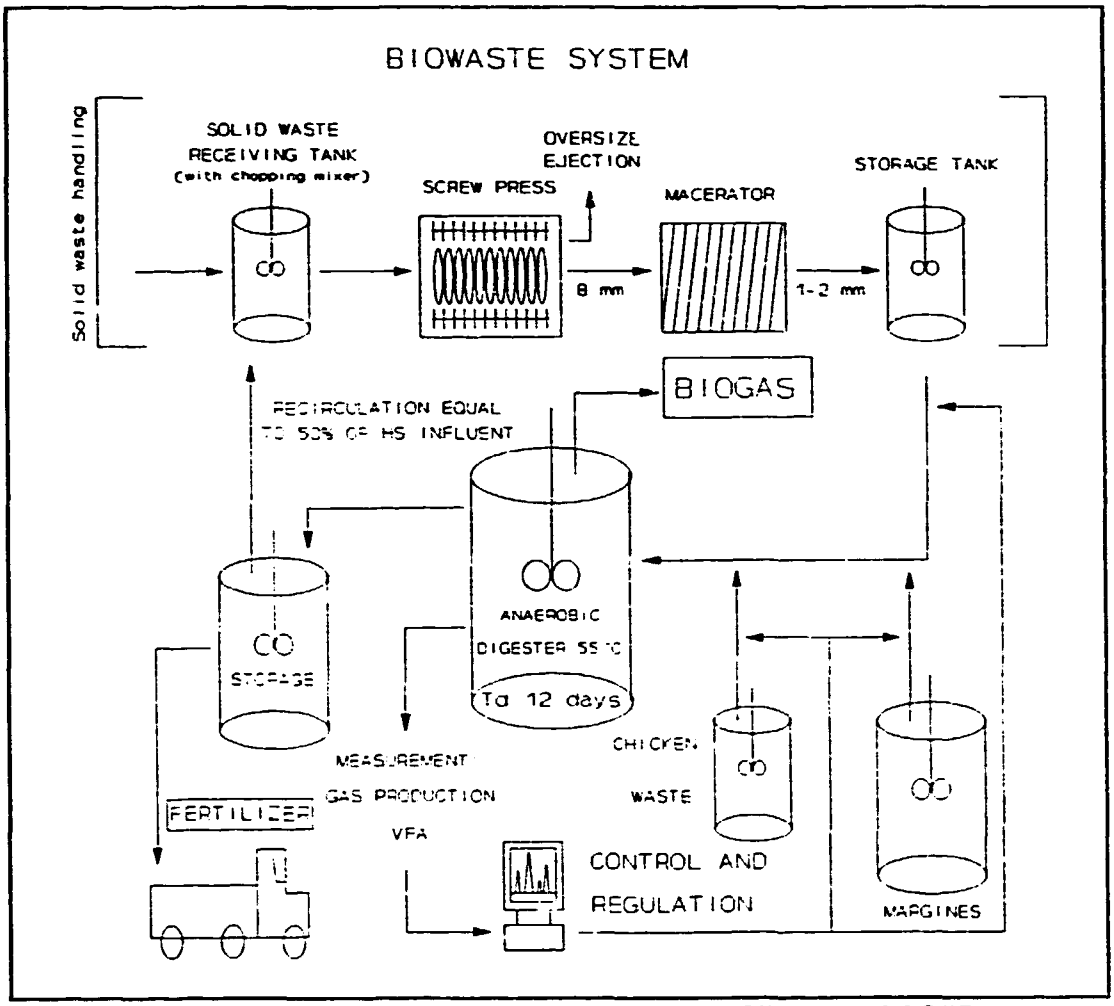
Wastes of the chicken and egg industry are regarded as Tunisia's other large environmental problem. The intrinsic problem with chicken waste is it's high nitrongen content and low ratio of carbon to nitrogen. The waste is an acceptable substrate for biogas production, solids content is high, 30-40%, but the high nitrogen content does not allow good digestion of the waste when handled alone.

Also to be included are wastes with a relatively high carbon to nitrogen content ratio and which contain fibrous and solid material, such as sorted household solid waste like that being generated at the pilot composting plant in Tunis, or animal manure.

Figure 1 shows a schematic diagram for a modern codigestion biogas plant. The key features are the tanks and pumping systems for individual storage of the various waste types to the main reactors (allowing controlled addition), and the main reactor with nearly continuous mixing.

The most important control parameter for such a system is the concentration of volatile fatty acids in the reactor. Measurement and interpretation of the quantities and composition of these important intermediates in the anaerobic digestion process has been a specialty of the DTI staff for many years and on-line automatic measurement systems have been developed at DTI. Expert system control programs are also being developed at DTI and will soon be available for automated control of biogas plants.

The proposed project is for a reactor system with a size of between 1000 and 2000 m^3. Such a system could treat up to 175 tons waste daily where les margines would constitute from one fourthe to one third of the waste, chicken manure one third to one half and other low nitrogen, fiber containing easily degradable wastes (such as sorted HSW, manure, vegetable and fruit market *etc.*) would make up the balance. Following (Table III) is a proposed budget for a 2000 m^3 plant that will also produce over 1 MW of electricity and 75-100 tons daily of soil conditioner with high nitrogen content.



CODIGESTION SYSTEM FOR LES MARGINES AND CHICKEN WASTE

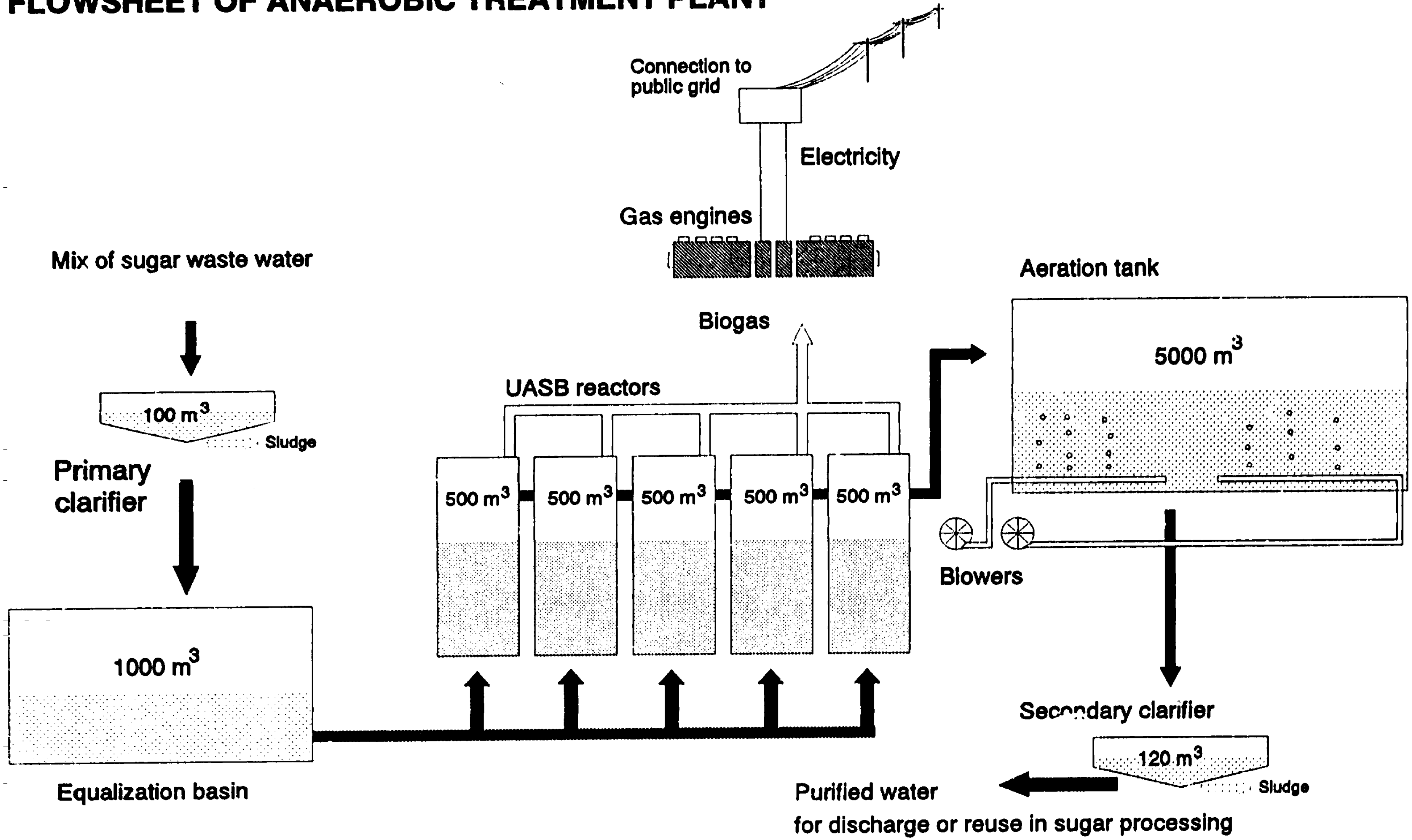
Table III - Proposed budget for codigestion plant treating les margines and chicken waste with HSW, manures, market wastes....

Cost in US $1,000	Tunisian production	Import - local buy	Import - foreign buy	Total
Construction	615	1210	185	2010
Design and management	110	50	265	425
Transport, gas handling	105	-	617	722
Laboratory	-	-	24	24
Training	340	-	270	610
Reserves unforseeable	100	-	100	200
Total	1270	1260	1461	3991

7.3.2. Sugar factory and distillery wastewater

As described in section 6.3 the sugar and distillery industries in Tunisia are very good candidates for production of biogas and energy recovery from their wastes. The best technology for treatment of these wastes are up-flow anaerobic sludge blanket reactors (UASB). These reactors are high-rate liquid waste systems which can be operated at thermophilic (giving very good sanitation) as well as mesophilic temperatures. Following a small aerobic polishing the reclaimed water is suitable for many purposes, including sugar beet washing, process water, irrigation *etc.* Figure 2 is a diagram of how such a treatment plant would look dimensioned for treatment of the wastewater produced at Beja from both the sugar factory and the yeast production. This plant will produce 1.25 MW electricity and 2.5 MW of heat for 300 days/year. The total cost of such a unit will be about USD 5 mio including a training programme.

FLOWSHEET OF ANAEROBIC TREATMENT PLANT



7.4 R&D and Technology Transfer

Included in both the proposed budgets for the demonstration projects are training programs for plant operators and involvement and training of the waste producers. These are not "turn key" proposals because as with any large-scale technological operation in-house expertise and a supporting infrastructure is required for sustainability.

As described in section 5.3 there are many educational and technological institutions in Tunisia which possess the capability for establishment of internal R&D and technology diffusion programs. Biogas research exists in Tunisia and infusion of the latest and most modern technologies available will strength this potential.

7.5 Development of a strategy for the use of biogas as waste treatment technology

Although the overall direction of the biogas effort in Tunisia touches the most interesting areas, a more integrated and concerted approach is needed. As a planning instrument for this a strategy for biogas development should be elaborated.

The strategy should involve:

- A mapping of locations where biogas plants for multiple applications can be established

- Evaluation of previous experience with biogas projects leading to the identification of risk and success factors

- To provide reliable estimates of the commercial value of the energy and fertilizer products coming from biogas plants

- To identify efficient channels for the marketing of fertilizers from the biogas plants.

- To provide estimates of the cost of biogas plants in various applications

- Identification of specific incentive programmes.

7.6 Institutional framework for project

The introduction of biogas as a technology for the treatment of industrial waste touches the field of interest of a wide range of institutions that each have an important role to play:

* MEAT and ANPE for being an environmetal technology with broad cross-sectoral applications; and ''ONAS for the treatment of municipal waste water and household waste

* L'Industries and its cellule environmental for its application in the agro-industry

* Direction de l'Energie and AME for being a renewable energy technology

* Agriculture for being a supplier of compost for farmers

* Peche for its potential use in the fish conserves industry

* Secretariat d'Etat de la Recherche Scientifique et Technologique for basic research in biotechnology of interest to biogas

There are two logical candidates for the assumption of the overall responsibility for the project: MEAT/ANPE for being the key institution for the promotion of environmental technologies and SERS for being the key institution for R&D. Since the biogas is not yet a "commercial" environmental technology, and the project aims at preparing the future for biogas, it is recommended:

* To entrust the overall project management responsibility to SERS

* MEAT/ANPE will be responsible for the elaboration of the strategy. The Ministry of Agriculture will within the strategy cover the fertilizer aspects and investigations, while AME will cover the energy related issues.

* The Sfax biotechnological institute will be responsible for the R&D component.

7.7 Possibilities for national co-financing

A number of possibilities exist for co-financing from national sources:

* The annual budget for R&D which is administered by SERS

* The specific financial incentive provides by AME to energy projects and by NEAT/ANPE for environmental investments

* Co-financing from industry

TABLE 2. TUNISIAN BIOGAS PLANTS - HISTORY AND STATUS

LOCATION	START DATE	SIZE m^3	WASTE TREATED	HISTORY	STATUS	FUTURE
Pilot compost plant, Tunis	1992	5.6	classified household solid waste	never operated, gas to be flared off	idle	planned experiments
Egg farm, Sfax	1988	1	chicken manure	operated intermittently gas to flared off	idle, under reconstruction	planned experimentsoptimize C/N ratios
Dairy, Sfax (2 reactors, 50+12)	1987	62	dairy cow manure	operated for 1-2 years, ≈50 m^3 biogas/day, gas use in cheese factory	idle, process disrupted due to scum layer formation	no plans
Rural village digestors (≈50 units)	1982	12-25	cow, sheep, goat manure	installed for rural cooking needs to replace wood	most operational	continued operation
Municipal wastewater treatment plant (100,000 m^3/day capacity) Tunis		full sludge treatment require 10-15K m^3	1° + waste activated sludge	generating electricity with biogas	operational	continued operation

TABLE 3. WASTE IN TUNISIA AMENABLE TO TREATMENT IN BIOGAS SYSTEMS

WASTE TYPE	QUANTITY/YEAR	CHARACTERISTICS	RECOMMENDED BIOGAS TECHNOLOGY	BIOGAS POTENTIAL/YEAR [m^3 CH_4 at 0°C,1bar] (% VS, % conversion)	ELECTRICITY POTENTIAL (MW generation effect)
Olive oil wastewater (Les Margines)	375,000 m^3	recalcitrant, up to 150 kgCOD/m^3	codigestion	11 X 10^6 (10,80)	3.8
Chicken waste	2500 tons	high N content, good biogas source	codigestion with vegetable matter	18 x 10^6 (23,80)	6.2
Sorted municipal solid waste	0.4 x 10^6 ton (1/3 of national production)	high C/low N, good for mixing with high N and recalcitrant wastes, *e.g.* olive oil wastes	codigestion with high N and/or recalcitrant waste	52 x10^6 (32,80)	18
Bleaching clay from food oil industry	1350 tons	high C, very biodegradable, clay mineral stabilizes biogas process and protects from recalcitrants and high N wastes	codigestion with recalcitrants and high C and N wastes, alone this is a small waste but it is a good additive to digestors	330000 (30,90)	0.11
Manure of 200,000 head cattle	730,000 tons	low C and N content, good to mix with recalcitrant and high C+N waste	codigestion with manure, municipal waste	11 x10^6 (5,50)	3.8
Fish processing solid waste	2000 tons	very biodegradable, high C and very high N	codigestion with manure, municipal waste	3.4 x 10^5 (36,95)	0.12

Sugar and yeast production (not including sugar beet pulp)	12000 tons	liquid, very bio-degradable, low N	UASB	4.3×10^6 (1.5, 95)	1.5
Municipal sewage sludge	130000 tons	low C and low N	codigestion with recalcitrants, municipal, and high N wastes	1.2×10^6 (5, 50)	0.5
Organic chemical waste	N.A	liquid, very biodegradable, high gas yield	UASB or codigestion	900 m^3 CH_4/ton	N.A
Municipal wastewater (smaller cities)	N.A	liquid, low C and N	UASB and codigestion	1.4 m^3/m^3	N.A

Codigestion - continuous stirred tank reactor receiving a mixture of compatible waste for process optimization

UASB - upflow anaerobic sludge blanket reactor, a high-rate liquid waste treatment system

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