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MINISTERE DES AFFAIRES ETRANGERES,
DU COMMERCE EXTERIEUR ET DE LA
COOPERATION AU DEVELOPPEMENT

Administration générale
de la Coopération au Développement

CONSULTATIVE COMMITTEE MEETING ON BIOMETHANATION OF AGRO-INDUSTRIAL RESIDUES FOR ENERGY RECOVERY AND NUTRIENT RECYCLING

US/INT/85/015

from 17 - 21 November 1986
Genval, Belgium

Organized by

the United Nations Industrial Development Organization (UNIDO)

in co-operation with

the Government of Belgium (AGCD/ABOS)

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I. INTRODUCTION

A Consultative Committee Meeting on Biomethanation of Agro-industrial Residues for Energy Recovery and Nutrient Recycling, organized by UNIDO in co-operation with the Government of Belgium, was held at the "Château du Lac" in Genval (Belgium) from 17-21 November 1986. It was directed at accelerating the industrial application of biomass energy and waste recycling technologies with the ultimate aim of increasing and diversifying energy resources and of environmental pollution abatement.

Background and Justification

The meeting was directly related to the implementation of the Nairobi Plan of Action on New and Renewable Sources of Energy.

Many Developing Countries have rich biomass resources although these are neither fully nor efficiently exploited. Among the new and renewable sources of energy, biomass is generally recognized as having one of the greatest potentials for exploitation in Developing Countries.

The heavy dependence of many Developing Countries on agricultural production and on energy imports makes it imperative to introduce modern industrial technologies for the conversion of agro-industrial by-products and wastes into energy and other useful products in order to increase the added value of agricultural production.
The agriculture-energy-industry link is obviously an important one for many Developing Countries, and it is, therefore, desirable that concerted international efforts are directed towards the implementation of industrial projects for energy production from agro-industrial by-products and wastes.

Belgium is one of the world leaders in biomethanation technology and it was believed that the convening, in Belgium, of a consultative committee meeting for biomethanation will lead to the transfer of belgian know-how and resources to interested Developing Countries in this important technical area.

Investments in the field of biomethanation of agro-industrial residues for energy recovery and nutrient recycling, are more difficult to assess and promote than other kinds of investments. If their socio-ecological benefits seem evident to many experts, their financial and economic benefits for the investor are often considered as marginal or even doubtful at first sight. Some of the reasons are:

(a) In the past, such investments were generally not considered as technically indispensable;

(b) If realized, their direct contribution to reducing the production costs appears marginal compared to the effect of other technically recommendable measures such as new or improved production equipment;

(c) Their financial returns can often be measured only in terms of benefits such as pollution abatement and resource recycling, and therefore assume real significance only if heavy penalties are imposed for non-compliance of anti-pollution laws.

Yet new trends in this field are being noticed. Many industrial managers, indeed, in both the Developed and the Developing Countries are more and more concerned by decreasing the energy dependence of their activities. Furthermore, in countries where the agro-industrial sector is rapidly developing, like in Brazil, one anticipates an increasing social pressure, on both the public and private policy-making and decision-making levels, to achieve effective environmental pollution abatement.

In accordance with the above statements and/or recommendations, the Belgian Government and UNIDO have decided to convene the above Consultative Committee Meeting from 17-21 November 1986.

Purpose of the Meeting

The purpose of the meeting may be defined as follows:

(a) To identify and facilitate investment projects for conversion of agro-industrial by-products and wastes into energy (methane) and other useful products, through biomethanation process.

(b) To identify opportunities for carrying out feasibility studies (covering socio-economic cost/benefit analysis) on biomethanation projects.

(c) To identify opportunities for further development work involving process and design studies and leading to pilot or demonstration plants for biomethanation where the application of this technology to a particular type of agro-industrial residue appears promising.

It is important to note that the objective of the meeting was not to be regarded only as one of the usual UNIDO initiatives for investment promotion in general. The initiative of the Government of Belgium and UNIDO, indeed, did not aim so much at promoting investment in the sector of the biomethanation in general but was more oriented toward the facilitation of their realization through the analysis of their structural impeding mechanisms and the elaboration of concrete and appropriate solutions.

Selection of Projects and Participants

Approximately 50 persons attended the Consultative Committee Meeting : 13 representatives of the Developing Countries (out of 15 invited) and 37 representatives of the Belgian business and/or academic community and one Unido officer.

Developing Countries Participants were selected on the basis of their investment proposal. In june 1986 UNIDO invited governments of selected Developing Countries to nominate up to three suitably qualified industrialists from public and private sectors and/or officials who have responsability at policy-making and decision-levels, to develop and promote biomass energy technologies (especially biomethanation technology) in general and investment in these technologies in particular. The final selection of participants was done on the basis of the candidates' personal data and of the project proposals by TRANSTEC (Brussels), a belgian consulting firm, specialized in transfer of technology and investment promotion, who had been entrusted, as a subcontractor of UNIDO, with the organization and the preparation of the meeting.

More than 50 project proposals were presented to the selection committee that comprised

- Edmond-Jacques NYNS, Master in Pharmaceutical Sciences and in Chemistry, Ph. D. in Biochemistry, Professor at the University of Louvain, Belgium;

- Alain DENIS, Economist, Experts in Investment Promotion;

- Philippe D. GROSJEAN, Master of Science in Engineering, Post-graduate in Business Administration and in Foreign Trade, Expert in Human Resources Development

together with representatives from the Belgian Office for Foreign Trade, the Office of the Belgian Prime Minister for the Programmation of the Scientific Policy, and delegates from Belgian Professional Associations.

The selection criteria of the project proposals and/or the candidates were essentially based on the richness of the candidate's country in potential biomass resources, its dependence on agricultural production and on energy import, the possibility of the proposed project to increase the added value of agricultural production, its degree of integration in the environment on both the social and the geographical point of view and finally the candidate's qualification to explain the project's specific difficulties of implementation.

Site visits have been undertaken to projects identified as "borderline cases" or when several projects were in competition in order to enable final selections to be made.

Fifteen candidates have been nominated by UNIDO to attend the Meeting. They were from : Angola, Argentina, Brazil, Burundi, China (2 delegates), Guyana, India, Indonesia, Paraguay, Philippines, Senegal, Sudan, Thailand and Zimbabwe.

Belgian participants were selected on the basis of their qualification to contribute on the topics that were raised in the project proposals and bring the best relevant answers to them.

Themes of Discussion

The analysis of the investment proposals presented by the selected countries indicated the existence of four main types of difficulties encountered by Developing Countries in the realization of biomethanation investments :

(a) financial difficulties comprising the negotiation of joint-ventures with foreign partners, the granting of commercial loans, the need of assistance from international financing institutions and finally the acquisition of hard currency through counter-trading techniques (compensation, linked purchases, clearing, counterpurchase, etc...);

(b) technological difficulties;

(c) economical difficulties and, more particularly, the socio-economic cost/benefit analysis of a biomethanation investment project;

(d) and difficulties related to the implementation of investments in this important technical area or to the realization of energy development plans based on the use of the biomass.

Consequently the work of the Consultative Committee Meeting has been divided into four main themes of discussion : Finance, Technology, Economy and Implementation, each one being taken as the main theme of discussion of a day as follows:

(a) Finance : on Monday, November 17

(b) Technology : on Tuesday, November 18

(c) Economy : on Wednesday, November 19

(d) Implementation : on Friday, November 21

Thursday, November 20 has been devoted to visits of plants.

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II. SELECTED INVESTMENT PROPOSALS and STATE OF THE ART in the Participating Developing Countries

Out of the fifteen nominees from the Developing Countries two have had to cancel their participation in the meeting at the last minute (Angola and Thailand). Thirteen delegates participated in the work of the meeting.

The investment proposals together with a short description of the State of the Art in each of the Participating Developing Countries, listed in alphabetical order of the countries, follow :

ARGENTINA

Report on the Use of Biomethanation in Argentina : by F. Sineriz, Secretariat of Energy, Department of Non Conventional Sources of Energy, Buenos-Aires, Argentina.

Argentina has no big reserves in oil and at present natural gas is vented away because there is no pipeline. The hydro-electric potential is big but the suitable generating sites are far away from the consumer centers. There also exists a nuclear programme. To fill the deficit in light liquid fuels an alcohol programme promotes the development of distilleries.

In this context biomethanation in Argentina is considered for the treatment of agro-industrial wastes, to reduce pollution and costs of wastewater treatment, and for the treatment of animal manure in locations far away from the energy distribution system.

For the treatment of stillage several designs have been tested and the UASB design has been retained on the basis of results obtained in a 100 l semi-pilot scale reactor. A contract has been signed between the Secretary of Science and Technology and a leading distillery to build and operate a 30 m3 UASB pilot plant. The expected production of a full scale plant would cover 65 to 75% of the energy needs of the distillery.

In the case of biomethanation of animal manure, since the animals graze freely all year round, the only farms that could profit from the biogas technology are the milking farms located far away from the electricity distribution system. In these farms the manure collected twice a day during milking time would produce the energy needed to cool the milk from 22°C to 4°C.

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DESCRIPTION :

The utilization of biogas in a dairy farm to cool milk:
project developd by INTA

The National Institute for Agriculture (INTA) is developing the use of biogas produced in a dairy farm to operate the milk cooling unit by means of absorption equipment. They are looking for technological cooperation to further develop the system.

LOCATION: Tambo "La Julia", Ciganotto Hnos.
Suipacha, Provincia de Buenos Aires.

ORIGINE OF RESIDUES:

The dairy farm is located in the suburb of Suipacha, in the state of Buenos Aires. It consists of 100 bovines producing an annual average quantity of 300,000 litres of milk. The bovine manure is digested in a two steps process biodigester with a nominal capacity of 30 m3/day to cover all the energy needs of the farm. At the moment it is used for water heating only and the balance is spoiled in the wind. The sludge is used as fertilizer in the farm.

DETAILS:

Energy is widely used in dairy farm for milk extraction and cooling. As the conventional energy in many cases is not existing or not made available because of the distribution cost, INTA and the owner of the farm "La Julia" decided in 1984 to develop a large scale biogas digester which could satisfy the entire energy requirement of the farm "La Julia". The cooling of the milk at the farm is of a paramount importance for it conservation. Extracted twice a day by a mechanical system, the milk must be cooled from 36 degree to 22 degree and maintained at this temperature till its transportation once a day at the dairy factory. Hence a milk cooling system by means of absorption machine operated by biogas, is being developed together by INTA, the owners of the farm "La Julia", the owners of the dairy factory "La Suipachense" and a private engineering company named DYNATHERM THERMODINAMIC based in Castelar.

DIFFICULTIES:

The main difficulties are : (i) the design of the absorption equipment to be oped by biogas; (ii) the mobilization of financial resources to complement these already obtained from the sponsors of the project
and finally (iii)the supply of special equipment (such as metering and control apparatus).

STUDY AVAILABLE:

A feasibility study prepared by Mr E.C. GIL ESPINOSA, M. BOGLIANI and J. HILBEkT of the INTA in 1984 concludes that the efficiency and the profitability of the system greatly depends on the successful design of the absorption equipment. According to the sponsors of the project, this kind of equipment is not existing on the world market.

RECOMMENDATIONS:

a) Request for Technical Assistance from UNIDO through UNDP local office outlining the type of assista..ce required.
b) Submit the investment proposal to the UNIDO Investment Co-operative Programme for further promotion.
The industrial investment questionnaire, duly filled in, is to be returned to R.O. Williams Industrial Development Officer, Chemical Industries Branch, IOTD, Department of Industrial Operations, UNIDO, P.O.BOX 300, A-1400 Vienna, Austria, Tel.:(0222)26313956, Telex : 135612.

BRAZIL

<u>Biomethanation in Brazilian Alcohol Programme</u> : by A.G. Salerno, Zanini SA Equipamentos Pesados, R&D Department, Sertaozinho, Brazil.

In Brazil the main crops are corn, soya, bean and rice. The waste potential of these crops is 120 million tons. The biogas potential from the 14 million head of cattle is 14 million cubic meter per day. Six thousand digesters of 4 to 6 m3 have already been built in rural areas.

The alcohol industry produces i7 million m3 of alcohol per year together with 204 million m3 of stillage at a COD of 30 g/l. The sugar industry produces 7 million tons of sugar per year with 50 million m3 of effluent at a COD od 9 g/l. The food and beverage industries are not considered because of the low COD concentration of their effluents. The bagasse resulting from the processing of sugar cane amounts to 57 million tons per year and it is used as cheap fuel in the sugar processing industries.

Economic studies show that biogas production in the alcohol industries is not profitable if it is to replace bagasse as fuel. But it would represent a 6.6% increase of income if it is used as automotive fuel in the lorries that transport the cane and/or if it is sold for other uses.

If all the residues mentioned above were to be treated anaerobically, including municipal wastes, it would mean a production of 7,000 million m3 of biogas per year i.e. half of the actual alcohol production in Brazil in terms of energy.

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DESCRIPTION :

Transfer of Technology in the Field of Biomethanation from Belgium to Brazil

ZANINI recently signed an agreement with the belgian company ARBIOS SA to gradually transfer a technology into Brazil. The initiative fits in the brazilian PRO-ALCOHOL PLAN and aims at further reducing the overall alcohol production costs.

LOCATION: still unknown

ORIGINE OF RESIDUES:

The residues considered in this project are mainly the bagasse from the sugar factories and the vinasse from the alcohol distilleries.

DETAILS:

In the last decade ZANINI has greatly contributed to the development and the implementation of the brazilian PRO-ALCOHOL PLAN. If on the energy side this development plan greatly contributed to reduce the brazilian dependence on imported energy, it also created huge quantities of agro-industrial residues which were not and still are not sufficiently taken care of to avoid massive environmental pollution.
Today the brazilian government wishes to reorient the implementation of the pro-alcohol plan towards reducing the distilleries production cost instead of increasing the number of new distilleries. This leads to consider the vast amount of energy still contained in the bagasse and in the vinasse and to match two different objectives ie: pollution abatement and energy recovery.
This is the context that induced ZANINI to agree with the belgian company ARBIOS SA to transfer their biomethanation technology and develop it in Brazil.

DIFFICULTIES:

The main difficulty encountered by ZANINI is to obtain an opportunity to build up an industrial biomethanation demonstration plant in Brazil. This is a typical difficulty for that kind of investments for the evaluation of their feasibility and the assessment of their profitability greatly depend on whether one considers a purely financial point of view or an economic point of view. Their financial returns, indeed, can often be measured only in terms of benefits such as pollution abatement and resource recycling, and therefore assume real significance only if heavy penalties are imposed for non-compliance of anti-pollution laws. But ZANINI has also to combat an existing reluctance of the industrial community in Brazil against the biomethanation technology which is based on previous experiences conducted by ZANINI's competitors who failed to meet the expected technological performances.

STUDY AVAILABLE:

Since january 1986 ZANINI have prepared many studies and proposals to private and public companies to buid up biomethanation plant. Among them three are particularly interesting and being further discussed; it concerns a brewery, a cognac distillery and a sugar cane alcohol distillery. They all have as a main conclusion that to demonstrate both the technological and economic feaseability one should mobilize state resources to assist in the financing of the investments.

RECOMMENDATIONS:

a) Request for Technical Assistance from UNIDO through UNDP local office outlining the type of assistance required.
b) Submit the investment proposal to the UNIDO Investment Co-operative Programme for further promotion.
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BURUNDI

Role of Public Authorities in the Successful Implementation of Biomethanation : the example of the Ministry of Energy of Burundi and its Co-operation with Belgium, China and West Germany :
by V. Baratakanwa, Ministry of Public Works, Energy and Mines, Direction Générale de l'Energie, Bujumbura, Burundi.

Burundi is an enclaved country. Its potential in hydro-energy is important but limited to urban centers for the time being. Consequently the fuelwood consumption is still excessive. Therefore the Ministry of Energy has set up a new department with the overall responsability for the popularization of new sources of energy. The selected fields of investigation are : biogas, solar energy, turf and saving in fuelwood by reforestation and stove efficiency improvement. The biogas programme started because of the following : (i) it was felt necessary to train staff people and to establish an inventory of the biodegradable biomass in Burundi, (ii) a largely scattered habitat that complicates both the collection of domestic waste and the distribution of gas, (iii) the existence of large communities like schools, hospitals, etc... and (iv) the fact that the Tanganyka lake was more and more used as a dumping area for the wastes of the agro-industrial industry. Three co-operation programmes were started.

From Belgium a funding by BADC allowed to set up a demonstration center and laboratory to promote the research on biomethanation, to train personnel and permit the scientific and technical follow-up of biomethanation projects.

Three chinese experts have been recruited to help realize pilot-digesters in the provinces (at a rate of 5-6 per province).

Finally the dissemination of the technology is mainly realized through a programme funded by West Germany : it consists mainly in training peasants via local training centers. The construction of biodigesters is promoted thanks to a credit system to individuals and/or local communities that allows very flexible and adapted reimbursement procedures.

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DESCRIPTION :

Biogas Production in the Bujumbura Slaughter House

A small pilot plant (funded by the Belgian Government) already exists. Further development envisaged is the production of steam for the slaughter-house and of dried soil conditioner.

LOCATION: Abattoir National de BUJUMBURA
BUJUMBURA - BURUNDI

ORIGINE OF RESIDUES:

The national slaughter-house of Bujumbura treats an average annual quantity of 120,000 head of cattle. This represents an annual quantity of 450 tons of solid residue (12% of dried organic material) and 1,800 m3 of liquid residue with a COD of 30,000mg. Today the liquid residues are drained off through the municipal sewage network and the solid wastes are left in the open air for decomposition.

DETAILS:

As far as biomethanation is concerned Burundi sets the priority in the development of the domestic use of biogas, the main reason being the scarcity of the available resources. The construction of an industrial biomethanation plant such as the one suggested for the Bujumbura slaughter-house, could only be possible if a special technical assistance programme is tailor-made.

DIFFICULTIES:

Such a technical assistance programme should comprise the finance of the feasibility study, of the process design and engineering studies and the construction of the plant.

STUDY AVAILABLE:

No study available yet.

RECOMMENDATIONS:

a) Request for Technical Assistance from UNIDO through UNDP local office outlining the type of assistance required.
b) Submit the investment proposal to the UNIDO Investment Co-operative Programme for further promotion.
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CHINA : first proposal

A review of Utilization and Main Problems about Biomethanation from Agro-industrial residues in China : by Liang He, Ministry of Agriculture and Animal Husbandry, Bureau of Rural Energy and Environmental Protection, Beijing, China.

By the end of 1985 biogas digesters were used in 5 millions households in the rural areas of China. At present, biogas is extending from rural areas to the cities. Already 19,000 large and midium size digesters have been built in livestock farms, distilleries, slaughterhouses and food processing factories. The biogas produced is used for the industries own consumption but it is also transported as fuel to 20,000 households. The main designs used are the hydraulic and plug flow designs. Other more advanced designs are beginning to be adopted such as upflow anaerobic sludge bed reactors and anaerobic filters.

The main reasons for the actual state of development of biomethanation in China are : (i) the promotion of the technology by the Chinese Government who helped biogas development by offering good conditions for manpower, material and finance; (ii) the establishment of special agencies to do the training of personnel, research, execution and diffusion of programmes, manufacturing of biogas tools and equipment; (iii) the establishment of technical regulations and standards for quality control; (iv) the establishment of heavy penalties on pollution.

Development of the technology anyway remains the key problem for the further development of biomethanation.

PRESENTED BY : Mr HE LIANG
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DESCRIPTION :

The Community Biogas Plant in North China Rural Area

Development of a new design of biodigesters in stock-farming : a first 10m3 pilot plant, designed by the Beijing Solar and Biomass Research Institute, is in operation. A larger digester (200m3) is being designed but requires engineering assistance.

LOCATION: Beijing East Suburbs Farm
Airport road, Beijing.

ORIGINE OF RESIDUES:

The stock-farm, where the first 10m3 pilot plant was installed, contains 4,500 pigs and produces annually about 3,000 tons of diluted manure with a concentration of 3-4% of dried organic material. One could also consider about 1,500 tons of poultry manure produced annually.

DETAILS:

The Beijing Solar and Biomass Research Institute has been given an assistance from the Ministry of Agriculture, Animal Husbandry & Fishery, to develop a biomethanation process for large stock-farms. The above mentioned 10m3 installation is the first step of development : the manure is pumped from the manure storage tank to the pre-heating tank where it is mixed and preheated by solar collector during the day and by the outlet of the digester durng the night. Then it is sent to the digester. After digestion the residues are used as direct spreading. From January to March 1986 this pilot plant was constantly followed up by a scientific team of the Beijing Solar and Biomass Research Institute. Based on the obtained results the Institute is planning to construct an industrial demontration digester (200m3) next to the first one.

DIFFICULTIES:

The difficulties are mainly :

* process design, engineering and technique :
Research works are still necessary in the pretreatment of the manure, optimization of the energy production and control of the overall system.

Besides the Institute wishes to acquire more advanced technology from foreign countries on various topics like the dry fermentation, the two separated phases digestion system, the design of biogas transportation and storage equipment, etc...

Certain equipment are not available in China such as gas compressor, ph-sensor, pump for thick material, etc...

* economic :
Based on the energy produced, the economic benefits are not so good; the construction cost should be reduced.

* training :
The persons involved in the process design should be trained.

* finance :
Although the project seems to be well supported by the Ministry of Agriculture, external assistance is required to finance imported equipment..

STUDY AVAILABLE:

The semi-phase separated digestion of pig manure, Li Weimei, 1986.
The balance of energy for mesophilic digestion, Jiang Xinian, 1985.

Their conclusions are that solar energy and the use of the exhaust heat may greatly reduced the energy requirement in mesophilic digestion and that the semi-phase separated digestion is better than the completely mixed digestion.

RECOMMENDATIONS:

a) Request for Technical Assistance from UNIDO through UNDP local office outlining the type of assistance required.
b) Submit the investment proposal to the UNIDO Investment Co-operative Programme for further promotion.
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CHINA : second proposal

Biomethanation of Industrial Effluents for Energy Recovery in China : by Yi Yong Wang, Ministry of Light Industry, Beijing, China.

China has got large amounts of effluents containing high organic loads. It is paying special attention to intensify the process of biomethanation to increase the biogas production per unit of reactor volume and to increase the reduction of pollution.

For example, the pulp industry working with straw as raw material and soda or lime as cooking material produces black liquors of 79 to 150 g COD per litre. The alcohol distillery working with sweet patato as substrate produces waste waters of 25 g COD per litre. The 200 tanneries of China produce a waste water of 40 g COD per litre.

At present a few realisations exist such as 3 plants treating urban waste water sludge, 2 plants working on effluents from a citric acid industry and 2 plants fed with effluents of alcohol distilleries. Biomethanation of waste liquor from pulp processing by lime has been studied on the laboratory scale and 79% COD removing has been obtained. A UASB pilot plant of 24 m3 fed with filtrated residual liquor of distillery produces 5 m3 per m3 digester and per day with a COD removal of 93%.

Until now the extension of biomethanation of industrial effluents has been limited because their COD content effluents is still beyond the effluent discharge standards.

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DESCRIPTION :

Biomethanation of Residual Liquor in Alcohol Distillery and in Sulfate Pulp Mill

The Belgian Government is currently assisting this Ministry for the feasibility studies of two investment proposals in the agro-industrial sector namely : the treatment of the residues from the WUHU PAPER BOARD MILL and from the JINAN ALCOHOL DISTILLERY with the aim to eventually transfer the belgian technology into China.

LOCATION: a) Wuhu City, Province of Anhui
b) Jinan City, Province of Shandong

ORIGINE OF RESIDUES:

(a) WUHU PAPER BOARD MILL
The mill produces 37,000 tons of semi-chemical pulp for the making of paper board. It is obtained from rice straw digested in eight 40m3 digesters and mixed with 70% of CaO. The specification of the pulping waste liquor (or black liquor) are : COD of 79,000 mg/l, BOD of 28,000 mg/l, ph = 10 and SS = 200 mg/l.
The daily production of black liquor is approximately 430 m3.

(b) JINAN ALCOHOL DISTILLERY
It is a sweet potato alcohol plant with an annual capacity of 30,000 tons of alcohol. It is obtained from cooked sweet potatoes, which after cooling are then saccarified by addition of yeast. The fermented liquor is then distilled to produce a 95% alcohol (by volume). The residual liquor from the distillation is filtrated to separate the suspended solid substance which is used as fodder in the nearby farms. Its specification are : COD of 25,000 mg/l, BOD of 14,000 mg/l and ph = 4.

DETAILS:

Both the effluents from the Wuhu Paper Mill and the Jinan Alcohol Distillery remain untreated. Because of their high content of organic matter, they exceed the standards imposed to the local effluent discharges. Through the anaerobic fermentation technology the Ministry intends to reduce the BOD to 10% of the original figures.

DIFFICULTIES:

The above investment proposals are in fact considered by the Ministry as two test cases where the proposed belgian technology is to be demonstrated and evaluated.

Belgium and China are now negotiating the conditions of their cooperation. The main topics under discussion are : the finance, the training of the personnel and the joint implementation of the process design and the construction.

STUDY AVAILABLE:

The technical feasibility studies are completed and concluded that the investment are technically feasible.

RECOMMENDATIONS:

a) Request for Technical Assistance from UNIDO through UNDP local office outlining the type of assistance required.
b) Submit the investment proposal to the UNIDO Investment Co-operative Programme for further promotion.
The industrial investment questionnaire, duly filled in, is to be returned to R.O. Williams Industrial Development Officer, Chemical Industries Branch, IOTD, Department of Industrial Operations, UNIDO, P.O.BOX 300, A-1400 Vienna, Austria, Tel.:(0222)26313956, Telex : 135612.

GUYANA

<u>Biomethanation in Guyana : History of its Development</u> :
by U. Bhimsen, Institute of Applied Science and Technology, Georgetown, Guyana.

Guyana initial interest in biogas dates back to 1977 when the National Science Research Council received a directive from the Office of the Prime Minister to pursue studies in this field. In 1980 the Guyana National Energy Authority and the Institute of Applied Science and Technology (IAST) constructed 8 family digesters with sponsorship and supervision from the Latin-American Energy Organisation (OLADE). This programme suffered serious set-backs and collapsed in 1983 primarily because of the high costs of the construction materials and the lack of trained personnel to manage and operate the system.

In 1985 a bilateral agreement with China led to the construction of 6 digesters, the training of 15 persons in biogas construction techniques and of another 30 persons in operation and management techniques. This agreement, together with a complementary UNU (United Nations University) programme led to a total of 21 operational digesters. The chinese design was chosen because of the availability and the low costs of the construction materials.

In the future the emphasis will be given to the development of medium size, industrial or commercial digesters. Opportunities exist in the large livestock farms away from national energy supply, in the national distilleries producing a total of 469 m3/year of spent lees, and for the biomethanation of the aquatic weeds infesting the water ways. For this further development of biomethanation Guyana will have to rely on international and regional financial assistance.

PRESENTED BY : Mr UKARRAN BHIMSEN
Director
Institute of Applied Science & Technology
Alternate Energy Programme
University Campus, Turkeyen, P.O.BOX 10.1050
GEORGETOWN - GUYANA
TEL : 65072 TX : 3049

DESCRIPTION :

Utilization of Biogas Technology to cover the energy needs of an integrated farm

Construction of an industrial biomethanation prototype to satisfy the total energy needs of a relativeley modern up-to date stockfarming enterprise of 3,300 pigs with cows, sheeps and poultry.

LOCATION: Alliance Pig & Poultry Farm
Coverden, East Bank Demerara, Guyana

ORIGINE OF RESIDUES:

Fresh pig and cow dung from the stockfarm (3,000 tons/year).
No treatment is being done other than soak-away pits.

DETAILS:

The main objective in the establishment of the prototype is to demonstrate that bio-energy is a practical and viable alternative to expensive fossil fuels which is difficult for most of the non-oil-producing countries to obtain. The integrated farm will demonstrate sanitation and erosion control and will turn hitherto harmful wastes into useful food for both plants and animals.

The opportunity will be taken to utilize biogas to satisfy the total energy needs of a relativeley modern up-to-date farm enterprise in a typical third world country. This will underscore the benefits of biogas in saving foreign exchange both in the use of fuel oil and expensive imported chemical fertilizer.

DIFFICULTIES:

The project proposal is since january 1986 submitted to the United Nations University but has not yet received any response.
The desired foreign contributions expressed by the Institute of Applied Science and Technology are mainly : assistance in financing the project, process design, engineering and technical assistance as well as training of the personnel.

Guyana has recently experienced a disappointing situation whereby a development project in the field of new and rewable energy, financed and supervised by an international cooperation agency, completely failed to produce its expected technical and economical benefits. Hence the Authorities are now insisting on very strict and severe inspection on any imported foreign contribution to development projects.

STUDY AVAILABLE:

Project proposal submitted to the United Nations University in january 1986.

RECOMMENDATIONS:

a) Request for Technical Assistance from UNIDO through UNDP local office outlining the type of assistance required.
b) Submit the investment proposal to the UNIDO Investment Co-operative Programme for further promotion.
The industrial investment questionnaire, duly filled in, is to be returned to R.O. Williams Industrial Development Officer, Chemical Industries Branch, IOTD, Department of Industrial Operations, UNIDO, P.O.BOX 300, A-1400 Vienna, Austria, Tel.:(0222)26313956, Telex : 135612.

INDIA

Status of Biomethanation Development in India : by B.P. GUPTA, Madhya Pradesh Urja Vikas Nigam Ltd, Bhopal, India.

There are more than 142 distilleries in India. Alcohol production from molasses generates 14 to 15 l of effluent per litre of alcohol. This means a production of 12,000 millions litres of effluent per year with a biogas potential of 22 to 30 litre per litre of effluent.

There are three methods to treat these effluents: (i) anaerobic digestion with biogas recovery followed by biological aeration to meet the depollution requirements; (ii) concentration and incineration to recover potass and steam; (iii) anaerobic fermentation in open lagoons followed by biological aeration.
Only four distilleries produce biogas from their effluents which is used to replace coal. The ambiant temperature of India, around 30°C, allows reduction of heating costs. The biogas plants have been built by Mesas Asoap Organics Ltd which possesses the know-how and sells the technology. Collaboration with various other industries have led to the construction of other biogas plants outside India.

Incentives for the development of biomethanation are provided in the form of ediction of pollution control laws, 33% subsidies on instrumental costs, special refinance and discounting schemes given by the Industrial Development Bank.

Other biomethanation plants are working on sewage wastes or garbage wastes. The biogas produced is used in individual households or for electricity generation. More than 200 community or institutional biogas plants of 35 to 140 m3 and more than 0.2 million family type plants of 1 to 15 m3 are working on animal wastes.

PRESENTED BY : Mr BHAWANI PRASAD GUPTA
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Madhya Pradesh Urja Vikas Nigam Ltd.
Block-'B' G.T.B. Complex
T.T. Nagar
BHOPAL-462003 - INDIA
TEL : 68122 TX : 0

DESCRIPTION :

Installation of Biogas Plants at Jawahar Lal Nehru Agriculture University

To make best use of the residues available in the Jawaharlal Nehru Agriculture University, to provide fuel gas to 330 families residing in the campus and to create basic facilities for education and research on biomethanation technology in the University.

LOCATION: Jawahar Lal Nehru Agriculture University
Krishi Nagar, Adhartal, JABALPUR-482004 INDIA

ORIGINE OF RESIDUES:

The University is equipped with a stockfarming installation for educational purposes. It contains about 2,000 head of cattle (bovines, pigs and poultry) producing more than 4,800 tons of dung or dropping per year. The residues are dumped in pits to convert it into manure but the manure so produced is not rich as compared to the manure produced through biomethanation of the residues. Sometimes it may also not be fully digested.

DETAILS:

Keeping this in mind a proposal was prepared (i) to make best use of the residues available, (ii) to provide fuel gas to 330 families residing in the campus and (iii) to create basic facilities for education and research on biomethanation technology in the University. It is planned to construct 7 digesters with a volume of 85m3.

DIFFICULTIES:

Difficulties encountered in the realization of the project are : (i) process design and engineering of the huge gas holders (ii) the huge quantity of input which is required for initial feeding and which is not made available by the beneficiaries of the investment and (iii) the non-availability of proper infrastructure such as roads at site/village in some of the cases.

STUDY AVAILABLE:

The Energy Development Corporation have commissioned 26 projects in the Stae of Madhya Pradesh from 1984 to june 1986.

RECOMMENDATIONS:

a) Request for Technical Assistance from UNIDO through UNDP local office outlining the type of assistance required.
b) Submit the investment proposal to the UNIDO Investment Co-operative Programme for further promotion.
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INDONESIA

Biogas Digester for Palm Oil Wastes and 1.8MW Generating System in Gunung Meliau with linkage to Pontianak System : by Ign Gde Pamayun, Directorate General of Electric Power, Department of Mines and Energy, Jakarta, Indonesia.

In Indonesia forest biomass represents 217 million tons, agricultural wastes 29.5 million tons and animal dung 114 million tons per year. Hundred digesters have already been built on animal dung.

In a common palm oil industry 400 tons of fresh fruit bunches are processed each day. The wastes resulting from this processing represents 64% of the weight of the fresh fruit. They are empty bunches, fibres and shells, usually burned to produce the steam needed in the processing, and sludge waters, usually discharged in rivers.

In such a palm oil industry a biogas plant of 4 x 400m3 capacity treating all the residues would produce 24,000m3 of biogas per day or 30Mwh. If the production of fertilizer (40 t/d) is included in the rentability study, the pay-back time is estimated to be 9 years and the unit cost 0.06 $US per kwh.

PRESENTED BY : Mr PEMAYUN IGN GDE

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Kuningan
JAKARTA - INDONESIA
TEL : 516056 TX : 62319

DESCRIPTION :

Biogas Digester for Palm Oil Mill Wastes in Gunung Meliau, Wesr Kalimantan

Necessity to decrease the cost of electricity at the palm oil mill and to reduce the pollution in a rural environment.

LOCATION: Palm Oil Mill of Gunung Melian
Gunung Melian, West Kalimantan.

ORIGINE OF RESIDUES:

The annual mill capacity represents 20,000 tons of palm oil. The residues are currently burned, or thrown into the river or used as landfill. A part of the waste is presently burned in a boiler to produce process heat and steam to run a generator for the oil mill.

DETAILS:

DIFFICULTIES:

A prefeasibility study was prepared by CESEN in association with E/Ci Future Resources Associates Inc. P.T. Widya Pertiwi Engineering. There is no particular difficulty encountered except the finance both in local and foreign currency. The sponsors of the investement proposal are ready to investigate counter-trading techniques to finance the project as well as to joint-venture with a foreign partner. Transfer of technology is being seeked also.

STUDY AVAILABLE:

see above.

RECOMMENDATIONS:

a) Request for Technical Assistance from UNIDO through UNDP local office outlining the type of assistance required.
b) Submit the investment proposal to the UNIDO Investment Co-operative Programme for further promotion.
The industrial investment questionnaire, duly filled in, is to be returned to R.O. Williams Industrial Development Officer, Chemical Industries Branch, IOTD, Department of Industrial Operations, UNIDO, P.O.BOX 300, A-1400 Vienna, Austria, Tel.:(0222)26313956, Telex : 135612.

PARAGUAY

Biomethanation in Paraguay : by L.M. Samaniego, University of Asuncion, Faculty of Chemical Sciences, Asuncion, Paraguay.

Paraguay does not produce oil, coal or natural gas. It produces electricity at the Itaipu Dam but the high costs of electricity distribution prohibit its use in the whole country. Thus non conventional solutions for energy are looked for.

Ten digesters have already been built in Paraguay, of which 9 are in operation, 6 are of the indian design and two are of the chinese design. Cattle manure is the most common substrate. Biogas appliances are lamps, stove burners, refrigerators and electric generators.

The Faculty of Chemical Science, University of Asuncion, is developing a biomass energy project funded by UNIDO. Its aim is, firstly to experiment biogas production on a pilot scale and, secondly to start the diffusion of the technology in rural areas with the help of a governmental institution, The Cattle Raising Fund that will select the farmers.

PRESENTED BY : Ms L.M.SAMANIEGO DE BOJANOVICH
Research staff member
University of Asuncion
Faculty of Chemical Sciences
SAN LORENZO
PARAGUAY
TEL : 500363 TX : 0

DESCRIPTION :

Technology Development for the Use of Biomass Energy

In 1983 UNDP/UNIDO funded a project to promote biomass energy in Paraguay. This ongoing project is coordinated by Ms Samaniego. It covers training and dissemination of design, engineering and construction of small pilot plants in Paraguay.

LOCATION: Chemical Engineering Department
Facultad de Ciencias Quimicas, San Lorenzo.

ORIGINE OF RESIDUES:

DETAILS:

The project funded by UNDP/UNIDO comprises the following stages : (i) collection of information on previous experiment in both private and public institutions in Paraguay and the evaluation thereof, (ii) market study of the potential utilization of the biomass in Paraguay, (iii) evaluation of the national experience in process design, engineering and construction of basic equipment and comparison with the experience of neighbouring countries, (iv) formulation, implementation and evaluation of an investigation programme on the perfomances of the said basic equipment in function of the material used and (v) finally the process design, the engineering and the construction of a prototype in Paraguay.

DIFFICULTIES:

The Faculty of Chemical Sciences wishes to develop a cooperation with other R&D Institutions, and more specifically from Belgium, to further promote biomass utilization in Paraguay. Assistance in the field of process design & Engineering is particularly required as well as training of R&D personnel.

STUDY AVAILABLE:

RECOMMENDATIONS:

a) Request for Technical Assistance from UNIDO through UNDP local office outlining the type of assistance required.
b) Submit the investment proposal to the UNIDO Investment Co-operative Programme for further promotion.
The industrial investment questionnaire, duly filled in, is to be returned to R.O. Williams Industrial Development Officer, Chemical Industries Branch, IOTD, Department of Industrial Operations, UNIDO, P.O.BOX 300, A-1400 Vienna, Austria, Tel.:(0222)26313956, Telex : 135612.

PHILIPPINES

Status of Biomethanation Development in the Philippines : by P.F. Ventura, Central Azucarera de Tarlac SA, Metro Manila, Philippines.

Two major agro-industrial entities have commercialized the biomethanation technology in the Philippines : the Maya Farm and the Central Azucarera de Tarlac.

The Maya Farm produces biogas from the manure of 25,000 pigs. The reactors are of the batch type. The gas production is used for electricity generation, water pumping and heating, solid waste drying, etc...

The Central Azucarera de Tarlac produces biogas from distillery slops and filter cake. The principle of the treatment is decantation followed by thermophilic anaerobic digestion, lagooning with and without aeration and finally, irrigation of the sugar cane fields with the final liquid effluent. The pollution load of the influent is reduced by 80% after anaerobic digestion and by 99% at the end of the treatment. The biogas produced is used to reactivate the spent carbon in the refinery kilns and in the boilers.

There are 19 alcohol distilleries in the Philippines, producing 8,900 tons of raw slops per day and 42 sugar factories producing 3,150 tons of filter cake per day. This means a biogas potential equivalent to 80 million litres of bunker oil per year.

PRESENTED BY : Mr PEDRO VENTURA
Chief Microbiologist
CENTRAL AZUCARERA DE TARLAC SA
Head Office,JCS Building
119 De La Rosa Cor.Alvarado street,Legaspi Village
MAKATI, METRO MANILA
TEL : 8183911 TX : 0

DESCRIPTION :

Extension of the existing 1600m3 digestion unit of
CENTRAL AZUCARERA DE TARLAC

This private company develops biomethanation technology since 1973. The existing unit produces 12% of the total energy need of the sugar factory and the distillery of Tarlac. The company plans to increase its capacity to 60% of the total energy need of the plant and to integrate the use of anaerobic digestion for sanitation/waste treatment, energy production and complete nutrient recycling.

LOCATION: San Miguel, Tarlac
Philippines

ORIGINE OF RESIDUES:

The CENTRAL AZUCARERA DE TARLAC comprises a raw sugar manufacturing plant (capacity of 7,000 tons cane/day), a sugar refinery (capacity of 6,000 bag/day at 50kg/bag) and an alcohol distillery with a capacity of 45,000 litre/day. The total quantity of by-products (filter cake, distillery slops and clarified mud) produced in a year at Tarlac represents a minimum biogas potential of 7,600 mio m3 per year.

DETAILS:

The existing biomethanation installation at the CENTRAL AZCARERA DE TARLAC treats the distillery slops only. The method consists of four treatment stages namely (i) the recovery of yeast and other gravity solids, (ii) anaerobic digestion, (iii) aerobic facultative lagooning and (iv) final stabilization and dilution.
The process is covered by letters of patent from the Philipine Patent Office and international patents have been filed in 1984.
At the same period the company has established that, based on the capacity of the biogas plant processing 20% of the total distillery slops discharged per day, the savings due to the diesel fuel and bunker oil that is displaced by biogas represent more than 41% of the initial cash outlay, corresponding to a pay out time of 2.44 years.

DIFFICULTIES:

The company is now willing to extend the existing installation to cover more than 60% of its energy requirement as well as to further develop sanitation/waste treatment and nutrient recycling. But they seem to face financial bottle-neck and wish to associate with a foreign partner who could provide finance and equipment not available in the Philippines.

STUDY AVAILABLE:

RECOMMENDATIONS:

a) Request for Technical Assistance from UNIDO through UNDP local office outlining the type of assistance required.
b) Submit the investment proposal to the UNIDO Investment Co-operative Programme for further promotion.
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SENEGAL

Use of Biomethanation in the Slaughterhouse of Dakar : by Mamadou Dianka, Ministry of Industrial Development & Craftmanship, New & Renewable Energy Department, Dakar, Senegal.

Every day more than 150 bovines, 460 sheep and 20 pigs are slaughtered at the Dakar municipal slaughterhouse. This corresponds to more than 130 m3/day of water-residue that has to be disposed off in the ocean. It comprises mainly stercoral matters, washing water and greases i.e. organic matters.

Now energy requirements in the slaughterhouse are mainly of two types : electricity and heated water. Electricity is used to operate the refrigerating rooms which represents 110kw and corresponds to a total cost per year of 50 millions CFA. Very frequent break-downs of the electricity distribution system perturb the operation of the slaughter-house. As far as the heated water is concerned the daily requirements correspond only to 2 m3 at 85°C but, as it is heated up with fuelwood (50kg/day) the annual cost of this amounts up to 450,000CFA.

Hence based on a prefeasibility study executed on behalf of the Ministry, tender documents for a turn-key supply of a biomethanation plant have been prepared and funding is being requested from various agencies.

PRESENTED BY : Mr MAMADOU DIANKA
Department Manager
Ministry of Industrial Development & Craftmanship
New & Renewable Energy Department
P.O.BOX 4037
DAKAR - SENEGAL
TEL : 215733 TX : 661

DESCRIPTION :

Installation of a Biomethanation Unit at the Slaughter-house of Dakar

Turn-key supply of a complete biomethanation unit with a capacity of 500 m3/day of biogas (75% methane) and of 6 7 ton/day of compost (25% dried matter). The slaughter-house produces 10.2 tons/day of solid residue and 11 m3/day of water residue.

LOCATION: Dakar slaughter-house
Dakar, Senegal

ORIGINE OF RESIDUES:

see summary above

DETAILS:

The main components of the proposed project are : (i) a 500 m3 digester, (ii) upstream components such as feeding tank, crusher, pumps. etc... (iii) downstream components such as a solid/liquid separator to produce compost, compost storage facility and laboratory, (iv) the biogas network consisting of gas holder, safety instrumentation, compressor, and necessary piping works and,finally, (v) three 40 kw generating sets dual biogas/fuel with heat exchanger between exhaust gas and cooling water, electric distribution equipment, etc...
A turn-key contract is being looked at provided finance could be arranged.

DIFFICULTIES:

The main difficulty is to finance the project. Normally it should be financed with the resources of the FONDS NATIONAL DE L'ENERGIE generated by the taxes levied on the super-profits of the National Oil Refinery (SAR) and of the oil distribution companies at the time when oil prices sky rocketed ! Now that the resources of the fund are all spent up, the investment proposal has been presented, in january 1986, to the AGENCE FRANCAISE POUR LA MAITRISE DE L'ENERGIE (AFME) and to the AGENCE POUR LA COOPERATION TECHNIQUE INDUSTRIELLE ET ECONOMIQUE (ACTIM) but without positive reaction till now. During the Consultative Committee Meeting in Belgium, the delegate from Senegal expressed the desire to start negotiation with the Government of Belgium.

The Senegal is ready to analyse the possibility to finance the project through non conventional financing techniques like counter trading.

STUDY AVAILABLE:

A prefeasibility study and tender documents for a turn-key supply have been prepared by the Ministry. The conclusions seem very positive specially on the saving of hard currency and the pay-back time.

RECOMMENDATIONS:

a) Request for Technical Assistance from UNIDO through UNDP local office outlining the type of assistance required.
b) Submit the investment proposal to the UNIDO Investment Co-operative Programme for further promotion.
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SUDAN

<u>Biomethanation in Sudan</u> : by A.A'Halim Elsheikh, Ministry of Energy and Mining, National Energy Administration (NEA), Khartoum, Sudan.

Sudan is among the most important producers of sesame, arabic gum, ground nut and coton. Its animal production is 9 million heads of cows, sheeps and camels. As far as energy is concerned, its forests produce 97% of the energy consumption of the country in the form of fuelwood and charcoal. Oil and gas have been discovered but are not yet exploited. Hydro-electricity is produced from the Nile for the cities. In 1983 the major sector of energy consumption was the household sector.

Agriculture residues and animal dung offer a real potential in biogas production as well as the residues of the 5 sugar industries and the municipal waste waters of Khartoum. The 5 sugar industries produce 400,000 tons of sugar per year together with 1,680,000 tons per year of molasse and bagasse. From a study of the NEA in the private and public sectors it has been deduced that the most attractive biogas utilisations are power generation and charcoal substitution.

In 1977 the German Co-operation Agency (GTZ) built the first digester fed with water-hyacinths from the Nile. In 1983 twelve other units were built mostly of the indian type. The gas produced was to be used in households for cooking and lighting purposes.

Work on the production of biogas from the effluents of ethanol from molass has been confined to preliminary data because of a Governmental Law prohibiting the production of alcohol in Sudan. The sewage waste water treatment plant of Khartoum is to be enlarged by 2 digesters of 1,500m3. The objective is depollution and production of electricity for the national grid.

PRESENTED BY : Mr A' HALIM A. ELSHEIKH
Director
Ministry of Energy & Mining
National Energy Administration,New & Renew. Energy
P.O.BOX 2649
KHARTOUM - SUDAN
TEL : 77209 TX : 215

DESCRIPTION :

Sewage Waste Treatment Project

Biogas production from the sewage sludge of the city of Khartoum. The present treatment consists of a sedimentation, a trickling filtration and a drying in a sludge bed. A prefeasibility study was undertaken by a german consultant (Ingenieurconsult, Hannover) that concludes to the necessity to undertake a detailed study before definite conclusions could be formulated.

LOCATION: Sewage Treatment Plant
Khartoum

ORIGINE OF RESIDUES:

see summary above.

DETAILS:

Khartoum city is highly populated since the last few years mainly because of the draught and the desertification in Western Sudan. Consumption of fuelwood, charcoal and butane gas increases to the extend that the supply of these fuels becomes an unbearable burden to the Nation. The sewage waste disposal is composed of three stations outside the city, constructed in 1961 and now completely outdated and overloaded. Hence the project aims at (i) providing cheap and reliable household energy, (ii) deminishing the environmental pollution and (iii) relieving the country from importing fuel for household purposes.

DIFFICULTIES:

The first difficulty is to finance a comprehensive feasibility study as recommended by the previous german study. An amount equivalent to 65,000 DM is required. The Italian Government has been asked to fund it but without definite reply till now.

STUDY AVAILABLE:

Prefeasibility study undertaken by INGENIEURCONSULT GMBH, Hannover in 1984.

RECOMMENDATIONS:

a) Request for Technical Assistance from UNIDO through UNDP local office outlining the type of assistance required.
b) Submit the investment proposal to the UNIDO Investment Co-operative Programme for further promotion.
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ZIMBABWE

__Status of Development of Biomethanation in Zimbabwe__ :
by C.E. Chimombe, Ministry of Energy, Water Resources and Development, New and Renewable Sources of Energy (NRSE), Harare, Zimbabwe.

Two main programmes have been developed in Zimbabwe. One for the development of biogas in the individual household level, with the implementation of 40 biogas digesters so far and the other for institutional users like schools and rural community centers where 10 digesters have already been built. The funding of the digesters is provided by the users themselves while the Government provides for technical advices.

The villages are not yet convinced that the biogas is the annswer to fuelwood shortage. Thus the time spent in collecting the feed stock for the biogas digester is considered unprofitable. Moreover there exists a problem of biogas storage.

Four projects of biogas development are considered : (i) a biogas promoter funded by UNDP will work in rural areas from village to village to inform leaders and teach the people to build digesters and use biogas; (ii) rural insettlement schemes based on dairy farming are planned to integrate biogas production; (iii) commercial farmers will get technical advices to build biogas digesters for their workers and (iv) finally two industries have been identified as condidates for biomethanation projects. One is a food processing company which produces 36 t/month of coffee bean residues, and the other is a brewery which produces 50 t/month of beer dregs.

PRESENTED BY : Mr CHIVARANGE EPHESUS CHIMOMBE
Deputy Director
Ministry of Energy, Water Resources & Development
New & Renewable Sources of Energy (NRSE)
P.BAG 7758 CAUSEWAY
HARARE - ZIMBABWE
TEL : 707861 TX : 2141

DESCRIPTION :

Biomethanation & Nutrient Recycling from Brewing and Food Processing Wastes

Production of biogas, soil conditioner and animal food out of beer dregs (Chibuku Brewery) and of coffee bean residue (Willard Foods Cy). A prefeasibility study has been done and shows unavailability of adequate equipment in the country.

LOCATION: 1)WILLARDS FOODS PLANT
2)CHIBUKU BREWERY

ORIGINE OF RESIDUES:

1) BEER DREGS : the brewers do not have any use for these and are keen to get rid of them. The residues consists of sorghum, water and alcohol (2,150 tons/y) with a concentration of 11% of dried organic material. They are sold to farmers for Z$2 per 90kg bag (wet mass) to be used as stockfeeds.

2) COFFEE BEAN RESIDUE : the nationwide annual quantity represents 2,150 tons of chopped beans and water with a concentration of 25% of dried organic material. 20% is used for other foods product and the rest is dumped in areas designated by the municipality.

DETAILS:

Both companies indicated a strong willingness to investigate the potential of producing biogas from their wastes to substitute at least some of their fossil fuel needs and squeeze some profit from wastes they are not currently benefiting much from. The problems impeding adoption of biomethanation are (i) ignorance of the potential of the process and its applicability to their particular operations, (ii) economic viability ie: those who are aware of the process may not be sure of its economic viability and the implication of moving away from their traditional fuels and (iii) conservatism : industrialists are cautious about investing in new techniques involving nutrient recycling and need reassurance in the form of other working installations which they can see. In the absence of local examples the problem is unlikely to be solved, except through joint ventures with experienced companies from the developed world.

DIFFICULTIES:

The Ministry wishes to negotiate the following contributions : (i) a joint venture with a foreign partner who could mobilize local engineering capability which is good, (ii) the supply of equipment which, due to foreign exchange constraints, are often difficult in obtaining from abroad and (iii) technology transfer for dissemination to other relevant local concerns.

STUDY AVAILABLE:

A study has been undertaken by the Ministry in 1983 which concluded to the necessity of obtaining the three main contributions mentioned above.

RECOMMENDATIONS:

a) Request for Technical Assistance from UNIDO through UNDP local office outlining the type of assistance required.

b) Submit the investment proposal to the UNIDO Investment Co-operative Programme for further promotion.
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III. SUMMARY OF THE LECTURES

A. Finances

Role and Activity of the Belgian Administration for Development Co-operation (BADC) : Address delivered by Mr. Ch. Winterbeeck, Administrateur Général, at the opening session.

Here follows a summary of this welcoming address.

After introductory welcoming words to the participants, Mr. Winterbeeck explained the reasons why BADC took the initiative to convene an international consultative committee meeting to discuss such a specific field as the biomethanation at a time when fossil fuel is becoming cheap again. They are mainly three : (i) the fact that the energy requirements of mainy Developing Countries will still be very difficult to cover because of their economical situation, (ii) that consequently their dependence on their own non-conventional energy resources will remain as important as before and (iii) that the present favourable situation of the fossil energy on the world market should still be considered as unstable on a long term basis.

It is therefore up to both the Developed and the Developing Countries to examine the problem of energy resources giving them all their necessary importance, and not to slacken the efforts towards the development of new and renewable energy that would guarantee a more balanced use of the biosphere and the preservation of the environment. In this context biomass appears as an energy source largely available in Developing Countries but with unexploited or ill-exploited potentialities at a time when efficient and attractive technologies are more and more feasible if given the right priority in the country development strategy.

Mr. Winterbeeck also gave an overview of BADC's role and activities in the development co-operation. BADC is the one department in the Belgian Ministry for Foreign Affairs - out of three departments - that is responsible for the public co-operation with Developing Countries. The two other departments are : the department for foreign affairs as such and the department for foreign trade.

In the field of anaerobic digestion BADC is presently undertaking two main projects : one in Burundi with the University of Louvain-La-Neuve and another in Indonesia with the University of Ghent. It also co-finances punctual initiatives of Non-governmental Organisations and is finalizing the negotiations for the belgian contribution to the World Bank Energy System Management Assistance Programme (better known as the ESMAP). Furthermore Belgium is preparing a co-operation programme jointly with the World Bank to promote the biomethanation of the organic domestic refuse.

In addition to the standard means of co-operation like training, fellowships, belgian experts, feasibilty studies, donation of equipment and materials, etc... BADC has been recently given two new instruments of co-operation namely : the Fund for Loan to Foreign Countries and the Fund for Development Co-operation. Thanks to these new instruments BADC is now in a position to assist by offering concessional loans, by participating in the equity of state-owned companies and by granting credit line to National Development Banks.

Mr. Winterbeeck ended his address by expressing the interest of both the State Secretary for Development Co-operation and himself in the works of the Consultative Committee Meeting as well as their will to base BADC's future action in the field of new and renewable energy, on the conclusions of the Meeting.

Financing and Co-financing Techniques : Lecture given by the Hon. Ambassador J.F.M. Hendrickx, Vice President International Relations, Arthur Young International Europe, Brussels, Belgium.

Here follows a summary of this lecture.

The lecture reviews broad historical issues concerning the factors that generally favoured the investments in both the developing countries - at the time when they were still ruled by westerner countries - and in Belgium during the 20th century. The arguments put forward are (i) that, in both cases, investments were more abundant and fruitful than they are nowadays in the developing countries and (ii) that the reason thereof basically lies on the favourable conditions that prevailed at the time to encourage risk-investments. These favourable conditions are then analyzed by the lecturer : a sound financial and economic management of the countries, inflation kept as low as possible, an adequate balance between external debt and gross national product, political stability, free trade policy and fiscal incentives.

Next it is argued that, if finance for development projects is seeked by the developing countries from the industrialized countries, then (i) it would mainly come from the private sector which is the most important source of capital in the western world and (ii) it will be made available only if the project is feasible and the local context is attractive to private capital.

If these conditions are not met the only possible alternative is the recourse to international devlopment multilateral agencies assistance.

Some of the new tools to help developing countries, designed by the World Bank, the IFC, and other similar agencies are subsequently discussed.

Counter-trading Techniques : Lecture given by Prof. J. Nagels, Free University of Brussels, Managing Director of Tracosa SA, Brussels, Belgium.

This lecture on the subject of countertrade (CT) consists of three parts.

The first one is devoted to the conditioning factors of CT. What are the economic, politic and social needs that CT tends to meet ? Why did CT make new strides since the last ten years ? Answers to these questions are given by the analysis of five main functions that are today served by CT.

In a second part the international environmental factors that favour the recourse to CT are briefly described.

Finally in the third part, a concise description of some basic CT techniques are given.

Main functions of CT

The five main functions of CT may be summarized as follows :

* make trade possible where and when prevailing conditions are such that, without CT, the purchase and sale of goods and/or services would just be impossible, constitutes a first function of the CT. To consider the problem in terms of "bad trade versus good trade" - the latter being brought by natural market-forces - is not often relevant. Indeed the alternative is not so much that one than the alternative between the so-called "bad trade" and no trade at all.

* a second function is the regulation of international trade. Through CT, indeed, zones of international trade tend to protect themselves against the squalls of an instable international environment. This securing function that allows to maintain international trade, is of the same nature as the one served by monetary and customs unions. Does the European Monetary System not constitute a relatively more stable zone in a world of fluctuating exchange rates ? Similarly private or public clearings serve the same purpose at the commercial level.

* a third function rests in the inability of certain countries to organize themselves the international marketing efforts in order to sell off their goods on the world market. Hence they base themselves on the experience of western companies to open up new channels for trade.

* a fourth function concerns the further elaboration of the international labour division in the micro-economic field. It could only be realized when the development gap between two traders is not too important. It implies a relative steadiness of inter-enterprise flow of business that could emerge then to complementarities, transfer of technology and know-how, industrial co-operation ...., in short, to a more elaborated international labour division.

* finally, the fifth function is related to the overstepping of bilateralism through monetarized barter techniques. Clearing agreements, indeed, which are numerous between East-countries and other countries as well as between South-countries, tend to achieve an impossible target i.e. the strict balance between import and export of the partners at the end of the clearing periode. Obviously the switch-dealers are able to bring a solution to this kind of problems. They transform bilateralism into multilateralism and so serve the targets of all parties concerned. In the same order of ideas CT allows to get round both the archaic and new forms of protectionism. In this latter case certainly, CT does serve the purpose of free trade.

<u>International environment</u>

These five functions could be totally or partially served without CT.

Nevertheless certain characteristics of the world market (price instability, fluctuating exchange rates, ...), economic maladjustments of socialist or developing countries (deficit of the current trade balance, external debt,...) and endemic disturbances in certain industrial sectors in the western countries (production overcapacity, weak profitability, ...) obviously constitute conditions which favour the recourse to CT.

<u>Some basic CT techniques</u>

The odds are certainly against to describing in details all possible CT techniques which are numerous and sometimes very sophisticated. Here follows a short description of the four basic CT techniques.

1. The monetarized barter

The conventional definition considers the barter as a trade of goods without money. It can be represented by the following formula :

$$q_1 \times M_1 = q_2 \times M_2$$

where q represents the quantities of goods and M the kinds of goods that are traded.

In this case there is no unit price for M_1 and M_2 and no necessity to finance the trade. It implies the simultaneity of the exchanges. When the simulataneity is not realized - which is a common situation - there is always a reference made to a monetarized global value of the barter. This is the reason why it is more correct to speak of a monetarized barter.

2. The compensation

Compensation always implies that there is only one contract between the western seller - of trucks for instance - and the purchaser of the South who is simultaneously selling compensated goods. Credit-insurance institutions (like the Office National du Ducroire in Belgium) never accept to cover such kind of transactions for they do want that the two parts of it be separated and covered by separate contracts.

Two types of situation exist.

The exporter from the North - selling trucks for instance - could be simultaneously purchaser of goods - for instance tyres - proposed by the partner from the South. In this case the payment of the transaction is done through the exchange of the goods (trucks and tyres). If the exchanges are not simultaneous it is necessary to agree upon short term financing conditions.

When the exporter of the trucks is not a purchaser of the goods offered by the South (coton for instance) then the trucks are still paid for with goods (coton) but through the instrumentality of a purchaser of the coton in the North who must be accepted by the partner from the South. The purchaser of coton cannot be a dealer but should be the end-user. The exporter of trucks and the importer of coton agree upon a "transfer clause" stipulating that the hard currency used to pay off the coton will serve to pay for the supply of the trucks.

3. The counter-purchases

Counter-purchases imply that two juridically separated contracts exist i.e. : one export contract and one import contract for the compensated goods. The export contract contains no reference at all to the purchase of the compensated goods not even in its annexes. It has its own life of export contract in all what concerns financing conditions, penalties, performances, insurance-credit, etc... This is a "sine qua non conditio" if one wants to comply with the requirements of the insurance-credit institutions. The implementation of the export contract is not at all affected by any possible misadventure occuring with the import contract (or counter-purchase contract).

On the contrary the counter-purchase contract always refers to the main contract (the export contract). It stipulates the rate of compensation, the kinds of goods selected for compensation, the penalty - covered by a bank guarantee - in case of not compliance with the counter-purchase commitments and finally, its duration (generally equal to the total duration of the main contract including the finance period).

4. The linked deals (or linkage deal)

The principle of a linkage deal is very simple : to buy first in order to sell later. The westerner exporter makes sure, in a way of an other, that his purchases in the country of the South or the East be recorded as valid to cover his future export in the same country. So, if everything goes according to the agreement, either his previous purchases will be credited as completed counter-purchases or he will be paid in hard currency.

This technique often uses the escrow-account.

An escrow-account, also named "trustee-account" or "special-account", is only a financial technique that allows to realize a linkage deal with countries from the South or the East.

The mechanism is as follws : there is an agreement between the exporters of a country of the South (bananas, coffee, manioc, coton, etc....) and their official monetary authorities that the payment of their exports be, up to a specific amount, credited in a bank-account with a foreign banker (generally in London or Singapore). This account is the escrow-account.

The monetary authorities of the country of the South and the exporter - of trucks for instance - from the North have previously agreed upon the escrow-banker and, in certain cases, upon the repartition of the interests accrued on the escrow-account. As soon as this account has been credited with the sum of say one million dollars - the selling price of the fleet of trucks - the exporter who has also made sure that this money be commited only to the payment of his supply, proceeds to the supply of the trucks.

This technique comprises the risk that an other creditor of the country from the South distrains the money credited on the escrow-account. Although its existence is always kept confidential by all parties concerned, such a distraint is still possible and very much depends on the local legislation of the escrow-banker.

B. Technology

Potential for Biomethanation of Solid Wastes in Developing Countries : Lecture given by S. Deboosere, Laboratory of Microbial Ecology, Rijksuniversiteit van Gent, Ghent, Belgium.

Cities of Developing Countries like Bangkok or Jakarta for instance, produce around 5,000 tons of municipal wastes per day. The organic matter content and the humidity of these wastes are higher than in the industrial countries. The treatments used are : dumping in the open, incineration at high costs and low caloric value, aerobic composting which fairly suits dry climate and anaerobic digestion. In this latter case 1 ton of the organic fraction of the waste produces 180 m3 of biogas.

The available technologies for the anaerobic digestion of municipal wastes are (i) the conventional completely mixed digestion that converts a waste problem into a water problem by using 10 tons of water for 1 ton of waste, (ii) the two phases digestion; (iii) the dry digestion either in landfills where it is spontaneous and lasts 20 to 50 years before complete recovery, or in semi-continuous digestion where biogas is recovered in 3 weeks.

At present there exists two examples of dry digestion of municipal waste : one in France where a 400 m3 digester works with a 35% dry matter substrate and produces 5 m3 of biogas per m3 of digester and per day, and another in Ghent, Belgium, where a pilot plant of 56 m3 produces 6 m3 of biogas per m3 digester and per day, using also the organic fraction of municipal waste at 35% dry matter. The temperature of the digester is 55°C. The gas produced is burned in an electric generator that produces electricity for the sorting out of the wastes and heat to maintain the temperature in the reactor and dry the effluent into a 80% dry matter compost.

Two full scale plants of this last design are under construction : one in Belgium and another in the Netherlands. Experiences on dry biomethanation of market waste and non-hazardous industrial waste already exist in Indonesia.

A New Process for Advanced Treatment of Waste Waters : Lecture given by L. Vriens, Artois Engineering SA, Leuven, Belgium.

The characteristics of the Artois Brewery wastewater treatment are (i) the construction of a compact rectangular tank divided into compartments having defined functions and allowing substantial reduction in capital and operation cost; (ii) the number of compartments and (iii) the design that allows better process performances thanks to a two-stage treatment system and a possibility of two reverse hydraulic flow directions.

The three stage anaerobic-aerobic unitank system with biological nitrogen removal (3SU-N-System) is an example of such treatment plant. It combines a biological conditioning tank for buffering, presedimentation, hydrolysis and acidification (3 compartments) with a hybrid methane reactor combining the upflow process and the anaerobic contact process (2 compartments) and with a low-rate oxidation stage for biological nitrogen removal (5 compartments). The efficiency of the system is a BOD removal of 98% and a nitrogen removal of 90%.

Technologies Competing with Biomethanation : Lecture given by H.A. Masson, Institut National des Industries Extractives (INIEX), Liege, Belgium.

Four topics have been discussed by Mr. Masson namely (i) the assessment of the appropriateness of new and renewable energy technology to Developing Countries, (ii) an overview of the technologies competing with biomethanation, (iii) global efficiency of biomass and (iv) some indications about the problematics of aquatic energy crop.

(i) The appropriateness of a particular new and renewable energy technology to Developing Countries is based on four main criteria i.e. : the raw material serving as energy resource, the energy distribution and the impact the technology may have on both the economical and social environment.

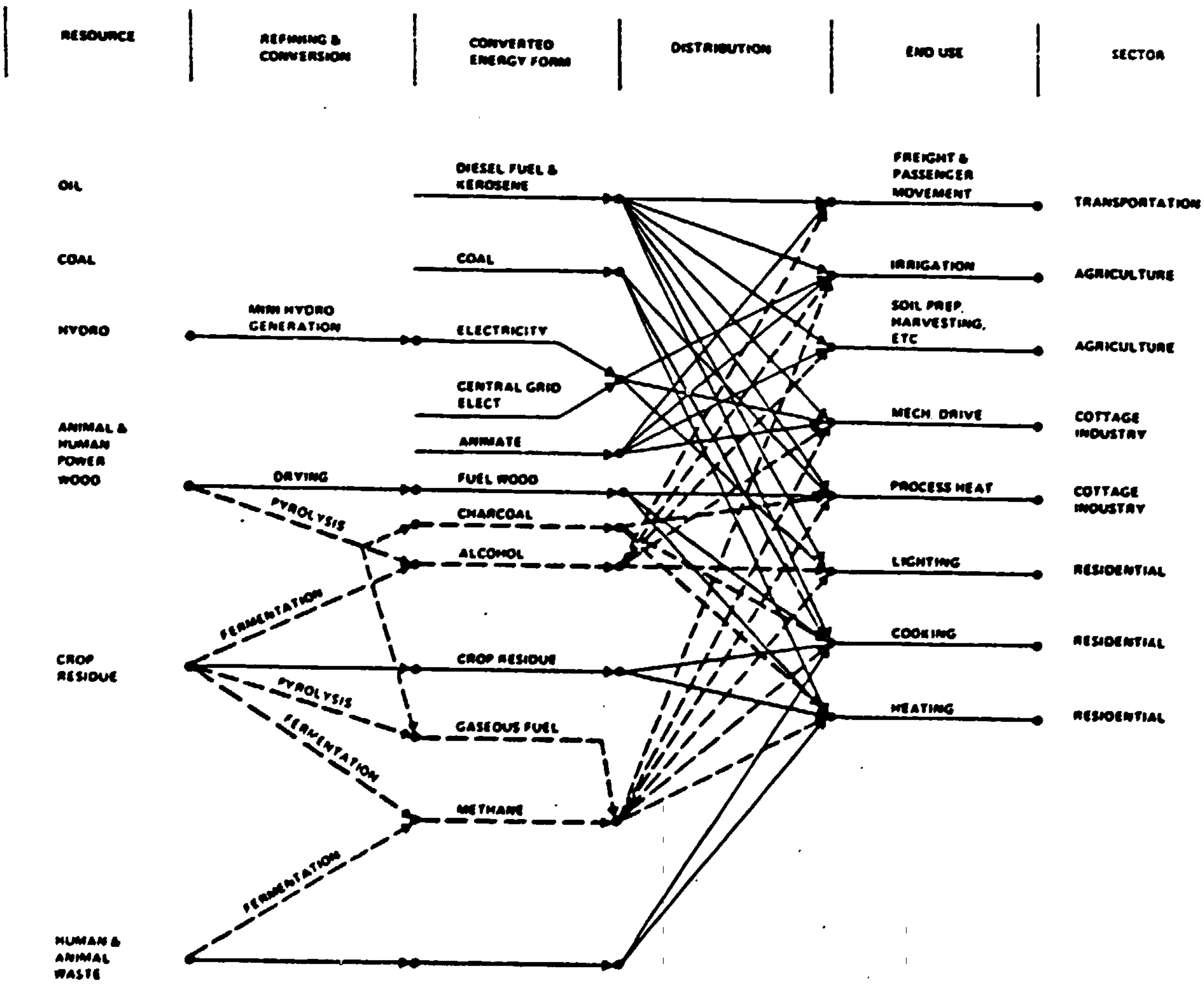
Eight basic energy resources are considered i.e. : oil, coal, hydraulic power, animal & human power, wood, crop residue, human & animal waste and energy crop. Now new and renewable energy technologies mainly concern four of these basic resources : wood, residue, waste and crop energy. Because generally food self-sufficiency is the most important challenge faced by Developing Countries, technologies based on crop energy may constitute a draw-back in terms of land resources allocation while, if based on crop residue or on human & animal waste, they constitute a net additional energy resource. Hence a technology that utilizes residue and waste - which is generally the case for biomethanation - is judged as being more appropriate to Developing Countries than other technologies (energy crop is being further discussed in the last part of the lecture).

The energy distribution aspect is also important when assessing the appropriateness of a technology. Many Developing Countries, indeed, do not have adequate transportation infrastructure and therefore the energy produced should as much as possible be used locally. This speaks in favour of small scale decentralized production units - which is also favourable to biomethanation.

Finally as far as the social and economical impacts of a technology are concerned the less the social environment and the country's import bill are affected the more appropriate is the technology.

(ii) The competitiveness of the biomethanation technology is illustrated by the figure below. It shows various basic energy resources with their corresponding refining & conversion processes and their converted energy forms on the one side and the potential end uses on the other side. Arrows are linking converted energy forms with their corresponding possible end uses. As it can be seen methane is one of the energy forms that allows the greatest number of possible end uses and therefore the competitiveness of biomethanation, measured in number of possible end uses, appears to be the best.

NB. The figure does not show a link between methane and transportation although many participants indicated that methane is being used as truck-fuel in several countries and particularly in Brazil.

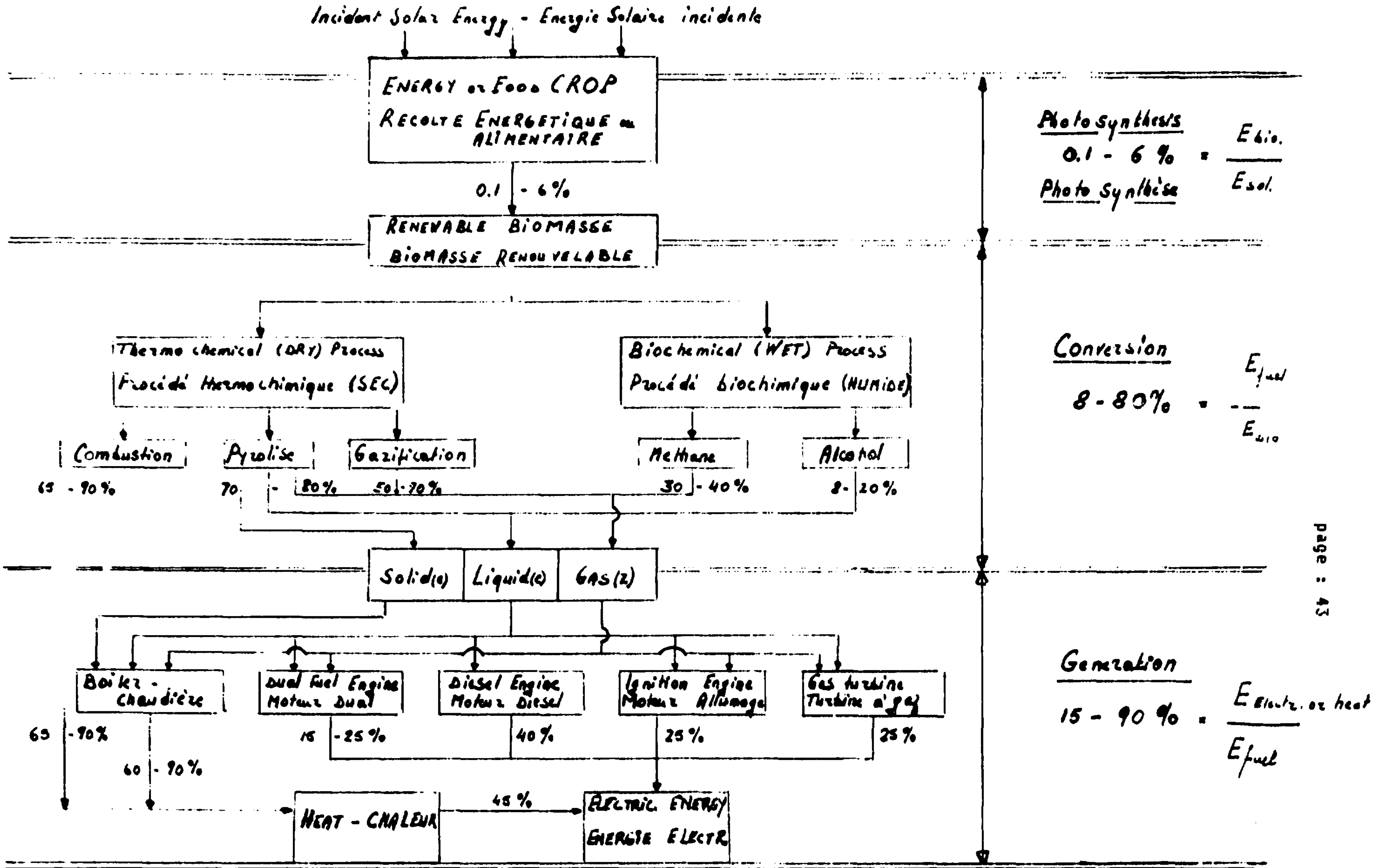


(iii) What is the global efficiency of the biomass ? In other words what is the amount of energy one can get out of it compared to what it contains ? This greatly depends on the refining & conversion process as it can be seen on the figure on the next page. The most efficient way to recuperate the energy accumulated in the biomass by photosynthesis is the combustion : out of 1 kJ one can recover up to 0.9 kJ in the form of heat. Biomethanation in this respect is certainly not the most favourable conversion process : its efficiency ranges from 30 to 40% but is still higher than alcohol fermentation.

(iv) At the beginning of the lecture, energy crop has been judged as generally inappropriate for Developing Countries mainly because of the land resources and of the human labour it requires and which are generally thought to be better utilized if used to develop food crop instead.

Now - as some of the participants confirmed it - there are circumstances when energy crop does not compete with food crop. This is the case of aquatic energy crop: many countries, indeed, enjoy quite large surfaces of water (lake, sea, lagoon...) that could be used for aquatic energy crop without too much difficulty and, in fact, both the Developed (EEC and USA) and Developing Countries (Guyana, Philippines and Thailand) are promoting research and development in this field.

RENDEMENT GLOBAL DE LA BIOMASSE RENOUVELABLE.



C. Transfer of Technology

Transfer of Technology and Development : Lecture given by Ph. D. Grosjean, Executive Director, Transtec SA, Brussels, Belgium.

Transfer of Technology is, since many years, one of the main topics discussed in national and international conferences dealing with development and cooperation between countries and particularly in the frame work of the North-South relations.

It is considered as one of the main factors to design strategy-planning and achieve better results in the development of national economies and I think that it is correct.

I am, indeed, a great believer that today world progress and development necessitate that one shares know-how as much as bread, food, the staff of life.This approach does not kill the goose that lays the golden eggs ! On the contrary, this is an investment advantageous to everyone's future.

This being recognized by almost everyone, one has also to recognized that conflictual interests and attitudes exist as to how technology transfer must be carried-out, remunerated, evaluated and what it implies for all parties concerned.

This is the reason why I propose to speak about the following topics:

. firstly, the words "technology" and "transfer" have not a common meaning for everybody and I think it important that we agree on their definition. This is done in a first part.

. secondly, I will analyse two of the main characteristics of the transfer of technology, derived from the proposed definitions, and

. thirdly, I will draw some conclusions on what should be undertaken to ease the implementation of transfers.

1. Definitions

Many different words are used when dealing with transfer of technology : KNOW-HOW, KNOWLEDGE, TECHNOLOGY,SCIENCE, etc.... and they lead to misunderstanding for, in fact, they do not cover the same concepts.

My Oxford Dictionary defines TECHNOLOGY as the science of the industrial arts. This is not correct, I believe, for it induces a confusion between SCIENCE and TECHNOLOGY which are different. In fact, although they both represent a systematically formulated volume of knowledge, TECHNOLOGY is oriented towards the production of something (goods, services, richness) while SCIENCE is not, at least not directly.

Professor John H. DUNNING, from the University of READING, Great Britain, proposes the following definition for technology: ALL FORMS OF KNOWLEDGE WHICH MAY AFFECT THE PRODUCTION FUNCTIONS OF A USER indicating that what is essential in the technology is its purpose to produce. The link between technology ant its implication of production is so strong and deep that some other authors prefer to complement the definition by including the material tools that are necessary to produce. They suggest that the definition be: ALL FORMS OF KNOWLEDGE AND SET OF TOOLS WHICH MAY AFFECT THE PRODUCTION FUNCTIONS OF A USER.

Although I am more in favour of a definition that differentiates what is material from what is not, this last definition stresses on the very strong link existing between technology and its tools. Indeed, technology without the tools is as useless as the tools without technology.

Besides the word "production" contained in the above definition one must also emphasize the words "all forms of knowledge" and "user".

"All forms of knowledge" means not only technical or process knowledge but also behavioural knowledge, managerial, organizational and other kinds of knowledge which are necessary to master the various factors affecting the capacity to produce. Usually technology is split up into three main components (i) the knowledge related to the manufacturing functions, (ii) the knowledge related to the product development functions (i.e. the product design and engineering) and (iii) the knowledge related to the management functions (i.e. the wielding of the required resources to achieve profitability).

Furthermore the word "user" should not be restricted to an individual person. It could be a user-firm, a corporation, an organization i.e.: a community of people having different role to play to realize their firm's production function in a given socio-economic environment.

Hence "all the forms of knowledge" also consists of the various knowledges on how to make people working with efficiency and effectiveness. It covers maintenance of equipment, logistic and procurement, accounting techniques, management and organization, marketing and commercialization, etc....

The reason why I very much insist on the broad meaning of technology, is that one shoud properly understand and apprehend the exact nature of what is to be transfered and therefrom of the difficulty encountered when doing it.

Let us come now to consider the TRANSFER of technology.

Once again I do not consider that TRANSFER is the proper word to define what is intended by it.

Transfering something, indeed, means that it is physically removed from one place to another and that nothing is left in the original place. The same applies when transfering a property : against a compensation of whatever kind, somebody accepts to abandon his property in the hands of somebody else; the property is removed from somebody'hands to other hands.

This is not true when transfering "knowledge" : the donor-party or the seller of a knowledge is not left ignorant after he transfered it to the receiver-party. He may have abandonned certain rights attached to the tranfered knowledge but he stil has the actual possibility to use it to the detriment of, or in competition with the receiver-party. This is an important characteristic of the transfer of technology as we will see.

I think that "dissemination" or "share" of knowledge are better words for what is actually realized - or intended - is the sowing of knowledge, the scattering of it in somebody else's brain for purpose of growth.

This is a crucial remark indeed.

In fact no education, no dissemination of knowledge could be realized without somme sort of "suicidal" consequence for the educator, the consequence being that the student eventually becomes as good as or even better than the teacher! This has always been experienced by parents and educators.

Moreover the success of the education greatly depends on how the educator reacts to this consequence. If he refuses that his student becomes better than him, he will try to dominate by pretending the student is never to acquire his own capability and sometimes even by refraining him from showing any initiative and independence. This usually leads to conflict!

On the contrary, if the educator is prepared to seeing his student becoming as good as or even better than him, he will let the seed grow and gradually adapt his role on the stage to permit the new actor to play his own.

As we will see it later, this remark is very important to understand problems arising in transfer of technology.

Let's summarize this first part related to the definition of the transfer of technology as follows:

. it is a dissemination rather than a transfer;
. it covers immaterial assets necessary to develop the production capacity of the user;
. it contains a suicidal consequence for the giver who, on the other side, is not left without noting after the transfer.

2. Characteristics of the transfer of technology

Let us now analyse the characteristics of the transfer of technology as we can derive them from the above definition.

Let's start first with the suicidal consequence.

As explained above it is an essential component of any educational process. In the economical context existing between two partners envisaging to realize a transfer of technology, it is associated with a process of deterioration/ennoblement of assets. Let's explain this.

Technology, as we have seen it, is an asset. Indeed it reoresents an accumulation of knowledge for the acquisition of which resources have been allocated in the past by the technology-holder.

Now this asset, for most of its parts, is not displayed on a company balance sheet because it is essentially embodied in the company's personnel capability and such kind of immaterial asset, indeed, - except if displayed in the form of a good will purchased from another company - is usually not recorded in a company's book-keeoing.

Hence the sale of technology must be considered, from the seller's point of view, as a transformation of "grey-cell" asset into "money-asset" (displayeo as a circulating asset in the book-keeping) while from the purchaser's point of view it is the opposite transformation of "money-asset" into a "gey-cell" asset.

On the balance-sheet of both the seller and the purchaser the transaction will induce a variation of the circulating assets while nothing will display the variation of "grey-cell" assets!.

Meanwhile the technology being disseminated the technology-purchaser is now in a position to compete with the seller and reduce his market position. Consequently to maintain his growth and keep staying into the market competition, the seller has to reinvest the new circulating assets acquired in order to develop new technologies of his own.

In fact this is a process quite similar to the degradation of energy into heat.

The heat, indeed, is a degraded form of energy for it may not be totally recovered unless a new source of energy is also consumed; and so the "money-asset" is a degraded form of "grey-cells" asset for it may not be reinvested unless more "grey-cell" asset is also consumed.

This process of degradation/ennoblement of assets when transfering technologies is fundamental. It should be properly identified and apprehended by both parties of a transfer; if not, it will worsen the conflictual situation already existing in any educational process as described above.

A second important characteristic of a transfer of technology is its immateriality.

We have just seen that the transfer of technology contains possible suicidal consequences and conflictual interests.

We will see now that the realization of a transfer presents other kinds of difficulties because of its immateriality.

To illustrate this let's envisage the conditions of an industrial development project carried out under the terms of a turn-key contract or of a product-in-hand or, even, of a market-in-hand contract.

Usually the parties of such a development contract have a completely different understanding of the objective of the contract and hence, a different intrepretation of its scope.

What the client (or the receiving partner) wants to acquire through the signature of an industrial development contract consists of both the material and immaterial components necessary to achieve mastery in a specific industrial field. As far as the immaterial part is concerned i.e.:the technology,(all forms of knowledge which may affect his production function), it is perceived by him as something which could be "sliced-out" from somebody else experience and transfered as a commercial good. It is named TRAINING in the contract and its meaning covers whatever might be necessary to make the client's personnel capable of performing their future jobs. Furthermore being considered as something transferable, the training is also considered as being measurable quantitatively and qualitatively, and hence, subject to the demonstration of its performance.

The opposite party, on the contrary, claims that training, being something immaterial and not measurable either quantitatively or qualitatively, it is not possible to demonstrate anything which might give an idea of its performance. This is the well known controversy on the responsability of the supplier of training services as to whether it represents a commitment to achieve a result i.e.the effective mastery by the client of the technology, or only to provide adequate and appropriate means of training.

In this controversy - as it is usually - both positions are extreme and the only way to reconciliate them is to clearly define everybody's responsability and role in the process of transfer as well as to identify, amongst the various tasks of the training programme, what is demonstrable and what is not.

3.Conclusions

There are mainly three conclusions.

The first one is related to the deterioration /ennobblement process existing in any transfer of technology.

No transfer of technology should be undertaken unless accompanied by the reinvestment of its money-compensation, into new research and development. Technology transfer, indeed, should not be considered as a today fashionable lucrative business but should be incorporated within an overall strategy of growth for the receiver and the giver. If one does not consider this ineluctable necessity, the effect of the transfer will be the accumulation of money-assets in the country of the technology-giver and the increase of competition on the world market. One shoulo better look at both parties long term interest by considering the effect on the world market of the newly created production capacities and reorienting his own strategy accordingly.

One should also - but this more on a long term basis - find new means to evaluate the immaterial assets of a corporation, to display them on its balance-sheet and to calculate their depreciation.

The second conclusion deals with the identification of everybody's role and responsability in a technology-transfer process.

It is obvious, indeed, that no party of this process could deny his responsability in its implementation. The problem is the identification of everyone's responsability.

The receiving party should remain responsible for any factor that deals with the management and the motivation of his personnel, the selection of the fundamental choices related to his strategy and development within the local environment, the basic organization principles, etc...These factors, indeed, are not controlled by the giver and they are likely to greatly affect the performance of a training programme.

On the other hand, the giving-party has the crucial responsability to provide adequate and appropriate training as agreed upon in the contract and this introduces the third conclusion.

The third conclusion, indeed, is related to the difficulty to apprehend an immaterial liability like the transfer of knowledge and to demonstrate its performance.

This covers to main issues:

. unbiaised quantitative and qualitative criteria should be elaborated and recognized to evaluate the results of training programmes. One of the best ways to explore in this direction, probably lies in a more sytematic use of computer-assisted training courses.

. it is essential that both the objective and the scope of a technology transfer be precisely define and formulated. It requires appropriate specification of what is going to be sold by one party and purchased by the other. As the usual international contracting techniques (e.g. the FIDIC standard contract) are not adapted yet to accomodate a combination of material and immaterial liabilities, it is strongly suggested that new contracting techniques be formulated in a way that permits different types of liabilities to properly dovetail into each others.

D. Economy

The Economic Costs and Benefits of Biogas Projects in Developing Countries : Lecture given by Prof. R. Renard, Universitaire Faculteit Sint Ignacius, Antwerp, Belgium.

Cost-benefit analysis is a technique for assessing the profitability of an economic activity. It consists of five distinct logical steps. (1) The alternative courses of action which are open to the decision maker are listed. Typically one wishes to compare a number of mutually exclusive variants. If only one activity is being studied the default alternative is to do nothing, i.e. to leave factors of production and other inputs in their best feasible alternative use. It is desirable to study as many alternatives as possible, but this could be very costly, and usually analysts settle for one or two alternatives.

The importance of this may be illustrated with a discussion among Indian specialists on the profitability of biogas. In one study, one particular type of family size biogas digester was found to be profitable when compared to the alternative of 'doing nothing', i.e. continuing the prevailing practices of energy use such as using cow dung as a cooking fuel. In a subsequent study it was claimed however that such digesters were less interesting than the combination of improved composting of organic wastes and the extra supply of coal to rural areas(1). To give another example, rural biogas projects set up to save on fuelwood derive much of their usefulness from the fact that they help to diminish the huge economic costs of excessive deforestation. However, an even more attractive alternative may be to plant fast-growing fuelwood trees near the villages.

(2) Costs and benefits are identified for every alternative under scrutiny. This step consists of listing the relevant costs and benefits. In the main this is a straightforward exercise, but it nevertheless requires careful thought. For instance, at first sight the benefit of producing biogas seem to be the value

of the gas itself. However more often than not biogas substitutes for other energy sources, so that its benefit may be the saving of foreign exchange (in case it substitutes for imported oil) or increased agricultural production (in case it substitutes for fuelwood the gathering of which leads to a degree of deforestation which negatively affects the agricultural capacity of the land).

(3) Costs and benefits are measured. This is done in monetary terms. The choice of money as the 'measuring rod' is a major strength but also a weakness of CBA. It allows all costs and benefits to be expressed in comensurate terms and forces the analyst to be as precise as possible. In addition many costs and benefits are 'naturally' given in money terms. Yet this is not always the case. How for instance are we to assess the health benefits which some biogas projects have? Economists have tried their best in such cases, but the end result is not always convincing. In some instances it has led to important costs or benefits being overlooked.

(4) Costs and benefits are weighted so as to make them collapse into a single figure of project worth. At first sight it may seem that all we have to do here is to add up all costs and benefits as they are already expressed in monetary terms in the previous step. Additional weighting is nevertheless deemed necessary because costs and benefits may accrue to different people and at different moments in time. And it is far from evident that a benefit of 100 pesos accruing to a rich person is 'worth' the same as a benefit of 100 pesos accruing to a poor person, just as it is not evident that a benefit of 100 pesos accruing now is 'worth' the same as 100 pesos accruing in 20 years time. Technically, intertemporal weighting is performed through the application of a discount rate, interpersonal weighting through the application of distributional parameters.

The following table indicates how much 100 pesos is worth in the future under different discount rates. The formula is

$D=(1+i)^{-t}$.

i (rate of discount)	t (in years)				
	5	10	20	50	100
5	78	61	38	9	1
10	62	39	15	1	-
15	50	25	6	-	-

("-": less than one tenth of a peso).

Discounting makes us see the future on a diminished scale. Costs and benefits occurring after, say, one hundred years must be extremely large to make a difference to the result of CBA. The problem which many critics see in this is that in certain fields such as energy important long term effects occur. Are we justified in ignoring them?

Discounting is performed for one of three reasons: because of pure shortsightedness ('myopia'), because future generations will be better off, or because of the scarcity of investment funds. Economists do not fully agree on which one to use. We cannot go into this discussion here in any detail, but it may be good to give some idea about the essence of the disagreement. First, environmentalists claim that there is no moral justification for pure myopia. Many economists sympathize with this view. Yet they stress that many actual decisions which have long term consequences such as the construction of nuclear plants or the rate of depletion of minerals can only be explained by assigning pure myopia to decision makers. The question then is whose preferences the economist must follow in performing his analysis. We come to this in the next section.

Second, it is consistent to apply a discount rate to the future on equity grounds if we are convinced that future generations will have higher standards of living than the present one, and if we also discriminate in CBA among contemporaries according to their income level. Economists have deviced formulas which make sure that an identical 'distribution bias' is used in both cases. It is not evident however that we can just apply this to any type of cost. Problems will typically arise when we are dealing with irrepairable damage to our planet. Can we leave future generations with a punctured ozon layer just because they will have a higher level of GNP per capita? And can we on the same basis justify that a whole series of wildlife species will have disappeared by then? Many people's answer will be no, but this is a moral position on which no consensus need exist in society.

Thirdly, the discount rate is sometimes used to express the opportunity cost of capital. If capital can earn 10% elsewhere in the economy, discounting at 10% ensures that the project will only be profitable if it earns more than 10%. An opportunity cost discount rate is usually higher, often two to three times as high, compared to an intergenerational distribution discount rate. The opportunity cost of capital is indeed an important consideration. However it can be brought in into CBA in two different ways which lead to the same due attention to the scarcity of capital. One is, as indicated, as a discount rate. The major disadvantage is that it does not allow an independent intergenerational discounting to be performed on equity grounds. The other way of bringing in the opportunity costs of capital, under the form of a shadow price of investment, is therefore superior.

(5) Formal investment criteria are applied for accepting or rejecting projects. Different valid investment criteria exist. They are all equivalent to simple NET PRESENT VALUE (NPV) rules. The NPV of a project is obtained by adding up all costs and benefits suitably weighted for interpersonal and intertemporal considerations. Future costs and benefits are thereby expressed in their present equivalent. Projects are acceptable if they have a positive NPV. Among competing projects, choose the one with the highest NPV. When facing a budget constraint for projects

which are not mutually exclusive, rank them by their NPV to budget cost ratio (NPV per unit of the budget), and go down the list accepting projects until the budget is exhausted.

SECTION 2: Further concepts of Cost-Benefit Analysis

CBA has basically two applications in economics. On the one hand it may be used to predict the actual behaviour of economic agents. This is the positive side of CBA. On the other hand it may be used to prescribe behaviour. This is the normative side of CBA.

Economics studies human behaviour under the assumption of individual rationality. This does not mean that economic agents are omniscient. Nor is it denied that they may be risk averse or that they are imbued with the cultural values of their particular society. It only means that agents, after assessing subjectively the pros and cons of alternative actions open to them will, on the basis of available information, choose the action which promises the highest excess of benefits over costs.

CBA is nothing else but a formalized way of representing such rational choice. If we have correctly modeled the environment and the objectives of the typical economic agent, and if the underlying assumption of 'rationality' is verified, we should be able to predict his or her actual behaviour. Looked at in this way, CBA may help us to answer such questions as what explains the uneven success of agro-industrial biogas installations in developed countries, why family-size biogas digesters seem to have been a far greater success in China than in India, or why governments everywhere do not invest more in the development of renewable energy sources. Once we have reached this position, we can go one step further and answer 'what if' type of questions: how will economic agents react to an increase in a subsidy, or to decrease in the price of the substituted energy source, etc.

Normative CBA on the other hand tells the economic agent typically a government, what to do. This exists in two versions. CBA may be based on the government's own preferences. The result of a cost-benefit exercise tells the government what it must do to be consistent with stated policy objectives. Alternatively, CBA may be based on some other set of objectives, e.g. those of the economist performing the analysis, or the preferences of the public as revealed in its market choices. Needless to say, the outcome of a cost-benefit exercise may depend crucially on which set of objectives is retained. Environmentalists would for instance include all the long term effects of air pollution, whereas many governments happily discount them into oblivion.

Apart from the distribution between positive and normative economics it is useful to introduce one further definition. CBA can be applied at two levels that differ from one another in their scope: financial CBA and economic CBA. In financial CBA the unit under scrutinity is a single economic agent: a farmer, an agro-industrial firm, a municipal sewage authority, and so on. The label financial refers to the fact that money is the measuring rod in CBA, as explained earlier, and should not be understood to mean that only financial receipts and outlays are to be considered.

In economic CBA the point of view is that of the country, or rather the totality of individuals inhabiting it(2). Economic CBA can be imagined as the sum of the financial CBA of all individuals. It would obviously be impractical to actually perform economic CBA in this roundabout way. Instead economic CBA is calculated directly. The trick is to use fictive prices rather than the real prices facing the economic agent used in financial CBA. The purpose of those fictive prices, called accounting or shadow prices, is to capture the economy-wide repercussions associated with the project's use of inputs or its provision of outputs. Major shadow prices include the shadow wage rate, the shadow exchange rate, the social discount rate, and the shadow price of investment.

To summarize, we have considered a double distinction in CBA: positive versus normative, and financial versus economic. By combining those, we have four types of CBA. In the rest of this paper we will be mainly interested in normative economic CBA, and to a lesser extent in its relation to positive financial CBA. This is illustrated in the following diagram.

	positive CBA	normative CBA
financial CBA	X	
economic CBA		X

When performing economic CBA from a normative point of view two difficult weighting problems arise, which are absent from financial CBA. In the latter case interpersonal weighting does not arise, as we are by definition dealing with only one economic agent. Also the relevant discount rate in this case is normally the market rate of interest facing the economic agent. In economic CBA things are not so straightforward. To arrive at a single figure of project worth we must weigh the gains and losses of many individuals. There is not objective way of doing this. What is required here is an ethical choice. Similarly discounting now essentially becomes an issue of intergenerational equity in which the costs and benefits to future generations are weighted against those of the present, as explained above. All this raises fundamental ethical questions.

There is an interesting link between normative economic CBA and positive financial CBA. In an economy with decentralized decision making by firms and households we require a mechanism whereby decisions by the private sector can be brought in line with the societal objectives set by the public authorities. That is, we would like private agents, while seeking their own advantage, to do what is good for society at large. Sometimes market forces will bring this about by themselves. It has for instance been calculated that in the period 1973-1984 energy consumption per unit of Gross National Product (GNP) has fallen by 1/5 in developed countries, oil consumption by 1/3[3]. This has been achieved largely as a result of deliberate action by private economic agents, and obviously corresponded to the needs of the national economies of those countries. The rise in energy prices has been responsible for this reaction.

On other occasions the market fails to bring about this harmony between the activities of individual agents and the good for society. Overexploitation of a country's forestry potential is a case in point, as is industrial pollution. There are then two lines of action open to the government: on the one hand it can at least make sure that economic rather than financial CBA is the basis for public sector decision making. In the same vein, it can eventually extend the activities undertaken by the public sector. On the other hand it can coerce, induce or otherwise convince private economic agents to adapt their behaviour.

In a subsequent section we will apply those principles to biogas projects in LDCs. First we make some general comments on the desirability of this type of energy generation, and on its poor financial profitability.

SECTION 3: The undervaluation of biogas by the market

Biogas production seems an extremely sensible way of generating energy. One reason for this is that the raw materials it uses up in production mostly have no alternative economic use and are in this sense costless to society. When for instance agro-industrial waste is being processed, its 'opportunity cost' will be zero if it has no feasible alternative use. In fact often there is a benefit associated with the fact that such by-products are disposed off. The same applies to biomethanation of sewage in urban areas.

A slightly more complicated case arises when such inputs as cow of pig dung are used in biogas production. These inputs have in fact an important opportunity cost to the extent that they are used as a fertilizer. However one of the characteristics of biogas production is precisely that it uses organic material as a provider of energy while at the same time retrieving the fertilizer value in the form of an effluent or solid residue. Therefore whatever opportunity cost we have to impute to this input in biogas production is offset by a corresponding benefit on the output side.

We now turn to the inputs other than the raw materials already discussed. An attractive feature of biogas technology in this respect is that it is very flexible. There are in fact many designs available, some of which do not require sophisticated imported machines or trained personnel. Instead they rely on simple, often locally available materials and semi-skilled labour, both for installation and operation. Many of those 'appropriate technologies' have been developed in LDCs, and correspond better to the factor intensities of those countries. At the same time more sophisticated units should not be ruled out a priori. Especially in large-scale applications it may turn out that they are advantageous despite a higher imported capital component and higher trained manpower requirements.

This picture contrasts with the high cost of using fossil fuels, given by their prices on world markets. Similarly, if fuelwood is used as an energy source the opportunity cost derives from the land, capital and labour and other inputs used in the production of wood. This supposes that demand is met from increased production. When fuelwood demand is met by cutting down trees without planting new ones, the opportunity cost may be much higher if this practice endangers the ecological role of forests.

May we conclude from the above that biomethanation offers a versatile, low-cost process for generating energy? It would seem so. This does of course not mean that it is the best in all circumstances. For instance: organic waste material with low or zero opportunity cost is not available everywhere. Also other sources of energy may be especially cost-effective in particular circumstances, such a hydro-electricity in mountainous areas, or passive solar energy for drying fabrics and food. It is up to CBA to establish when an where a certain type of biogas plant can be economically profitable. This is an empirical matter.

The logical next question is why biogas is not more successful than it is today. Apart from applications in China and some other LDCs, biogas is far from widespread, despite the availability of field-tested technologies and the prima facie concurrence of favourable circumstances in many areas. Several reasons can be advanced to explain this state of affairs, such as the lack of institutional support for its introduction (demonstration projects, information campaigns, training programmes, and so on). Or we can mention the cultural inhibitions related to the treatment of human excreta. One further reason which is the main topic of this paper is the insufficient financial profitability of biogas installations to private decision makers.

There are usually some benefits to the economic agent who considers setting up biogas installation. Let us take the example of family sized biogas digesters in rural areas. The smoke generated by fuelwood during food preparation in the small, badly ventilated houses of the poor may cause serious respiratory and eye complaints. People do value the health advantage of smoke-free biogas and will include this in their overall assessment. Also biogas permits to have evening lighting in the house which adds significantly to the quality of rural life. This is keenly appreciated by the people. The same goes for the time saved on gathering fuelwood. Such benefits accrue directly to the people involved. Although they are not necessarily financial, people will take them into consideration.

In other cases advantages accrue to other people than the ones immediately involved, but they are reflected in the financial CBA of the decision making unit. Suppose the farmer who has set up the biogas installation sells some of the effluent to his neighbours to be used as a fertilizer. The neighbours profit from the biogas installation in this way, but their benefit is signalled to the owner of the biogas installation who acquires an extra income from his sale.

On the other hand there may exist important advantages related to biogas installations (and which will therefore show up as benefits in a properly conducted economic CBA), but which do not trickle down to the level of the decision making unit. In other words the economic profitability of biogas projects may exceed their financial profitability. We mention three categories of such so-called <u>external benefits</u>. They need not all occur in every project of course.

(a) <u>health benefits to the population at large</u>

This will especially apply to biomethanation of urban sewage and night soil. During anaerobic fermentation sterilization takes place by which pathogenic organisms are destroyed. There seems to be some uncertainty about just how effective this sterilization process is in the different biogas techniques. It will at least lead to a partial destruction of many disease carrying organisms. As such this constitutes a major health benefit. However it is a benefit for which the project itself is not rewarded.

(b) <u>environmental benefits</u>

Biogas installations avert the environmental damage otherwise caused to waterways and to the land by the organic effluents they use as an input. Although such benefits are difficult to measure exactly, most studies indicate that they can be very substantial. The point again is that such benefits are not felt by the individual decision maker who considers setting up a biogas plant.

(c) agricultural benefits related to avoiding deforestation

In LDCs a major source of energy is fuelwood and charcoal[4]. Forests are cut down much more rapidly than they can be replaced by natural growth. Important human reforestation takes place, but in many LDCs far from enough to close the gap. A major fuelwood crisis is thus building up in the Third World[5]. This does lead to higher prices for fuelwood and charcoal, but does the increase capture all the costs? Certainly not in the case of wood poaching, a widespread practice in many LDCs. Here the price charged to the customer essentially reflects the extraction, transformation and transport costs. It will go up as forests get depleted and less accessible and more marginal forests are being cut. But this price does not include the investment which went into the planting of the forest, nor the cost to agriculture which indiscriminate deforestation may cause.

There are also external costs associated with biogas production, and they have to be duely taken into consideration. Air pollution is the main problem. The burning of biogas releases certain gaseous residuals into the atmosphere. Although biogas is credited as being less harmful than many other fuels, it releases relatively large amounts of carbon dioxide[6]. We proceed on the assumption that overall the external benefits of biogas far exceed the external costs.

SECTION 4: What governments can do

The problems which we identified call for remedial action. Private agents will always be mainly guided by their own advantage, financially and otherwise. Markets pass on the signal about what other people like and dislike, but incompletely so. The baker or the car-mechanic will work hard not out of altruistic love for their fellow countrymen but because the market passes on the preferences of consumers for bread or car-services into attractive prices for those who supply them. Unfortunately there is no market mechanism which rewards biogas producers for the general health, environmental and agricultural benefits which they create. The individual decision maker will include the non-pecuniary benefits which they themselves derive from biogas such as time saved or evening lighting, but are unlikely to be moved by the non-pecuniary benefits to society at large, unless they are translated into hard cash.

In such circumstances it is the government's task, as the guardian of the welfare for all, to intervene,. We will sketch in this section how the government can choose out of several modes of intervention.

(I) The government can undertake very useful actions at a central level. It can fund applied research on biogas, e.g. on the use of locally available organic waste materials. Or it can provide the institutional framework already mentioned which is necessary for introducing biogas to people who are unfamiliar with it, e.g. through demonstration projects. Those are illustrations of necessary actions to support the private sector of the economy in the use of biogas. Sometimes it is also apparent that the private sector will not undertake certain activities which are nevertheless useful from the social point of view, such as setting up sewage treatment plants in urban areas. In that case the public authorities can undertake such activities themselves.

(2) In most LDCs, even those that call themselves socialist, the majority of economic activites take place in the private sector. One way to influence the actions of the private sector is through regulation. Governments have a legal power to coerce, and they frequently use it in economic sphere in their efforts to reduce external costs. In most countries there is extensive legislation forbidding the discharge of certain waste materials in the environment, setting limits to such a discharge, or imposing certain devices to reduce pollution. Regulation is the most direct way of influencing the private sector, and most politicians feel it is the most efficient way to do so. Yet there are some problems.

In the case of pollution control, regulation requires information about the kind of residuals different economic units are discharging, and about the technical options available in each case to reduce pollution. Especially in technically advanced societies this is a formidable task. Then those regulations must be enforced, usually requiring extensive policing. The complexity of all this is illustrated by the measures taken in most developed countries to limit the air pollution caused by car engines. Governments will typically force producers or importers of cars to install certain technical devices before the car can be sold. Once cars are in circulation it is necessary to ensure that such devices remain in proper working condition. Often this is done by compulsory yearly check-ups of all cars passed a certain age, and by road controls by the police. Similar examples can be given for industrial pollution. It should be clear that controls are never watertight, and very expensive to enact.

Yet regulation is an important way of influencing the behaviour of economic agents, and it has certainly yielded valuable results. An illustration which related to biogas is provided by the regulations in different European countries which restrict the discharge of manure from pig farms. The obligation to dispose of at least part of organic waste material in some other way can make it profitable for farmers to install biogas installations.

LDSc are in a somewhat better position because their economies are technologically less sophisticated so that it should be easier for governments to monitor the private sector. On the other hand, LDC bureaucracies are much less equipped to perform these tasks in terms of personnel and other means.

(3) The solution preferred by economists is the use of financial incentives(7). By carefully chosen taxes and subsidies the government can change the financial profitability of economic agents to bring it in line with economic profitability. In this way external costs and benefits are internalized in the decision making unit. This will lead in general to better solutions than regulation, or so economists claim. Indeed, financial incentives permit the fundamental economic allocation principle to be respected, i.e. that marginal cost equals marginal benefit. The rational economic agent will go on combatting pollution until the incremental cost of pollution reduction (e.g. the cost of a more sophisticated anti-pollution device) is equal to the incremental benefit (e.g. a decrease in the effluent charge). In the case of pig farms an effluent charge may thus make biogas attractive and lead to the same overall reduction in pollution as direct regulation. When the total level of pollution is still judged too high, the government can increase the charges. This will lead to further reduction in pollution. However the reduction will not be spread out evenly among producers. In those enterprises where the cost of pollution abatement is lower, more remedial action will be taken. In this way the total economic cost of pollution abatement should be lower than it is with regulation.

As with regulation, taxes are difficult to monitor. This will be especially so in the more refined approach favoured by economists, when there is no lump sum tax but charges which vary with the amount of pollution. If this system is to work properly, we need measuring devices and in situ checks. This in turn requires qualified staff, important expenditures on equipment and transport, and in general a civil service which is relatively immune for corruption.

Subsidies can achieve the same result as taxes. Consider an effluent charge on agro-industrial enterprises. As a result such firms may find biomethanation an attractive proposition. The same result could be achieved by giving firms subsidies which are conditional on the setting up of effluent treatment devices. The government can for instance subsidize part of the initial investment in a biogas installation. Or it may give an indirect subsidy through credit facilities or tax relief for those firms that install biogas units.

Although the end result of a subsidy or a tax may be similar in terms of pollution abatement at the level of the firm, they differ in other important respects. In the case of a tax, the economic agent's financial profitability worsens in the process, whereas in the case of a subsidy it remains the same, or even improves if the subsidy more than covers the cost of pollution abatement. This has consequences for the distribution of income which may or may not be considered desirable. It has also consequences for the level of activity in the sector in question. In the end taxes will have a depressing effect on the activities causing pollution whereas subsidies do not. For instance the imposition of a tax may lead a firm to quit a line of activity altogether. This is as it should be. If the present value of benefits does not exceed the present value of costs, taking into consideration external benefits and costs, factors of production should be released for some better use. Economic logic suggests that subsidies are appropriate in dealing with external benefits, taxes with external costs.

In the previous section we have suggested that biomethanation creates external benefits. This would seem to suggest that governments should do well to subsidize biogas projects. Note however that those external benefits only arise because there are external costs elsewhere in the economy. Thus we have argued that biogas projects helps to stop the spread of diseases (mainly through contaminated water). But the contamination risk would not have arisen if economic agents elsewhere would be penalized for the health dangers they impose on society at large. So the better intervention would be to levy taxes on the polluters. Similarly with the environmental benefits of biogas: they are related to the discharge of effluents for which the perpetrators are not penalized. If they were, they would have an incentive to take the necessary preventive measures themselves.

Deforestation is a comparable story. Biogas helps to avoid it, but the real problem is that the economic agents who cut down forests do not pay the economic price for their activities. What is required here is the establishment and especially the enforcement of common property rights on forests. Economic management of forests, which takes due account of externalities, can then be envisaged. This implies more judicious harvesting than is now the case. Those parts of a forest designated for harvesting can be opened to private agents at prices set by the forest authority, or at prices obtained through auctioning. Alternatively the forest authority can undertake the harvesting itself and sell the produce to private traders. Whichever way is chosen, much higher prices are to be expected for fuelwood. This in turn will induce families and firms to save on wood products by investing in better heating equipment (cooking stoves, drying killns,...), by being less wasteful in use (e.g. drying wood before burning), and by investing in private tree planting. By the same token, biogas projects will also become more attractive.

(4) Many externalities are caused by the great mass of the poor, both as producers (e.g. deforestation) and consumers (waste disposal). Many of those people live outside of the market, and do not pay any taxes. It is difficult to imagine a cost-effective way of controlling their behaviour through financial incentives in the way described above. The same applies to regulation, as those people also live to a large extent beyond bureaucratic control. Apart from the problem of feasibility, there is a problem of equity. Levying taxes or otherwise hamper the poorest in their daily struggle for survival may indeed be questioned on equity grounds.

For this reason another approach is often advocated: that of <u>convincing</u> economic agents. The idea is that if people are made aware of the external costs or benefits of their actions, maybe they will be prepared to take them into consideration. The government could for instance start an information campaign in rural areas about the need to protect certain forest areas. The hope is that people will cut down less tre?s when they are informed about the wider econological consequences.

The principle has wider applications. The government could launch a campaign in favour of biomethanation directed at agro-industrial firms. The success of this and similar actions depends on the context. To begin with it depends on the trust people have in the public autorities. In some countries the government has forfeited its moral credit with the population through past exploitation and corruption. It is then in a very bad position to lead such campaigns.

There are other factors which play a role. Economic agents may pollute rivers, cut down ecologically strategic forests, or otherwise act against the interest of their countrymen either out of ignorance or out of selfishness. If the former is the case an information campaign may be very helpful. If the latter is the case not much should be expected. For it is unlikely that people will become much more altruistic just by being exposed to moral preaching by outsiders. More successful will be campaigns which make use of the extensive social control mechanisms within the local community. This will be easier to accomplish if the target population is chosen in such a way that the external costs under attack are felt within it. If for instance deforestation hurts the whole local community, and not just some far away towns, collective actions aimed at controlled tree cutting and reforestation have a chance of being accepted. If a majority of the local people, inclusive a sufficient part of the local elite, would benefit from such actions, there is i[illegible] for a concerted campaign by the public authorities in association with community leaders and eventually also with non governmental development organisations.

SECTION 5: Concluding comments

In the final analysis many economic problems turn out to be political problems. So it is with the introduction of biogas projects. We have argued in this paper that one reason for their lack of success is insufficient financial profitability. This has led us to the position that what is required is government action to cover the gap between financial and economic costs and benefits. How likely is it that governments will play the role of custodians of present and future social welfare which we have assigned them? Are they not all too 'human', i.e. as selfish and short-sighted as the rest of us, or even worse?

This question is not without foundation. LDC governments often feel it is justified to let the economic engine run at a higher speed by soft-pedalling on environmental issues. Given the pressing problem of development, concern for the environment is considered a luxury they can ill afford. They may however well be wrong. Environmental problems have a tendency to str[illegible] back at the economy. Loss of tourism revenues, decreasing land productivity, or additional health expenditures are sure signs. Also environmental degradation may not show up immediately in economic measures like Gross National Product, but it affects the welfare of human beings all the same. Governments come under increasing pressure to do something about it. In LDCs pressure is building up in urban areas, politically the most sensitive. With population growth still at historically unprecendented rates the situation is rapidly worsening. By the year 2000 out of the 10 'megatowns' (more than 15 million people) in the world, 8 will be in developing countries. As a consequence many LDC governments are coming back on their earlier position that pollution is a problem of developed countries which does not concern them. They increasingly realize that it is a pressing and growing problem, affecting their citizens, including those on whom they themselves rely for their political survival. Similarly, more and more LDC governments are learning from bitter experience that successful development must start in the countryside. Once this is granted, it is usually also accepted that a steady increase in energy supply in rural areas is necessary as an essential ·edient of rural development.

As regards the concern for future generations the question is whether we can expect governments to be less short-sighted than the average citizen, i.e. not very much. The answer is that it is quite likely that individuals want their governments to be more concerned for future generations than they are themselves. This apparently schizophrenic behaviour can best be explained with an illustration. Suppose I want something to be done about the air pollution from car engines. I would prefer all car drivers to run their cars in unleaded gazoline. However I will not drive myself on unleaded gazoline unless others are forced to do the same. For it would impose costs on me, whereas the benefits are enjoyed by all, and I would still be affected by the pollution caused by all the others. The point is that if this is the general feeling, nobody will initiate the move towards unleaded gazoline, but all will welcome the government imposing it on all. It has been argued that this 'isolation paradox' applies in several areas, including our concern for future generations(8). The consequence is that governments have probably the support of their citizens in restricting external costs imposed upon future generations.

While governments may therefore become increasingly environment-conscious, it must be granted that there are things which are beyond their grasp. One factor which may have an important influence on the future success of biogas projects in LDCs is the pricing policies of energy exporting countries. One could advance sound economic ar nents to underscore the claim that prior to the 1973 OPEC price boom oil prices understated their opportunity cost to the world economy. The reason is similar to the one which explains deforestation at a national level: insufficiently enforced common property rights. The OPEC oil cartel re-established those rights in the form of higher prices for producing countries. OPEC was in this perspective a blessing in disguise for the world economy(9). As indicated above, it led to a considerable energy saving per unit of economic activity. Conversely the apparent collapse of the OPEC cartel in the mid-1980s poses anew the problem of proper pricing of non-renewable resources. The financial profitability of a renewable energy source as biogas directly depends on it.

If governments show a willingness to do more about external costs and benefits in the field of energy, specialists can draw up a coherent strategy. It will consist of some combination of regulation, financial incentives and direct conving of economic agents, together with supporting actions by the central government. The correct balance may be difficult to find however, especially with respect to taxes versus subsidies. In the case of biogas economic logic suggests that what is required is not so much subsidies to biogas installations as penalizing economic agents who cause the external costs which biogas installations help to alleviate. But this solution would require a change in other aspects of economic policies as well. Penalizing peasants for cutting trees is correct in an overall context where rural development is vigorously pursued. If, as is often the case, the rural sector is economically exploited and neglected, further depriving peasants can be questioned on both efficiency and equity rounds.

FOOTNOTES

(1) Indian Council of Agricultural Research (ICAR) The Economics of Cow-dung Gas Plants, New Delhi 1976. R. BHATIA, Economic Appraisal of Biogas Units in India, Framework for Social Benefit Cost Analysis, Economic and Political Weekly, August 1977.

(2) It could also be more than one country. In energy projects, where there are often important international consequences (e.g acid rain, depletion of renewable resources) it may be desirable to perform CBA from the point of view of all countries affected.

(3) The figures are from the International Energy Agency, Annual Oil Market Report, Paris, 1984.

(4) The situation is most outspoken in Africa, were 90% of the population is reported to use fuelwood/charcoal for cooking; see e.g. D. ANDERSON, Declining Tree Stocks in African Countries, World Development, vol 14; no 7, 1986, pp 853-863. In Asia and Latin America relatively more non-traditional fuels are being used. Still the share of wood is impressive in many countries. In Bangladesh a recent survey revealed that in urban areas between 30 and 50% of fuel consumption was provided by firewood. See M. PRIOR, Fuel Markets in Urban Bangladesh, World Development, Vol 14, no 7, 1986, pp 865-872.

(5) See e.g. E. ECKHOLM et al, Fuelwood: the energy crisis that won't go away, Earthscan, London and Washington DC, 1984.

(6) See the technical background paper to this conference.

(7) There is a huge literature on environmental externalities, and how to deal with them. See e.g. R. DORFMAN and N. DORFMAN (eds) Economics of the Environment - Selected Readings, W.W. Norton and Co., New York, 1977. A.C. FISHER, Resource and Environmental Economics, Cambridge University Press, Cambridge, 1981.

(8) Much of the academic discussion on this topic took place in the 1960s. See for example, A.K. SEN, Isolation, Assurance and the Social Rate of Discount, Quaterly Journal of Economics, Vol 81, 1967, pp 112-24.

(9) Of course, one may question at the same time the way in which the economic rent created was distributed among nations, just as one may regret the abruptness of the price increase which probably contributed to a slump in the world economy.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The conclusions of the works of the Consultative Committee Meeting for Biomethanation of Agro-industrial residues for Energy Recovery and Nutrient Recycling, are as follows :

(i) biomethanation is certainly a well-tried technology that is applicable to both agro-industrial and agricultural types of activities to help solve problems at both community- and family-level.

(ii) its appropriateness to Developing Countries is one of the best if compared with other new and renewable energy technologies.

(iii) the cost-benefit analysis (CBA) of a biomethanation project is fundamentally different whether it is a financial or an economic CBA i.e. : whether the unit under scrutiny is a single economic agent or a country or rather the totality of individuals inhabiting it.

(iv) the present worldwide economic situation leads many countries to investigate new and non-conventional financing techniques; amongst these the acquisition of hard currency through counter-trading techniques constitutes a focal point - because it is more and more used and it proved its effectiveness in solving specific problems - and therefore deserves to be further explored and promoted by international development agencies.

(v) finally, even if biomethanation is an appropriate technology for Developing Countries, it nevertheless requires that its tranfer be effective and efficient which means that :

* the training of the personnel should be as comprehensive as possible (i.e. : covering operation, maintenance and management) and tailor-made to the project specific requirements;

* the training programme should comprises an agreed methodology to measure its performance in terms of training results;

* the intended biomethanation project be accompanied by the development of a sectoral infrastructure to assist in logistic and training similarly to what often exits in Developed Countries for the agricultural sector.

B. Recommendations

Based on the discussions held during the Meeting and the conclusions drawn at its closing session, the consulting firm entrusted by UNIDO with the preparation and the organization of the Meeting has been requested to formulate a proposal for a biomethanation technical assistance programme in the participating Developing Countries.

(i) Recommendations on behalf of each investment project proposal

As far as the investment project proposals studied during the Genval meeting are concerned, it must be said that no sufficient time was available - both during the preparation phase and the meeting itself - to allow a sufficiently detailed study of each proposals and the formulation of individual assistance programmes adressed to each of them.

Nevertheless with the available information one may certainly conclude that each of the investment proposals presented for the meeting constitutes an opportunity for carrying out further feasibility studies covering socio-economic cost-benefit analysis and environmental impact assessment as explained below as well as further development work involving process and design studies leading to pilot or demonstration plants.

Concerning the necessary financial resources it should be observed :

* that each individual proposal - being a relatively small project in terms of capital required - does not attract the attention of international development agencies or large financial institutions;

* that all the investment proposals are suspended by lack of finance to undertake the next step;

* and that - in addition to the common lack of funds of Developing Countries - there is another basic difficulty to get the finance which comes from the fact that, although each proposal's economic profitability is very attractive, the financial profitability remains insufficient to private decision makers.

This leads to the important conclusion that there is an inherent structural impeding mechanism to promote biomethanation projects. It consists of the fundamental fact that many of the important advantages related to biogas installations (which will therefore show up as benefits in a properly conducted economic cost-benefit analysis) do not automatically trickle down to the level of the individual decision making unit.

Thus biomethanation appears as a technology that is more useful to a community as a whole than to its members individually and, therefore, its promotion and development are basically a governmental responsability. In fact, because of the very nature of its benefits to the community, biomethanation must be considered as an essential element of the national environmental policy. If such a policy is fully integrated in the national development policy through systematic environmental impact assessment and cost-benefit analysis of development projects as well as through coherent antipollution regulation then biomethanation installations may prove profitable on both the financial and economic points of view.

Finally this problem being common to many Developing Countries, it is believed advisable that any technical assistance initiative in this field be envisaged on a multi-country basis.

(ii) Recommendations on behalf of the participating Developing Countries

This is why it is recommended to elaborate a technical assistance programme that initially could be adressed to the countries that participated in the discussions of the Genval Meeting and, in a later phase, be extended to other interested countries.

The development objectives of the programme would stand as follows :

(i) strengthening the participating countries' capability in environmental planning and management;

(ii) assisting the participating countries in increasing the profitability of biomethanation installations for wastes and/or residues for energy recovery and nutrient recycling through systematic environmental impact assessment of development projects and effective legislation towards pollution abatement and resource recycling;

(iii) promoting studies and investigation in the field of non-conventional financing techniques including the countertrading techniques;

(iv) ensuring effective and efficient training and transfer of technology in the field of biomethanation.

It is suggested to name the programme : BIOMETHANATION ENERGY AND ENVIRONMENTAL MANAGEMENT ASSISTANCE PROGRAMME (BEMAP).

In its principle, BEMAP's institutional framework would be similar to what prevails in existing programmes like for instance the Regional Network for Agricultural Machinery (RNAM Project) with the exception that it would not be restricted to the countries of a particular Region but be adressed, in its initial stage, to the participating countries in the discussions of the Genval Meeting.

BEMAP's concept should be further developed and conceived in conjunction with existing or intended initiatives from other multilateral agencies (like for instance the Energy System Management Assistance Programme - ESMAP - financed by the World Bank). Guidelines and support could also be sought from UNEP and from the Asian Development Bank that organized, in February 1986, a Regional Symposium on Environmental and Natural Resources Planning the proceedings of which have been published under the title : ENVIRONMENTAL PLANNING AND MANAGEMENT.

As far as Belgium is concerned and taking into consideration (i) its leadership position in biomethanation technology and (ii) its ongoing initiatives and intentions expressed by the Administrateur Général of BADC at the Consultative Committee Meeting opening session, it is suggested that belgian expertise and resources be mobilized to play a leading role in the proposed BEMAP programme.

A formal invitation - in the form of a draft BEMAP project proposal - should be presented to the Belgian Government by UNIDO.

Brussels, february 1987.

APPENDIX 1

WASTES AND RESIDUES IN DEVELOPING COUNTRIES AND AVAILABLE APPROPRIATE TECHNOLOGIES OF BIOMETHANATION

A. Introduction

In the course of the Consultative Committee Meeting for "Biomethanation of Agro-industrial Residues for Energy Recovery and Nutrient Recycling", it has been possible to determine which wastes and/or residues and in some cases how much wastes and/or residues are at hand in the Developing Countries, the delegates of which were present at the meeting.

This was then matched with the available technologies of biomethanation to assess whether these technologies are appropriate to the type of wastes and/or residues as well as to the country in which these technologies are to be implemented. The results are to be found below.

B. Wastes and/or Residues at Hand in the Developing Countries Represented at the Meeting

Table 1 lists the wastes and/or residues at hand in the Developing Countries represented at the Consultative Committee Meeting. It should be noticed that, besides wastes and/or residues from agricultural and municipal origin, most Developing Countries exhibit an increasing interest for agro-industries and hence claim an increasing amount of agro-industrial wastes and wastewaters to treat.

China is the typical example. From a well known policy favouring the implementation of domestic family digesters, China is definitely moving towards a policy of agro-industrial digesters of large scale.

Table 1. Wastes and/or residues at hand in the Developing Countries represented at the Consultative Committee Meeting

Country / Waste	Sudan	Guyana	China	Senegal
Agriculture				
Animal		X	150 10^6 t/y manures	
Plant/Crops		Aquatic weeds		
Industry				
Slaughterhouse			X	9.5 t/d paunch manure, in 130 m^3/d wastewaters
Distillery		70 000 l/d = Spent lees		
Paper mill			9000 mills 100-200 m^3/d.mill Black liquor	
Tannery			200 tanneries	
Pharmaceutical			(Research) X	
Municipal	60 000 m^3/d Khartoum wastewaters		Urban sludge	

X : Waste or residue at hand; quantities not known.

Table 1. Wastes and/or residues at hand in the Developing Countries represented at the Consultative Committee Meeting (continuation)

Country / Waste	Indonesia	Brazil	Argentina	Philippines
Agriculture				
Animal	114 10^6 t/y manure	128 10^6 heads of cattle = 14 10^6 m^3 biogas	Milking farms	Pig manure
Forest	217 10^6 t/y			
Plant/Crops	29.5 10^6 t/y			
Industry				
Distillery		204 10^6 m^3/y stillage COD = 30 g/l	2.5-10 10^6 m^3/y stillage COD = 77-100 g/l	2.4 10^6 t/y raw slops (1 t = 30 m^3 biogas)
Oil refinery	2.7 10^6 t/y = 657 10^3 t sludge + 2 10^6 t solid wastes			
Sugar refinery		50.4 10^6 m^3/y effluents COD = 9 g/l		504 10^6 t/y filter cake (1 t = 150 m^3 biogas)
Municipal				

X : Waste or residue at hand; quantities not known.

Table 1. Wastes and/or residues at hand in the Developing Countries represented at the Consultative Committee Meeting (continuation)

Country / Waste	India	Zimbabwe	Paraguay
Agriculture			
Animal	200 community digesters 0.2 10^6 family digesters	X	X
Industry			
Distillery	12 10^6 m^3 effluents (1 m^3 = 22-30 m^3 biogas)		
Food processing industry Brewery		36 t/month coffee bean residues 50 t/month beer dregs	
Municipal	X		

X : Waste or residue at hand; quantities not known.

C. Appropriate Biomethanation Technologies for Developing Countries (**)

Biogas is the product of an anaerobic biological process called methanogenesis and of a technological process called biomethanation. Hence, the present paper is divided into three main parts, the first one dealing with biogas itself, the second one dealing with the biological process of methanogenesis and the third one with the technology of biomethanation.

1. BIOGAS

1.1. Properties of biogas

Biogas is a mixture of methane, CH_4, and carbon dioxide, CO_2. It is produced from a number of organic matters, which will be referred to as biomass substrates, S, through the action of microorganisms which will be referred to as active biomass, X.

It is generally understood that biogas contains between 50 and 80 % methane, CH_4, and between 15 to 45 % carbon dioxide, CO_2. It contains usually also about 5 % water, H_2O and traces of hydrogen disulfide, H_2S, a fact of importance for most of its uses.

Biogas is an energy vector. Its energetic properties depend upon its carbon dioxide, CO_2, content. Table I lists the lower calorific value of biogas.

Table I

	Methane content	Carbon dioxide content	Lower calorific value	
	(% by volume)		kJ g^{-1}	kJ l^{-1}
	50	50	13.4	17.9
Biogas	65	35	20.3	23.3
	80	20	29.9	28.7
Methane	100	0	50.0	35.9
Petrol			45.0	33300.
Gasoil			42.1	34500.

All values at standard pressure and temperature

N.B. (**) based on a paper by A. PAUSS, H.NAVEAU and E.J. NYNS in BIOMASS ENERGY, edition D.O. HALL and R.P. OVEREND, to be published soon by John WILEY, U.K.

Methane is gaseous at all temperatures at which biomethanation processes can be conducted. Furthermore, as will be detailed below, methane is little soluble in water. Hence, methane escapes spontaneously from fermentation mixed liquors, so that no particular process is necessary for its recovery. This is an important fringe benefit, so obvious that it is often overlooked. It is sufficient to recall here the problems associated with the recovery of ethanol, CH_3-CH_2OH, from fermentation mixed liquors, not to speak of the energy requirements of such recovery processes.

Methane has a critical point at -82.1°C. This means that it cannot be liquefied at temperatures above -82.1° C. This is a serious drawback for the end-use of biogas in cars or lorries. From Table I, it is clear that 1 l of methane CH_4, has a lower calorific value roughly equal to one thousand of that of 1 l of petrol. Still, under a pressure of 200 bar, 1 l of pressurised methane, CH_4, has a lower calorific value equal to 1/5 of that of 1 l of petrol.

Methane is little soluble in water. In equilibrium with biogas at 1 atm containing 60 % methane, CH_4, by volume, the solubility at saturation of methane in water at 35°C is equal to 0.6 mM or about 10 mg/litre.

Under usual fermentation conditions, as will be seen below, methane is produced in such amounts per unit fermentation mixed liquor, that the amount lost because of its solubility in the effluent is negligible, relatively to the total amount which escapes as gas. However, when the substrate biomass to be biomethanized is a very dilute wastewater, such as domestic wastewater with an average biological oxygen demand (BOD) of around 300 mg O_2 per liter, or below, the amount of biogas lost by solubility in the effluent, may become relatively important, mainly also if furthermore the fermentation is conducted at ambiant temperature.

1.2. Composition and utilization of biogas

Besides methane, CH_4, biogas contains carbon dioxide, CO_2. In view of the impact that the relative content in carbon dioxide, CO_2, in biogas has on its energetic value, it may be appropriate at this point to discuss thouroughly the factors that influence this relative content.

Basically, the content in carbon dioxide, CO_2, of the biogas depends upon two factors. The first one is the mean oxidation state of the substrate biomass, the second ones are the physico-chemical equilibria of the inorganic carbon species among its various forms in the liquid fermentation medium.

Methanogenesis is an anaerobic process. This means that no dioxygen, O_2, nor any other oxidizing agent is introduced in the reaction mixture during methanogenesis. Hence, the mean oxidation state of the fermenting system, gas phase included cannot vary with time. As a result, the relative amounts of the final products of methanogenesis : methane, CH_4, and the inorganic carbon species with all its forms, are strictly depending upon the mean oxidation state of the substrate biomass accessible for the fermentation. This can be examplified by the dismutation equation of glucose :

$$C_6H_{12}O_6 \longleftrightarrow 3\ CH_4 + 3\ CO_2$$

The complete methanogenesis of one mol of glucose will necessarily produce 3 mol of methane, CH_4 and 3 mol of inorganic carbon, formalized here in a simplified way by CO_2. More reduced biomass substrates will produce relatively more methane and less inorganic carbon. More oxidized biomass substrates will produce relatively less methane and more inorganic carbon.

In turn, the inorganic carbon species will equilibrate among its different forms.

Not all of the inorganic carbon will appear in the gas phase. First, part of the inorganic carbon will dissolve and hydrate in the aqueous fermentation medium. This means that, in equilibrium with biogas at 1 atm containing 40 % carbon dioxide, CO_2, by volume, the solubility at saturation of the forms carbonic anhydride, CO_2, and carbonic acid, H_2CO_3, is 16 times higher than methane in concentration, 43 times more than methane in weight.

It may be interesting to recall here that, by increasing the pressure in the gas phase, the partial pressure of carbon dioxide, CO_2, increases accordingly as a result of Boyle Mariotte's law, and the solubility of the forms carbonic anhydride, CO_2, and carbonic acid, H_2CO_3 increases accordingly too as a result of Henry's law. Whereas this is equally true for methane, CH_4, because of the large differences in solubility between methane, CH_4, and carbon dioxide and its hydrated form, $CO_2 + H_2CO_3$, an increase in pressure in the methane digester from one to two bars for example will result in small losses of methane, CH_4 in the produced biogas but in larger decreases in the carbon dioxide, CO_2 content of the produced biogas. This concept is being looked at as an easy mean to decrease substantially the carbon dioxide, CO_2, content of biogas, mainly under dilute fermentation conditions.

Biogas, as a mixture of methane, CH_4 and carbon dioxide, CO_2, can be used as well for combustion in burners or furnaces as for combustion in engines. The relative amount of carbon dioxide, CO_2, is usually not critical. However, the biogas produced should remain at all times of constant relative composition, as the efficiency of the combustion as well in burners or in engines is rather sensitive to variations in biogas composition.

Water vapor in biogas can be removed by a condensation trap, by physical absorption in glycols, by physical absorption on silica gels and beads, alumina, activated carbon, bauxite or molecular sieves (silicates) and by condensation after compression and/or cooling. Hydrogen sulfide, H_2S, can be removed by dry oxidation, namely on iron oxide, sponges or fillings.

The mixture of hydrogen sulfide, H_2S, and carbon dioxide, CO_2, can be removed simultaneously by physical absorption in water at high pressure, in glycols at high pressure (Selexol process) in propylene carbonate at high pressure (Fluor solvent process) or in potassium carbonate solutions at high temperature and pressure, as well as by chemical absorption in an aqueous mixture of sodium carbonate and ferric hydroxide.

Carbon dioxide can be removed by water scrubbing, possibly in the future in phosphate buffer solutions or by membrane separation. Cryogenic methods have not proven successful.

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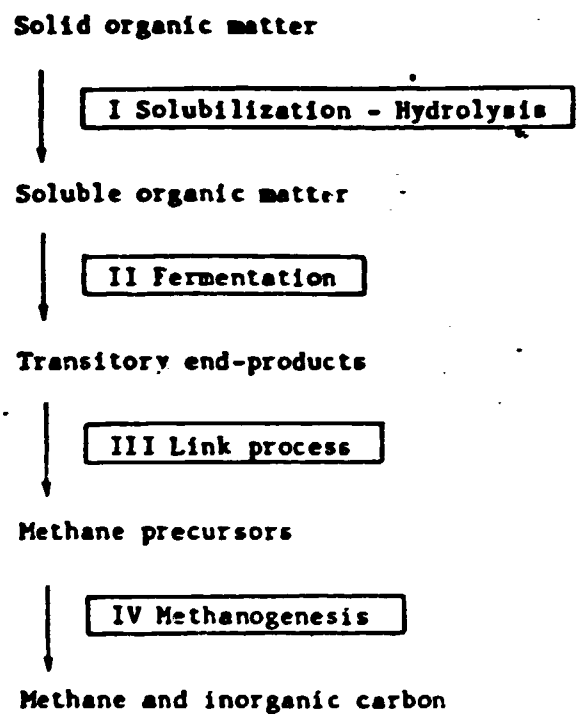
2. METHANOGENESIS

The global process of methanogenesis is the result of four consecutive actions (Fig. 1) :

- solubilization - hydrolysis,
- fermentation (or acidogenesis),
- link processes,
- methanogenesis (in the strict sense)

It is due to the joint action of a rather large number of microbial species.

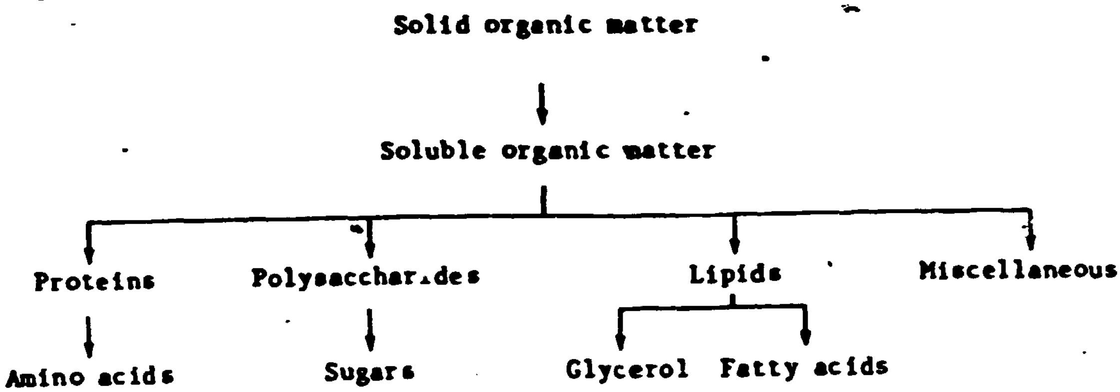
FIGURE 1



2.1. The first action : solubilization of insoluble material and hydrolysis of polymeric molecules

Whenever solid material is present in the substrate biomass, the first action must consist in the solubilization of insoluble material either into soluble polymeric material or into soluble low molecular weight or monomeric compounds (Fig. 2). This first action involves as well a physical desorganization action on the structured solid as a (bio)chemical hydrolytic action on the disorganized molecules.

FIGURE 2



The first action is often, if not always, rate limiting. This means firstly that the amount of solubilization work which can be achieved per unit réactor volume and per unit time limits the rate of loading of the bioreactor, in unit weight substrate material per unit volume of bioreactor and per day. This means, secondly, that the length of time required to obtain the maximum solubilization of a single piece of solid may be long, up to days or even tens of days, depending upon the size of the solid material. The latter fact will influence the mean residence time of solid material in the bioreactor.

The rate limitation is severe in the case of ligno-cellulosic material, in which case the pretreatment of the substrate material prior to the solubilization-hydrolysis step may become necessary. Possible pretreatments are being looked at. These pretreatments may be physical such as irradiation, steam explosion and or grinding or chemical such as treatment at high temperatures. Such pretreatments are always expensive.

The rate limitation becomes less severe as the content of lignin in the cellulosic material decreases, namely from woody material, a poor substrate material for biomethanation, to straw which usually requires a pretreatment and to green plant material normally suitable for biomethanation as such. When straw is used as bedding material for animals, the incubation of straw and animal waste in the stables where the mixture is also trampled by the animals, is an efficient pretreatment.

The loading rates and the mean residence times vary depending on the nature of the biomass substrates and on the applied technology.

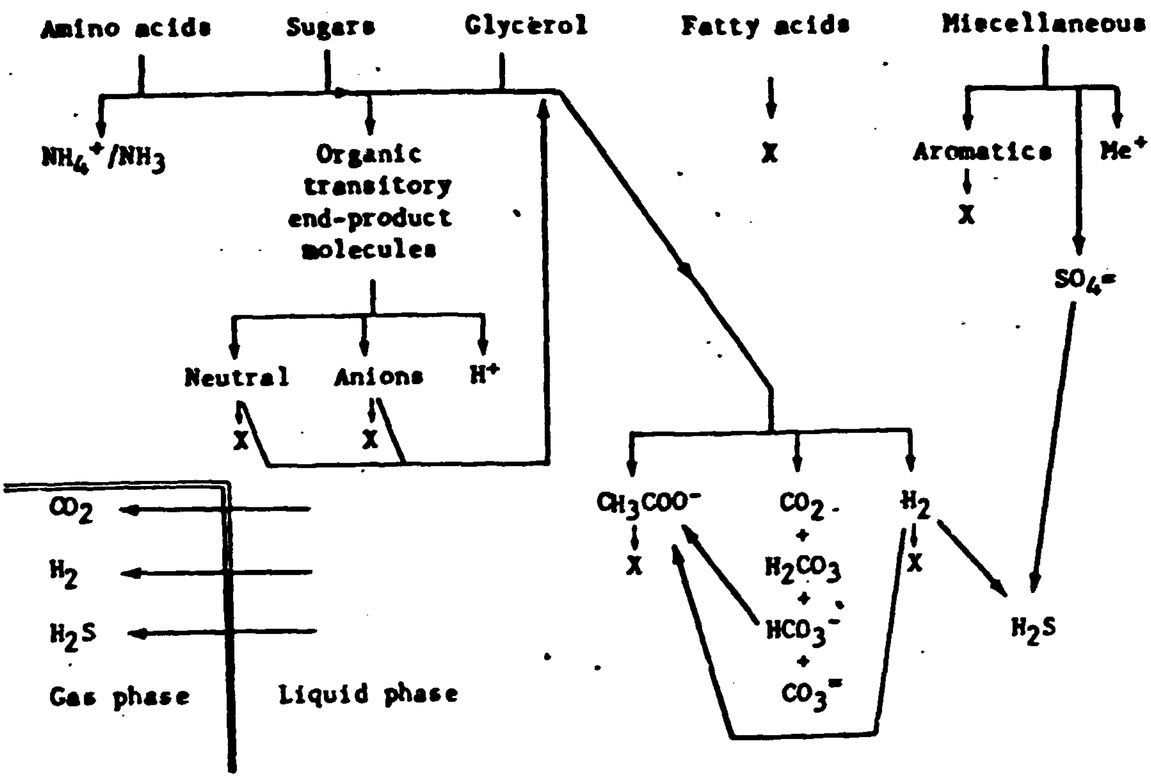
The limits are :

- loading rate : from 1 to 10 kg per day and per m3 of methane reactor.
- mean residence time : from 5 to 20 days

2.2. The second action : fermentation of soluble organic monomeric material

Soluble organic matter, initially present in the substrate biomass, or orginating from the solubilization of organic insoluble material, basically consists of proteins and amino acids, polysaccharides and sugars, lipids, glycerol and fatty acids and miscellaneous compounds in minor amounts, some of which are however of major importance for the global process of fermentation. Fig 3 gives a flowsheeet of the fermentation step, once the depolymerization of soluble polymeric material is achieved.

FIGURE 3



X : Not further fermented in this second action.

The pH at which the fermentation of soluble organic matter spontaneously occurs, that is with no external pH control, is the result of biological and physico-chemical reactions.

As can be seen in Fig. 3, organic anions appear as "transitory end-products". These organic anions are end-products released in the fermentation medium by fermenting bacteria. They have to be looked at as electron sinks if the energy-conserving biological redox reactions are considered from the electron transfer point of view. They have to be looked at as reducing equivalent-rich waste molecules if these reactions are considered from the hydrogen transfer point of view.

This question is not elaborated further here. The basic conclusion which should be remembered is that neutral organic substrates have a potential acidifying power revealed by fermentation but that part if not all of his potential acidity can be located as carbon dioxide, CO_2, which escapes from the mixed liquor as a gas.

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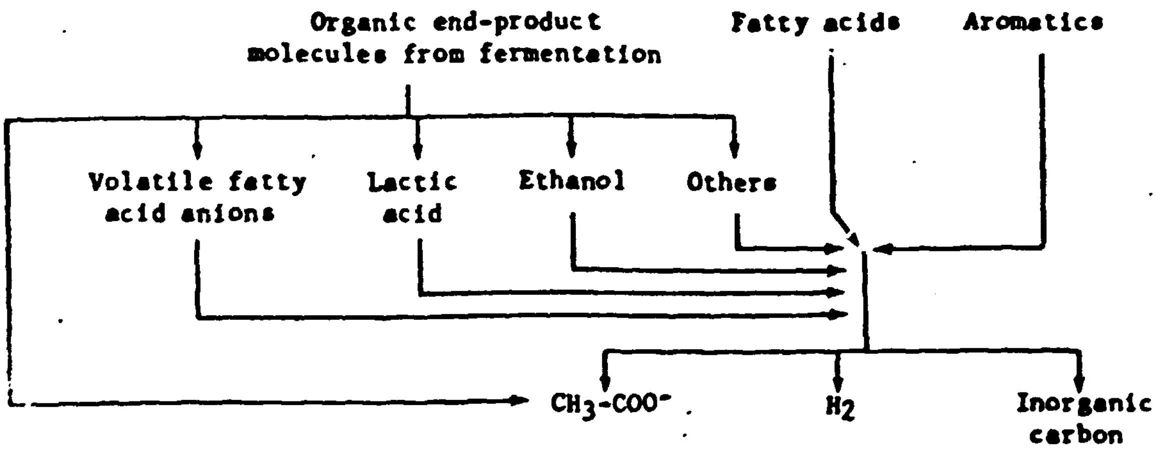
2.3. Link processes between fermentation and methanogenesis

A number of end-product molecules from the fermentation action cannot serve as such as substrate molecules for the methanogenic action. This is namely the case for volatile fatty acid anions with 3 and more carbon atoms, lactate, ethanol, aromatics and long chain fatty acids, indeed all molecules but acetate and the couple dihydrogen, H2, and inorganic carbon, namely carbon dioxide, CO2, and bicarbonate, HCO3-.

A number of bacterial species exist which are able to metabolize these compounds into acetate, CH3-COO-, dihydrogen, H2, and inorganic carbon (Fig. 4). These bacteria are called "obligate hydrogen-producing acetogenic" or OHPA. With their peculiar metabolic pathways, these OHPA bacteria constitute a closed link between the fermentation action and the methanogenic action. In other words, through their peculiar metabolic pathways, these OHPA bacteria exert a remarkable "funnel" effect on the overal process. Indeed, these OHPA bacteria collect most if not all simple soluble monomeric molecules which originate or are left over from the fermentation action and "funnel" them down, that is metabolize them solely into acetate, CH3-COO-, dihydrogen, H2, and inorganic carbon. As a result of this link processes, the latter four molecules are the only end-products remaining in the mixed liquor at this stage.

FIGURE 4



There is however one major drawback to these link processes. From a thermodynamical point of view, these metabolic processes are only possible, i.e. exergonic, when the partial pressure of dihydrogen is kept low to very low, that is down to 10-5 atm.

The major result of this thermodynamical limitation is that large absolute amounts of dihydrogen, H_2, must flow in the fermentation medium but at an extremely low partial pressure of dihydrogen at all times. This problem was solved by nature by promoting the syntrophy between obligate hydrogen-producing acetogenic (OHPA) bacteria and hydrogenscavenging bacterial species.

Whenever biomethanation is split in a two step process, acidogenesis (fermentation) and methanogenesis, the link process with sulfate-reducing or methanogenic bacteria takes normally place in the second step of methanogenesis. Not all end-molecules of the first fermentation step will make the link process in the second methanogenic step equally easy. The fermentation of lactate, CH_3-CHOH-COOH and ethanol, CH_3-CH_2OH to acetate, CH_3-COO^-, are little endergonic in their standard state and, hence, tolerate relatively high partial pressures of dihydrogen, in the fermentation medium. The fermentation of volatile and long chain fatty acids and aromatics to acetate is more endergonic in the standard state and, hence in these cases, the requirement for low partial pressure of dihydrogen is more severe. Propionate, CH_3-CH_2-COO^- is the worst substrate for the OHPA bacteria from the thermodynamical point of view. This explains why, throughout the related literature, the presence of high propionate concentrations (of the order of 1 to 3 g per liter fermentation medium) has been considered as trouble-shooting.

When biomethanation is considered in a one-step process, the following scenario must be considered. Under perfect running conditions in continuous, completely-mixed processes without recycle, the fermentation of simple organic soluble molecules will lead only and directly to acetate, CH_3-COO^-, dihydrogen, H_2, and inorganic carbon, without any need for OHPA bacteria and in a process perfectly hooked onto methanogenesis. No other transitory end-products are produced. Hence, no link process is necessary. OHPA bacteria will thus be normally absent from such fermenting ecosystem.

2.4. The last action : methanogenesis in the strict sense

At this stage of the overall biological process, as was written above, the fermentation medium contains only acetate, CH_3-COO^-, dihydrogen, H_2 and inorganic carbon. These compounds are substrates for a number of microbial species belonging to a new kingdom : the archae-bacteria.

All methanogenic archae-bacteria are temperature-demanding as they can usuallly only grow around 35° C in mesophilic conditions and around 55-65° C in thermophilic conditions. Some species are thermotolerant and grouw up to 85° C.

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3. THE TECHNOLOGY OF BIOMETHANATION

The process of methanogenesis has found suitable biomethanation technologies to host it.

First of all, a number of environmental requirements for the proper running of these technologies mentionned in the preceeding section, can easily be met from a technical point of view : anaerobiosis or better anoxy (absence of dioxygen, O_2), temperatures around 35 or 60°C, pH between 7 and 8 at least for the methanogenic action, absence of toxics. These factors will not be discussed further here.

Secondly, because of the "funnel" effect also described above, as one passes from fermentation through link processes onto methanogenesis, it can be anticipated that methanogenesis being open to on extremely wide variety of molecules, biomethanation will be found suitable for an ever increasing variety of biomass substrates. Indeed sewage sludges animal wastes and most agricultural wastes, wastewaters of agro-industries are classical substrates for biogas production by biomethanation. Wastes originating from other industries, supposedly more toxic, add nevertheless every day to the list of potential biomass substrates for biomethanation. Biomethanation of municipal solid wastes is extensively applied. The topic is well documented in the literature and will not be further detailed here.

After digestion, the digested slurry can be disposed of on land or used as animal feed. Whereas little is being published on the latter, the former is now well documented.

Thirdly, a wide variety of biomethanation technologies has appeared on the market. It is not intended to describe once more these technologies in a systematic way as numerous papers have gone this way.

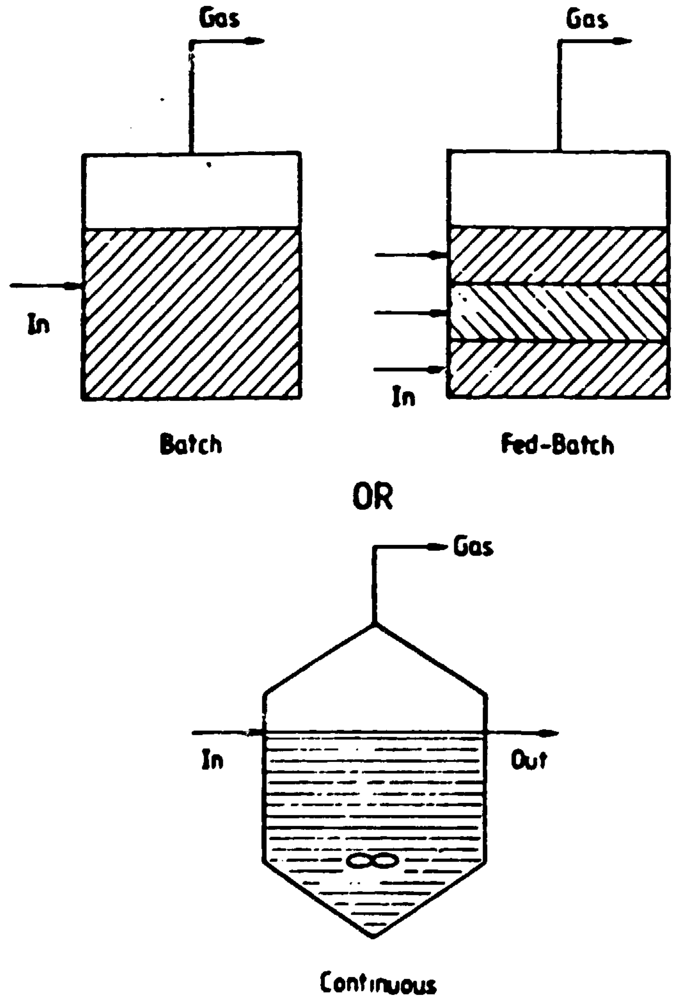
Instead, the reasons why given biomethanation technologies are most appropriate for given methanogenic processes will be discussed at some length.

Moreover, it must be noted that, irrespective of the biological constraints and of the type of the biomass substrate degraded, biomethanation technologies are adapted differently depending upon their objective : energy production, depollution or a combination of both.

3.1. Batch or continuous biomethanation systems

Basically, the technologies for biomethanation can be divided into two major categories. In the first one, the batch system, the substrate biomass is introduced in one time at the beginning of the process. In a variant way, the fedbatch system, the substrate biomass is introduced in two or three times but nothing is removed from the reactor until the end of the process. In the second category, the continuous system, the substrate biomass is introduced continuously or intermittently; the total volume of the mixed liquor remains constant, the digested mixed liquor being removed continuously or intermittently at the same flow-rate as the substrate biomass in introduced.

FIGURE 5



All reasons favor the continuous process over the batch process. From a biological point of view, batch processes are always in a transient state where the proper balance between the various microbial subcommunities in the global methanogenic ecosystem remains delicate at all time. On the contrary, continuous processes are in a stationary state where the proper balance between the various actions is easier to maintain.

From the point of view of a physical state of the substrate biomass, as long as the mixed liquor remains "liquid" that is up to the slurry-type, continuous systems are easy to handle. The simplest variant include the manual semi-continuous (daily for example) loading of the methane digester. When the substrate biomass is a solid and remains so in the mixed liquor, giving rise to what is known as dry fermentation, even then continuous processes are to be preferred to batch processes. Indeed, and namely for urban solid wastes, continuous technologies are reaching the demonstration stage. Only when a very simple technology is wanted, as is the case until animal manure with bedding in rural areas, can the batch process be preferred to the continuous process. Even then, some form of fed-batch process should be considered, namely the progressive addition of water or liquid to the solid substrate biomass.

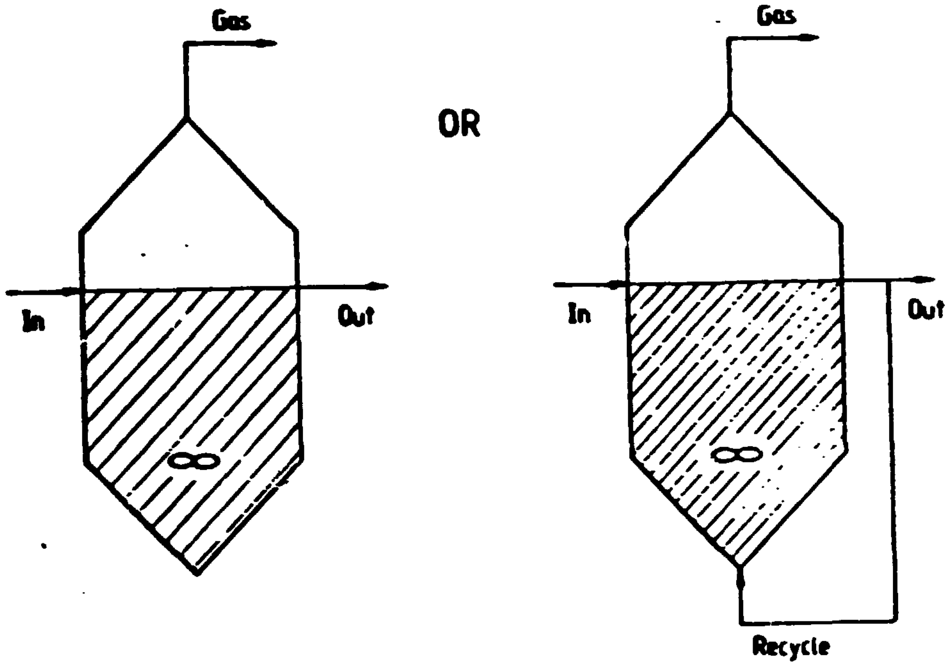
An interesting batch process is the biogas extraction from landfills. Hughe amounts of domestic waste are disposed off in landfills. Economically interesting quantities of biogas can be simply collected over long periods of years from these landfills from pipes plunging deep into it.

From a performance point of view, the total biogas productions, for a same amount of substrate, are comparable in batch and continuous processes. Yet the biogas production in batch process is non modulable and inconstant. In continuous systems, on the contrary, the biogas production potential remains the same over indefinite periods of time. A production of biogas, adapted to the energy demands, can be modulated by a corresponding handling of the loading rate. Indeed, methanogenic ecosystems in continuous processes can be maintained for long periods of time without feeding on the one hand and on the other hand, the response of the gas production rate to an increase in loading rate is rapid, of the order of hours. The response of the gas production rate to a decrease in loading rate depends upon the content of the mixed liquor in slowly degradable matter and may take from a few hours to some days.

In the future, these systems, at present the most widespread in the world due to the simplicity and the low cost of building and to the easy maintenance of the process, will remain widely diffused, especially in rural countries and in developping countries.

3.2. Active biomass recycle ?

FIGURE 6



Whenever the substrate biomass is a slurry of 7-10 % (wt.wt, dry weight) containing a large portion of insoluble material, the most appropriate biomethanation system remains the continuous, completely-mixed methane digester without active biomass recycle. It must be recalled that a slurry remains Newtonian up to 7-10 % dry weight concentration. At higher dry weight concentrations, the mixed liquor becomes essentially non-Newtonian. This means a completely different set of physico-chemical laws for mass and heat transfer. This also means a reaction mixture more difficult to render homogeneous. This results in increasing difficulties to run the biomethanation process in a reliable way.

But when the substrate biomass is more dilute and contains essentially soluble material, the situation is different. One of the limiting factors as far as mean residence times are concerned in continuous methane digesters, is the bacterial specific growth rate. In usual cases of biomethanation, hydrogenotrophic methanogenic archae-bacteria have specific growth rates, between 7 and 10 days but obligate hydrogen-producing acetogenic bacteria may have longer specific growth rates up to 12-14 days.

In the absence of active biomass recycle, the mean residence time of the active biomass is necessarily equal to the hydraulic mean residence time. This explains why in continuous biomethanation systems without recycle, the hydraulic mean residence time is usually maintained around 12-14 days. It is possible to run continuous biomethanation systems without recycle at lower hydraulic mean residence times but the effluent then usually contains amounts of volatile fatty acids increasing with decreasing hydraulic mean residence time.

The average permissible substrate loading rate, in continuous biomethanation systems is of 1 kg dry organic degradable matter per m3 of mixed liquor (working volume of methane digester) and per day.

1 kg dry organic degradable matter will produce as much as but not more than 0.8-1.0 m3 of biogas containing 2/3 of methane, CH_4. A large array of erroneous (much) larger values are to be found in the literature, mainly the older one.

With mean hydraulic retention times of 14 days, the lowest biomass substrate concentration which still permits the optimum loading rate, is 14 kg dry organic degradable matter per m3 substrate biomass. In the case of pig manure, the conversion is about 35 %, that is 35 g organic matter eliminated per 100 g influent organic matter. Hence, optimum conditions for biomethanation of pig manures in continuous systems without recycle can only be encountered with pig manures with a concentration of 40 kg organic weight per m3, which usually makes 50 kg dry weight per m3 manure. In barns which are regularly cleaned with water, the mixing of these washings to the pig manure easily results in much lower concentrations.

The only way to overcome these limitations is to differentiate the mean hydraulic retention time from the mean retention time for the active biomass. This is achieved in practice by trapping the active biomass in the methane digester or by recycling it after a sedimentation (clarification-tickining) step. How this is done, will be discussed in the following section.

Once these two mean residence times are differentiated, the next two limitations to the rate of biomethanation are the following. First, there is an optimum food to microorganisms ratio. Methanogenic organisms, on an average, cannot metabolize much more than 1 kg organic degradable matter per 1 kg organic suspended solids, and per day. Whenever the substrate biomass contains little non-biodegradable matter, the organic suspended matter in the mixed liquor reflects rather well the active biomass.

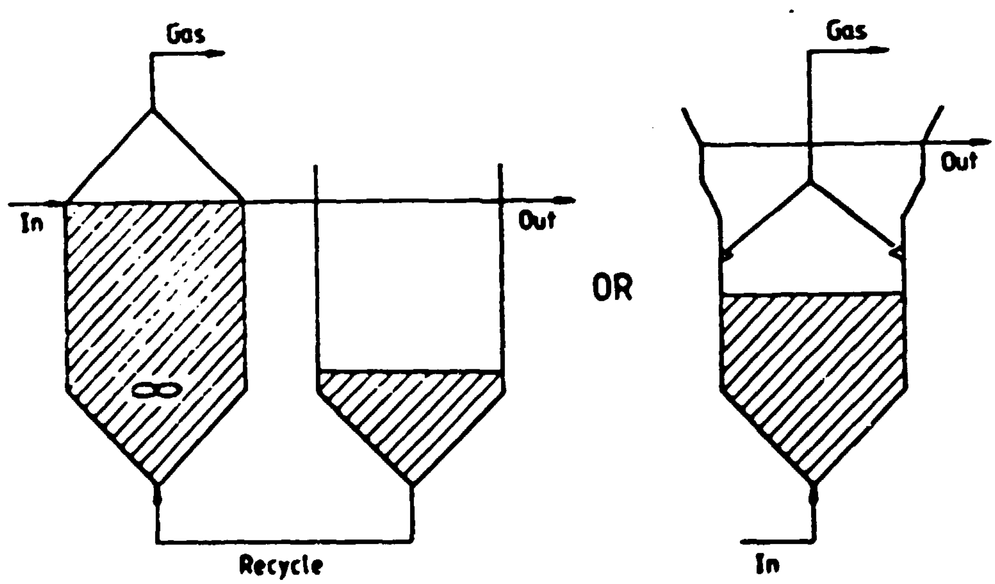
The amount of microorganisms which can exist in 1 m3 of mixed liquor is limited by the volume which these microorganisms occupy specifically. This is reflected in the Sludge Volume Index (SVI) or volume in ml occupied by 1 g dry active biomass (as dry (organic) matter). Average concentrations between 10 and 40 kg active biomass (as dry organic matter) per m3 mixed liquor can be achieved in practice in continuous biomethanation systems with active biomass trapping of recycle. This then means that organic loading rates in such systems with active biomass recycle, is limited to 10 to 40 kg organic degradable matter per m3 mixed liquor (digester working volume) and per day, values often reported in the literature.

The second limitation is the absolute minimum residence time. Even though the hydraulic mean retention time is differentiated from the mean resulting from for the active biomass, the mean residence time for soluble substrate molecules, remains the same as the hydraulic mean residence time. The shortest mean residence time for soluble substrate molecules is not yet known. It should be of the order of hours, perhaps lower. It surely depends upon the nature of the molecule.

It is also most propably very short when only the absorption of the substrate molecule by the microorganism has to be considered, and longer when both absorption and metabolism by the microorganism have to be considered. The former case is encountered at low food to mircroorganisms ratios, say between 0.1 and 0.3, expressed in organic matter. The latter case is encountered at high food to microorganisms ratios say around 1, expressed in organic matter.

3.3. Trapping or recycle of active biomass ?

FIGURE 7



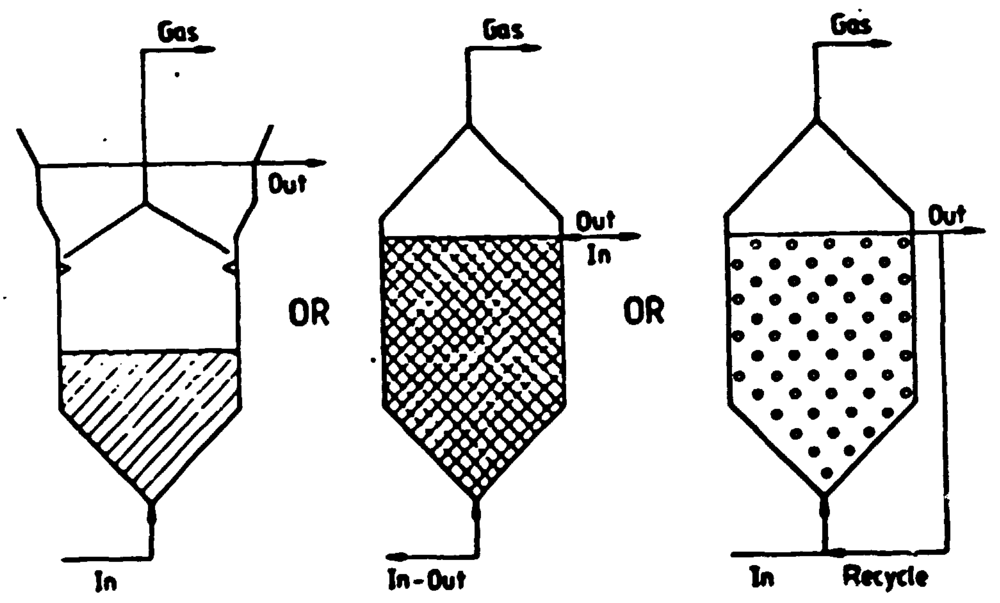
Contact processes where the substrate biomass is put into contact with large quantities of active biomass in a continuous, completely-mixed reactor and the active biomass subsequently decanted in a separate decanter are well known and most generally used for the aerobic treatment of wastewaters. It is thus quite normal that this type of contact process was among the first ones to be tested when the anaerobic treatment of wastewater appeared more economical. Contact process have performances in practice about twice as large as the simple completely-mixed continuous process without recycle.

However, the active biomass seems to withstand poorly the decantation step. First, because biogas evolves within the active biomass flocs, the apparent density of the latter is often below that of water. Hence, in order to exhibit good sedimentation properties in the decantation basin, the anaerobic flocs have to be degassed. This is usually achieved by lowering the temperature of the mixed liquor between the methane digester and the active biomass decanter. The recycled active biomass has hence, to be reheated. The active biomass seems to lose a substantial part of its methanogenic activity in the process.

These were sufficient reasons to trap the active biomass with the methane digester itself, a point which will be discussed further in details below.

3.4. Sludge beds, fixed beds or fluidized beds ?

FIGURE 8



Fixed beds are processes in which the active biomass is trapped as a fixed film on a biologically non-active matrix. Fixed-beds are also well-known though less used in the aerobic treatment of wastewaters where they carry the name of trickling filters. Matrices can be of all sizes from a few cm to large blocs. They can be of all forms, some of them particularly intended to channel the liquid flow. They are made of various materials. The important characteristics of these materials are their hydrophily or hydrophoby, their internal porosity, their adsorbing potential. Plastic, clay and active carbon are typical examples of materials used as matrices for fixed-beds. Fixed-beds can be operated with an up or a down liquid flow in the reactor.

As early as 1970, one questionned the need for a matrix, the porosity of which is around 0.5. As an alternative to fixed beds, one tried thus a similar system but without matrix and called it upflow anaerobic sludge blanket, UASB. It has been found that the active biomass formed very dense granules in this type of anaerobic upflow digester, the sludge volume index of which was as low as 20. As a result, very high active biomass concentrations per unit working volume could be achieved, up to 50 kg dry organic matter per m3. Hence, very high loading rates, of the order of 50 kg of COD per m3 of digester working volume and per day were obtained but not in a regular and reproducible way.

The relative instability of the dense active biomass granules still remains the weak point of the UASB process. Flocs with a sludge volume index of 50-100 are easy to maintain for long periods of time in this process but granules with sludge volume indexes as low as 10-20 are stable only under still ill-defined conditions

The tranformation of granules into flocs is accompanied by a 5-10 fold increase in the specific volume of the active biomass. As a result, whenever this transformation occurs, most of the active biomass usually leaves the digester with the effluent.

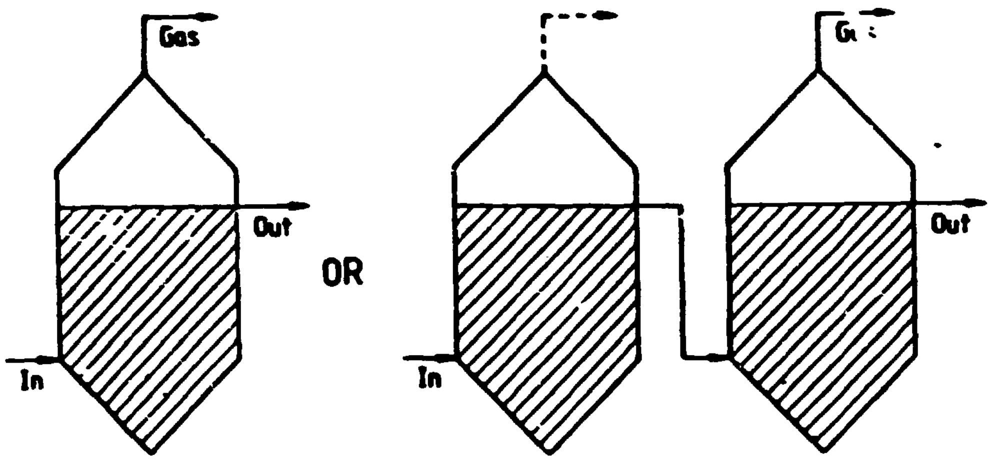
The draw-backs due to active biomass losses in upflow anaerobic sludge blankets can be seriously reduced if the reactor incorporates some system of solid-liquid separation. The following systems are proposed. First, a decanting area is installed in the top part of the reactor. It is characterized by a larger section which reduces the upflow velocity of the liquid. The produced biogas is trapped below this area. Secondly, the upper part of the reactor is equipped either with a fine-mesh sieve or with a lamellar decanter. Thirdly, the upper part of the reactor consists of a fixed-bed. The simplest way to achieve this is to use floating polymer sponges.

The idea to "help" active biomass flocs to gain density with dense micro-carriers gave rise to the fluidized bed process. In this process, the active biomass is allowed to grow as a thin film around heavy particles like sand, of 0.1 to 1 mm average diameter. Other materials have been proposed , namely active carbon. As an alternative, the microbial flocs are allowed to incorporate a large number of smaller heavy particles, the size of which lies between 10 and 70µm. In the latter case the microbial flocs are "micro-carrier assisted". In order to allow these active biomass "grains" to work properly, the upflow velocity of the liquid in the reactor must be increased, eventually with the aid of an additional recycle, untill the fixed bed expands or fluidizes.

At the present time, fixed beds are the most robust process, upflow anaerobic sluddge blankets, the most performant processes. Both are presently well implemented throughout the world, essentially for treating agro-industrial wastewaters. Dilute manures and extracts from solid biomasses will become the next targets. Fluidized beds remain more delicate and may well be better suited for more sophisticate biotechnological processes.

3.5. One or two step process

FIGURE 9



The overall biological process of methanogenesis consists of two main biological sub-processes : acidogenesis and methanogenesis. It has therefore often been proposed as an absolute rule that, each step having its own optimum conditions set, biomethanation should be separated into two distinct technological processes for optimal performances. It is erroneous to consider this concept as absolute and valid in all cases.

However, from what has been discussed above in section 2 on methanogenesis, there appears to be a number of cases where, indeed, a two-step process offers advantages over a one-step process. These cases will be summarized here.

First, when the fermentation of given substrate biomasses is not only an acidogenesis but is also very acidifying because the major pairing cation is the hydrogen ion, H3O+, it has been said above that a first acid acidogenic fermenting step resulted in the elimination of a substantial part of the potential acidity as CO_2 in the gas phase. This is often the case with green plant material and wastewaters from agro-industries, namely sugar refineries.

Secondly, when the substrate biomass is a solid, it may be advantageous to organize a first step to transform the solid into a liquid or to extract a liquid from the solid. In these cases, the first step will often be a purely physical step or a combined physical-biological step. In this category of first steps, the handling of the solid portion of the biomass and the operation of the process dealing with this solid portion may differ from the handling of the liquid portion of the biomass and the operation of the process dealing with this liquid portion. Percolation of solid urban waste is a classical example of this category of first step.

Thirdly, a simple first step is often set up for technical reasons. Whenever the supply of the waste, namely a wastewater, varies with time both in flow-rate or in quality (charge) then an equalizing basin offers a "buffer" and allows a more steady loading of the methane reactor. In this equalizing basin, not only does the biological process of fermentation occur but solid material may sediment and be collected to be treated separately.

It should however be recalled that transfer of large amounts of dihydrogen, H2, under low pressures of dihydrogen, is the central link between the fermentation action and the methanogenic action and that this phenomenon may impair with step separation of biomethanation.

CONSULTATIVE COMMITTEE MEETING ON THE BIOMETHANATION

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REUNION DU COMITE CONSULTATIF SUR LA BIOMETHANISATION

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