Review of Biomethanation Program

Centre de Développement des Energies Renouvelables (CDER)

Morocco

for

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Office of Energy and Natural Resources

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I. Introduction

Following the recent evaluation of the project under which AID provides assistance to the Centre de Développement des Energies Renouvelables (CDER), USAID/Rabat felt that a more detailed review of CDER's biomethanation program - both current activities and future plans - could serve both CDER and USAID well. After discussions with USAID/Rabat/ENR, a review based on the following general approach was decided upon:

1. Review of the progress of the CDER biomethanation program;
2. Review of biomethanation activities being undertaken by groups other than CDER;
3. Analysis of the basis for, and utility of current and planned biomethanation programs in Morocco in terms of input materials and benefits and costs;
4. Recommendations for future directions for CDER's biomethanation program.

This report is based on the results of extensive interviews with the major players in Morocco's biomethanation activities (CDER, l'Office Régionale de la Mise en Valeur (ORMVA) du Haouz, Peace Corps), examination of the reports of the AID evaluation team and the Energy Sector Management Assistance Program (ESMAP) report of the World Bank, interviews with representatives of the university community, visits to university laboratories, and personal visits to several rural biogas plants. (A detailed list of persons contacted and site visits is given in Appendix A.)

The concerns and recommendations outlined in this report are based on a commitment to the encouragement of renewable-energy systems in general, and a conviction that biomethanation in particular is a practical and often valuable way of handling human, animal, and agricultural wastes. Where national policy is involved and where there are many competing uses for limited public funds, however, a program of promotion of biomethanation must be accompanied by a firm analytical and economic argument to justify the priority desired. Advocacy alone is not enough. It is certainly not enough to convince a poor farmer to invest scarce capital - or to borrow money to invest - in a biogas installation without a convincing argument that the payback will justify the investment; nor is it enough to justify the use of scarce government funds and manpower in a major effort in this area.

The economic argument is often difficult to make in the conventional manner, however, especially where national policy is concerned, because of the many intangible societal benefits of renewable-energy systems - and of biomethanation in particular. Nevertheless, the argument must be made, and the burden of the recommendations of this review is the need to gather the data to make this argument before a further serious commitment of funds can be justified.

II. Summary of Conclusions and Recommendations

A. CDER's biogas program needs a stronger justification than just the desirability of providing cooking fuel.

CDER has succeeded, in a relatively short time, in creating and staffing a new organization, establishing temporary office and laboratory facilities, establishing cooperative programs with other agencies and institutions, beginning construction of permanent facilities, and commencing a varied program in a variety of renewable-energy activities. Nevertheless, CDER has not yet established an analytical basis for its current and planned biomethanation program.

> **Recommendation No. 1** - CDER should immediately begin the design of, and as soon as possible commence a series of studies that will provide the data needed to justify a biomethanation program. Certainly, no expanded biomethanation program should be contemplated unless justified by the results of the recommended studies.

The studies should provide the data needed to evaluate biomethanation as a system in Morocco, taking into account the cost and value of the input materials as well as the value of the products. This information, together with firm estimates of capital costs, production and operating costs, and an evaluation of social, environmental, and policy issues that are not easily quantifiable, is necessary to make the case for continued expenditure of public funds for biomethanation.

> **Recommendation No. 2** - To meet CDER's legitimate needs required by the recommended data gathering, these studies should be planned in conjunction with the appropriate universities and other institutions of higher learning to involve students to as great an extent as possible in gathering data.

This approach provides the manpower that CDER needs to gather the necessary information. Furthermore, the recommended studies provide an excellent opportunity to improve relations between CDER and these institutions, while at the same time providing meaningful scientific survey experience for students.

B. The choice of digester type and design is based more on experience in other countries than on Moroccan needs.

It is always wise to begin a new program by building on the experience of others. With few exceptions, however, the digesters thus far installed seem to be of a size and type used in the

Peoples Republic of China for purposes not easily related to conditions in Morocco.

Recommendation No. 3 - The type and size of digester to be used in any future biomethanation program should be based on the results of the studies recommended in Recommendation No. 1.

Recommendation No. 4 - While awaiting the results of the recommended studies, and in preparation for the possibility of a continued biomethanation effort, CDER should experiment with digester designs better matched to current loading rates and gas requirements, less costly in use of materials, and matched to current practices of use of manure as fertilizer, in terms of substituting digested sludge for manure.

The digesters currently being installed are being loaded at about one-fifth the rate for which they are designed. At the very least, if the current patterns of use are to be continued, serious consideration should be given to redesign of the digesters to save construction materials.

C. CDER's role in promotion of biomethanation is unclear.

CDER is seen as a catalyzing organization, on the one hand, stimulating a national biomethanation program and then withdrawing from this activity. On the other hand, the emphasis given to biomethanation in its printed materials, and by some of its staff, indicate a deeper interest in continued involvement. Furthermore, the ORMVAs continue to look to CDER to play a leading role in development of biomethanation systems.

Recommendation No. 5 - Pending the results of the recommended surveys, CDER should use its present staff capabilities to consider plans for construction of two or three small demonstration units, in collaboration with the appropriate ORMVAS, in public areas (such as souks) where the systems can be examined by a broad audience on a continuing basis.

In the event the results of the studies justify CDER's continued involvement in biomethanation, CDER would be in a better position to move ahead in a promotional role if it had already formulated plans for public demonstrations. (The current system of relying on visits to farm installations reaches a very small audience.)

III. Detailed Findings

A. The Basis for CDER's Biomethanation Program

At the outset, it must be noted that, within the relatively short time since its creation, CDER, with the assistance of its contractor (RTI), has to its credit a commendable achievement in having created an organization, acquired the appropriated funds needed to function, assembled a staff, established temporary laboratory and office facilities, established a cooperative program with the Peace Corps, established cooperative activities with other GOM agencies and educational insititutions, and having started construction of permanent facilities. The domains of activity have involved solar-thermal techniques, measurements of solar radiation, photovoltaic pumping, windmills (for both pumping and electricity generation), and biomethanation.

At this stage in its life, however, CDER is facing the need to respond to questions dealing with its role in the overall Moroccan energy scene, its programmatic goals, and specifically the basis for its biomethanation program.

A rational policy of government support for any program aimed at increasing the use of one energy resource relative to competing alternative resources must necessarily be based on an analysis of a number of variables, in the context of other government policies that bear on the issue. This economic and social benefit-cost analysis should include comparisons of:

- capital costs
- production costs
- operating costs
- energy value and unit energy cost to the consumer
- foreign-exchange requirements
- public-health implications
- environmental impact(1)

This is not always easily done, as has been pointed out in previous analyses of renewable-energy systems, primarily because the most difficult aspect of this kind of analysis in the renewable-energy field is the quantification and valuation of direct and indirect benefits and costs.(2)

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(1) See Appendix B for details of such a study.
(2) Meta Systems Inc. 1980. State-of-the-Art Review of Economic Evaluation of Non-Conventional Energy Alternatives. Bioresources for Energy Project. U.S. Dep't. of Agriculture, Forest Service. Contract No. 53-319R-0-137. December.

> This....point is particularly important because it is less easily taken into account. Resources (e.g., capital, cement, dung, water, labor) allocated to biomethanation systems have alternative uses. Thus, to justify this particular use, three things must be demonstrated by the social and economic benefit-cost analysis. First, it must be shown that the aggregate benefits to society are greater than the aggregate costs. Second, the benefits per unit capital cost must be greater than for an alternative use. Third, evaluating the aggregate benefits and costs to society must take into account the 'total welfare of the society' in such a way that it is not diminished by this use of the resources.(2,3)

Such a complete analysis is not easy to do, and, unfortunately, is not always performed. Nevertheless, it is no less important as a basis for a policy of encouragement of biomethanation than it is for policies that determine the subsidized price the consumer will pay for electricity or butagaz

Some preliminary estimates have been made regarding the production, uses, and consumption of wood, for example, that provide a link between this energy resource and deforestation.(4) The point to the study proposed by the World Bank is to strengthen that link and provide the basis for a policy of support for improved wood-conversion techniques to lower wood consumption rates - such as improved cookstoves and charcoal-manufacturing techniques - and increased resource availability through afforestation and accelerated reforestation programs. Unfortunately no such preliminary estimates seem to have been made regarding biomethanation. Although some data pertinent to the potential for biogas use will be provided by the proposed Bank study dealing with woodfuel consumption for cooking, additional information is needed.

Discussions with CDER staff (including Peace Corps Volunteers), RTI personnel, and faculty of Hassan II University in Rabat elicited no quantitative data - either estimated or measured - on crop residues, animal manure, or domestic wastes that might be available as substrates for biomethanation systems. ORMVA du Haouz was able to provide some estimated figures for such things as number of cooperatives, area under irrigation, and type of irrigation system in use, but figures on waste production did not

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(3) Brown, Norman L. and Prakasam B.S. Tata. 1985. 'Biomethanation.' Environmental Sanitation Reviews, No. 17, December. Bangkok: Environmental Sanitation Information Center.
(4) World Bank. 1986. Energy Sector Management Assistance Program. Morocco. January.

seem to be available. Although some experimental systems have been built at Hassan II and by the Peace Corps Volunteers working at CDER, there seemed to be no data on production rates of potential substrates, and only some anecdotal information on current uses of cow manure. The current program of promotion of biomethanation seems to be based instead on the knowledge that these systems are used in large numbers in other countries, mainly the Peoples Republic of China, and that substituting biogas, a renewable energy source, for butagaz is a good thing.

The position of the biomethanation program within CDER's overall programmatic responsibilities and goals would be strengthened considerably if a firm analytical basis could be established not only to justify the current level of activity, but also to serve as an argument for the expanded program that is desired by the CDER staff.

In order to establish such a basis, it is as necessary to examine biomethanation as a system as it is to look at woodfuel consumption not only as a cooking-fuel issue, but in the broader context of techniques of charcoal manufacture, transportation costs of wood and charcoal, cookstove efficiency, domestic and public health, and deforestation. Therefore, to be able to respond adequately when the justification for its biomethanation program is questioned, and to be able to make the case for retention of current support and/or for increased funding, in the face of competing uses for scarce government funds, CDER must be in a position to adduce evidence that demonstrates the potential value of this program to the people of Morocco.

Recommendation No. 1 - CDER should perform, or sponsor, studies to provide the following information:

1. Substrates (manure, crop residues, human wastes, domestic wastes) available for biomethanation
   a. Reasonable census of production units (farms and livestock)
   b. Type, rate of production, composition of substrate materials
   c. Current use, amount available for biomethanation
   d. Value of current use
      i. If sold, profit to seller, cost to buyer, value to buyer
      ii. If not sold, value to user (in terms of increased crop productivity or other use, and cost of replacement)
   e. Cost of collection and storage
   f. Availability and cost of water.

2. Gas
   a. Rate of production, composition

b. Value as fuel
   i. Cost of fuel displaced (unit energy cost basis)
   ii. Cost/inconvenience of transportation of fuel displaced
   iii. Foreign-exchange savings
c. Cost of end-use appliances
   i. Cost of replacement/modification of current appliances (stoves, lamps)

3. Digested sludge
   a. Rate of production, composition
   b. Value as fertilizer/soil conditioner
      i. Effect on agricultural productivity (compared to fertilizer currently used)
      ii. Cost of fertilizer displaced
      iii. Cost/inconvenience of transportation of fertilizer displaced
      iv. Cost of storage/application (compared to fertilizer displaced)

4. Environmental impact
   a. Impact on domestic health (e.g., respiratory disease) compared with alternative fuels (e.g., crop residues, fuelwood, charcoal, butagaz)
   b. Impact on public health (anaerobic digestion of wastes compared with current uses or disposal methods)
      i. Disease control
      ii. Water-quality improvements
      iii. Air-quality improvements.

The information needed will be, at best, the result of reasonable extrapolations from detailed surveys of a representative sample of production units within each region, and within each type (single-family farm, cooperative farms, commercial farms; but such sample surveys must be carried out to obtain this basic information.

B. Institutional Cooperation

CDER believes that its current staff situation, in terms of manpower and skills, will not permit it to pursue such a series of studies. This concern may well be justified. Nevertheless, without having gathered the basic data needed to demonstrate the public policy need to expand either CDER's staff or its program emphasis on biomethanation, CDER will not be able to make the case for that expansion.

Recommendation No. 2 - In order to perform the necessary studies with its limited staff, CDER should seize

this opportunity to improve and cement relations with the appropriate universities (e.g., Hassan II in Rabat, Faculté des Sciences in Marrakech) and other institutions of higher learning, by involving the professors and students in the design and performance of these studies. CDER should also enter into discussions with the ORMVAs to explore the involvement of the extension agents in their Centres de Mise en Valeur, since these technicians are already in the field and acquainted with their districts.

Some collaboration between CDER and institutions of higher learning has taken place. For example, the Ecole Normale Superieure (ENS) is cooperating by allowing CDER's solar-radiation instruments and solar-thermal test equipment to be installed on its facilities, with measurements being performed by ENS students. Also, the Ecole des Mines has lent its facilities for the installation of a photovoltaic pumping system belonging to CDER, to be used for student training. Nevertheless, collaboration between CDER and university groups working on biomethanation - l'Institut Agronomique et Vétérinaire at Hassan II University, for example - could be improved significantly. CDER's need for the studies recommended above provides an excellent opportunity to improve CDER/university relations by sponsoring faculty and student performance of the studies. If the studies are designed in collaboration with the professors, an opportunity would be created for all parties to benefit - CDER by acquirng the necessary data and sharing in the resulting publications, the students by gathering meaningful data and learning scientific inquiry techniques in an academic setting, and the professors by receiving some support for data gathering useful to their own research.

ORMVA (Haouz) has expressed interest in increased cooperation with CDER, and specifically noted the importance of studies of farming practices in the region in addition to development of new and improved digester designs. It would seem a good opportunity, therefore, to increase this cooperation by exploring the possibility of using the CMV personnel to assist in carrying out the recommended surveys.

C. Technical Issues

Field observations and discussions with CDER, Peace Corps, and ORMVA indicate that, with very few exceptions, the digesters thus far installed in Morocco are the Chinese type of "water-pressure" digester, of 6-10 m^3 capacity. Digesters of this size are designed for loading rates of approximately 125-150 kg/day of manure. Currently, the Moroccan installations are being fed with about 20-25 kg of manure per day. This means that the time required to reach their loaded capacity is 5-6 times the length of time for which they are designed, and the gas-production rate is much lower - perhaps as much as a fifth - than the design capaci-

ty. The reduced loading rate also means that the digested sludge is available for use as fertilizer/soil conditioner less frequently than would otherwise be the case.

Recommendation No. 3 - The type and size of digester to be used in any future biomethanation program should be based on the results of the studies recommended in Recommendation No. 1.

Recommendation No. 4 - While awaiting the results of the recommended studies, and in preparation for the possibility of a continued biomethanation effort, CDER should experiment with digester designs better matched to current loading rates and gas requirements, less costly in use of materials, and matched to current practices of use of manure as fertilizer, in terms of substituting digested sludge for manure.

The digesters currently in use are over-designed in terms of wall thickness and reinforcement, besides being larger than can be justified by the loading rate and detention time. In the interim period pending the results of the studies, CDER should experiment with smaller digesters with thinner walls, and particularly with plug-flow designs. The one experimental digester of this type that has been installed at Ghouiba is a start in this direction. This kind of experimentation should continue, primarily because such digesters, appropriately sized, are likely to cost significantly less than the Chinese type currently in use. If less expensive digesters, such as these, prove to be practical in Morocco, the economic analysis of the data to be gathered would be strongly affected.

D. Future Activities

CDER's role in the promotion of biomethanation in Morocco is unclear - this uncertainty of purpose could well be a natural consequence of the lack of a firm analytical and policy basis for CDER's biomethanation activities. Although it sees itself as a catalyzing organization with no future continuing responsibility in this field, its own literature emphasizes the continuing importance of CDER's role in biomethanation. Furthermore, other organizations and institutions continue to look to CDER to play a continuing role. Hassan II University, for example, would like CDER to support continued academic research and development in biomethanation systems. ORMVA du Haouz looks to CDER to be responsible for research and development in biomethanation (a role consistent with that suggested by Hassan II), and to provide the ORMVAs with improved designs for digesters. Finally, the work of CDER's own Peace Corps Volunteers demonstrates the value of continued work on improvement of end-use appliances for biogas.

Recommendation No. 5 - Pending the results of the recommended surveys, CDER should use its present staff capabilities to consider plans for construction of two or three small demonstration systems (manure collection and preparation, digesters, stoves, lamps), in collaboration with the appropriate ORMVAS, in public areas (such as souks) where systems in use can be examined by a broad audience on a continuing basis.

This recommendation is based, of course, on the assumption that the results of the suggested surveys justifies a continued promotional role for CDER in this field. It seems clear, however, that such a program of "demonstration" units in souks would be useful apart from the survey results, in view of the regularity of the gathering of large numbers of animals (donkeys, horses, camels) and the public-health problems created by the accumulation of manure.

In the event that the recommended surveys do indeed justify a continuing role for CDER in promotion of biomethanation systems on farms, the suggested demonstration systems would put CDER in a better position to move ahead quickly in a promotional role. In any case, it might well be a useful basis for discussion with the Peace Corps in terms of the incoming group of Volunteers to be assigned to CDER.

Appendix A

Contacts in Morccco

Rabat:

USAID Mission:

Stephen Klein, ENR
Samir M. Zoghby, ENR

Peace Corps:

David Frederick, Country Director
David Black, Assistant Director

Université Hassan II, Institut Agronomique et Vétérinaire Hassan II:

Dr. Faouzi A. Senhaji, Département de Génie Industriel Alimentaire
M. Abdelatif Achkaria, Département de Génie Industriel Alimentaire
Professor Philip R. Goodrich, Agricultural Engineering Department,
University of Minnesota

Université de Rabat:

Mme. Bahraoui, Faculté des Sciences (Président de GERER)

Marrakech:

Centre de Développement des Energies Renouvelables (CDER):

Mohamed M'Zabi, Secrétaire Général
Hassane Maarat, Ingénieur d'Etat, Section Biomasse
Technicians
Albert Himy, Chief of Party, Research Triangle Institute
Michel Fabre, Research Triangle Institute
Kenneth Thornton, Peace Corps Volunteer
James Fesperman, Peace Corps Volunteer
John Birkey, Peace Corps Volunteer

l'Office Régionale de la Mise en Valeur (ORMVA) du Haouz:

M. Benjelloun, Directeur

Centre Scientifique et Technique du Batiment:

Mme. Saida Benabdeljalil

Ecole des Mines:

Ecole Normale Supérieure:

Lycée Technique.

Mohammed Jehadi, Directeur

Various farms with biogas installations (including Ferme Ch'Bani at Ghouiba)

Other contacts:

Brace Research Institute
Tom Lawand, Director of Field Operations

Appendix B

Analysis of Biomethanation Systems

[The following material is excerpted from "Biomethanation" by Norman L. Brown and Prakasam B.S. Tata. (Environmental Sanitation Reviews, No. 17, December 1985. Bangkok: Environmental Sanitation Information Center.) For references, see the end of this appendix.]

PLANNING BIOMETHANATION SYSTEMS

Biomethanation systems are of little interest unless they are accepted and used. Too often the importance of the frequently intangible and generally unquantifiable social and ecological impacts has been overlooked in planning systems. The result is dissatisfaction on the part of the user and eventual abandonment of the system. Thus, conventional benefit-cost analyses must be broadened to the type of social and economic benefit-cost analysis discussed in the previous section.

Methodologies for performing such analyses are available from many of the sources already cited. The approach used by deLucia and Bhatia (1) and by Meta Systems Inc. (2) is particularly comprehensive and the reader involved in planning a biomethanation program is urged to refer to those or similar works. The approach suggested is summarized as consisting of the following steps:

> "(i) calculating the financial viability of the project when benefits and costs are valued at market prices and market interest rate is used for the opportunity cost of capital;
>
> (ii) making corrections in financial costs and benefits by eliminating taxes and subsidies which are treated as transfer payments and do not reflect real resource costs;
>
> (iii) recognizing the distortions in market prices on account of price and quantity controls, minimum wage regulations, imperfect capital markets, and regulations of trade and foreign exchange by the government; and, hence, replacing the market prices by "accounting prices" or "shadow prices" which reflect the real values of inputs and outputs of each project;
>
> (iv) incorporating considerations of income distribution, regional development and employment through explicit weights on these objectives; and
>
> (v) calculating the social profitability of the project by using appropriate values of social rate of discount and shadow price of investment to estimate Net Present Value, Benefit Cost Ratio, and the Internal Rate of Return."(2)

When such an approach is applied to specific circumstances for planning purposes, a host of specific items must be taken into account. The check-list approach used by the Bangkok workshop is helpful in this regard, and is shown in Table 1. It should be noted, however, that each table of issues in a particular area is a companion to a table of technical parameters and variables in

Table 1. Use of Energy from Biomethanation: Socio-Economic Issues Check list(a)

Quantifiable Aspects	Non- (or Not Easily) Quantifiable Aspects
Fuels or systems displaced (relative calorific value vs. cost) + Firewood + Charcoal + Crop residues + Dung + Other biomass systems - Gasification - Ethanol - Methanol + Fossil fuels - Kerosene - Gasoline - Diesel oil - LPG + Electricity - Grid - Local generator + Water power (mechanical) + Solar energy - Cooking - Drying - Photovoltaics + Wind Labor Costs + Construction + Operation and maintenance Capital Costs + Digester + Gas storage and distribution Cost of End-Use Appliances/ Equipment	Impact on: + Food preservation (from cooking smoke and heat) + Insect repelling (from cooking smoke and heat) + Space heating (side effects from cooking) + Deforestation - Erosion - Water control - Water tables + Alternative use of limited labor pool + Employment generation - Construction - Collection of feedstock - Operation and maintenance - New jobs created by increased availability of energy + Employment displaced - Jobs associated with previous uses of substrate - Jobs displaced by new energy source + Human resources/skills - Availability of manpower for technical assistance, maintenance - Skills training needed - Education + Communication (public education required to encourage acceptance)

a. Source: Ref. 3, p 48.

the same area, which must be reported in some recognized standard manner as the basis for rational and useful social and economic cost comparisons.(3) (The Bangkok workshop report recommends such a standardized manner of reporting technical details of biomethanation systems.)

One of the major controversies associated with the introduction of biomethanation systems concerns alternative agricultural uses for the raw-material feedstocks (manure and other agricultural wastes). Evaluation of these alternative uses is meaningful only in comparison with use of the residues of biomethanation, and a comprehensive list of these uses is given in Tables 2 and 3, which are adapted from the report of the Bangkok workshop.

Table 2. Agricultural Uses of Biomethanation Residues Used as Fertilizer/Soil Conditioner - Socio-Economic Issues Check List.(a)

Quantifiable Aspects	Non- (or Not Easily) Quantifiable Aspects
Fertilizer/Soil Conditioner (relative value vs. cost) + Dung + Crop residues + Forest residues + Chemical fertilizer + Night Soil Effects on Crop Fields Labor Costs + Transportation + Storage + Application Income Generation from Sale of Residues Energy Costs + Transportation + Processing + Application + Manufacture (of displaced fertilizer) Relative Concentration of Toxic Substances	Impact on: + Self sufficiency + Human resources/skills - Availability of manpower for technical assistance, maintenance - Skills training needed - Education + Communication (education needed for acceptance and use) + Pollution - Air - Water - Soil + Habitat for pests + Soil fertility and land value + Land carrying capacity + Employment generation - Handling, processing, storing residues + Employment displaced - Jobs associated with previous uses of feedstock + Safety (sanitation)

a. Adapted from Table 10, Ref. 3, p 50.

In discussions of the use of biomethanation residues as fertilizer, the issue of nitrogen availability (see section on Raw Material) seems to be of particular concern, especially to economists. There are two major reasons it remains an issue. First, the chemical analytical data available are inadequate - inaccurate analyses, estimates only or no information, and no uniformity in handling and use of residues. The second reason is that in addition to the recycling of nutrients, a major value of application of biomethanation residues to the land comes from the humic materials they contain; that is, the value of the residue as a soil conditioner - its contribution to the tilth of the soil - must be considered.

In Table 3 are listed the issues to be considered that are related to the use of biomethanation residues as feed supplements.

Table 3. Agricultural Uses of Biomethanation Residues as Feed Supplement - Socio-Economic Issues Check List (a)

Quantifiable Aspects	Non- (or Not Easily) Quantifiable Aspects
Feed/fodder supplemented or displaced: + Crop residues + Commercial feeds + Fodder/forage	Impact on: + Self sufficiency + Human resources/skills - Availability of manpower for technical assistance, maintenance - Skills training needed - Education + Communication (education needed for acceptance and use) + Pollution - Air - Water + Employment generation - handling, processing, storage + Safety (sanitation) + Land carrying capacity
Effect on yield/productivity	
Labor costs + Transportation + Packaging/handling + Storage + Use	
Equipment costs + Transportation + Storage	
Income generation from sale	
Energy costs + Processing + Transportation + Manufacture (displaced feed, if any)	
Toxic substances	

a. Adapted from Table 10, Ref. 3, p 50.

Finally, those aspects of the impact on health and sanitation that should be considered are listed in Table 4.

Table 4. Public Health/Sanitation - Socio-Economic Issues Check List (a)

Quantifiable Aspects	Non- (or Not Easily) Quantifiable Aspects
Capital Costs (equipment)(b)	Human Resources
Use of Outputs	+ Availablility of manpower for technical assistance, maintenance
+ Cost of use	+ Skills training needed
+ Income generated	Communication (education needed for acceptance and use)
	Social Organization needed for successful use of systems
	+ Latrines
	+ Night soil/dung collection

a. Source: Table 11, Ref. 3, p 51.
b. Allocation of these costs must be shared among other uses for biomethanation systems, because these systems would not be constructed solely for public health/sanitation purposes.

REFERENCES

1. deLucia, Russell J. and Bhatia, Ramesh. 1980. "Economics of Renewable Energy Technologies in Rural Third World: A Review." Meta Systems Inc., Cambridge, MA, USA. October.

2. Meta Systems Inc. 1980. "State-of-the-Art Review of Economic Evaluation of Non-Conventional Energy Alternatives." Bioresources for Energy Project, U.S. Department of Agriculture, Forest Service. Contract No. 53-319R-0-137. December.

3. Equity Policy Center. 1983. Report of the Workshop on Uniformity of Information Reporting on Biomethanation Systems. Bangkok, Thailand, May 14-18, 1983. Washington, DC: Equity Policy Center.