NONTECHNICAL ISSUES IN BIOGAS TECHNOLOGY DIFFUSION

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David Stuckey opened the "State of the Art on Biogas Technology, Transfer, and Diffusion" Conference with a challenge to the participants to provide the detailed economic and production information on biogas technology that could justify its expanded use. He maintains that in spite of extensive experience with biogas in research settings and actual field operation, too little is known to estimate its value or potential applications:

> "Surprisingly, there is a dearth of substantive data on which to evaluate the economic viability of biogas. This is particularly acute in the area of industrial and feedlot applications, but less so with domestic and community level applications. However, in the latter two cases, most of the data come from India and are derived from theoretical design figures using the floating cover design with cattle dung as the feedstock. It is obvious with such a narrow data base that few, if any, conclusions can be drawn about the viability of biogas under other circumstances, e.g. using different designs and feeds in different social and environmental milieus, and in varying areas of application."

And the problems do not end with the collection of data. Stuckey argues that no agreed upon methodology exists for evaluating the significance of the data:

> "In addition to a lack of substantive data, existing economic evaluations suffer from the lack of an agreed upon methodology. Common problem areas include: lack of data on

the effect of technical parameters on plant performance; valuation of inputs; valuation of biogas in relation to substitutable fuels and end-uses; valuation of slurry with regards to its use as a fertilizer/soil conditioner and animal feed; marginal utility of output; and the valuation of secondary benefits. A consensus on methodology needs to be developed which will allow economic data to be compared amongst the various applications, under varying circumstances, and enables rigorous economic comparisons to be made between biogas and other renewable energy technologies or with conventional energy sources."

Vaclaav Smil followed Stuckey's approach with a reevaluation of the Chinese biogas program, which is by far the most ambitious in the world. He claims that the disappointing performance of many of the Chinese digesters and changes in the country's agriculture policies have taken the steam out of biogas developmenet. He estimates that the total number of Chinese digesters has dropped from 7 million to 4 million and that gas production in cold climnates falls far short of expectations. Smil lists the following obstacles to the diffusion of biogas technology, the impact of which has been vastly underestimated:

"The steady flow of organic wastes needed for continuous high-efficiency operation of biogas digesters is often absent. Climatic factors make the year-round generation impossible or they cut production during cold months to a fraction of peak flows making it impossible to rely on the gas as the main source of energy. Engineering complications abound: the structures may be simple but workmanship must be first-rate if the container is to remain leakproof under pressure for years and be easiy cleaned and maintained. Operation may appear straightforward in experimental set-ups but everyday care in actual rural setting will be far from approaching the optima of acidities, alkalinities, C/N ratios, temperatures, liquidities, and uniform mixing required not only for the best performance but, if left to deteriorate for a while, for the very survival of a digester as a biogas generator rather than as a simple fermentation pit."

Smil also points out how nontechnical factors can influence the adoption of biogas technology. The Chinese government recently changed its policy to allow individual farmers to plant trees to produce firewood. Chinese farmers are accustomed to using firewood for cooking and are likely to prefer it to biogas. Now that they have the opportunity to plant trees, many are abandoning their biogas plants. China has also allowed farmers more freedom in choosing what crops to grow, and many farmers have switched to crops that they can sell for cash. Moving into the monetized economy has changed their view of what is economical. In Sichuan province, where biogas has enjoyed its greatest success, many farmers have found it more economical to devote their energy to expanding crop production and to buy energy and fertilizer rather than tend a biogas digester. This change of heart illustrates the difficulty of assessing the economic viability of biogas technology.

Both Smil and Stuckey spoke favorably of the potential of biogas, but both emphasized that the technology is not universally applicable. The problem is not with biogas technology but with the unrealistic projections some people claimed for its energy contribution. Biogas has succeeded admirably in some situations, both would agree, but Stuckey argues that we really do not have a clear idea of how well it has succeeded, and Smil claims that its potential is real but very limited. Smil estimates that in China, where conditions for biogas development are very favorable, the most that can be expected is that biogas would supply 10 percent of rural energy needs. He estimates that it now supplies less than half a percent.

T. K. Moulik, whose studies of biogas installations in India are among the world's most detailed and sophisticated, agrees that cost-benefit analysis needs improvement. He pinpoints the spots where the methodology is weakest:

"The uncertainties or inadequacies in input-output calculations in monetized quantitative terms are largely in relation to the following parameters:

(1) Given the widely varying decentralized operating conditions of biogas systems, there is a lack of standardized data about the quality and quantity of inputs and outputs. Since it is difficult to estimate accurately the supply-response factors in such uncontrolled decentralized operations, the input-output parameters are

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usually estimated in cost benefit analyses of biogas projects at the ideal experimental conditions, which most often are far away from the actual field conditions.

(2) For the same reasons of decentralized variable conditions the economic life of a biogas system irrespective of different designs cannot be easily standardized.

(3) Pricing of inputs and outputs poses some insurmountable problems. In pricing there are on the one hand the questions of domestic market price and price movements over a period of time (i.e. inflation) and the world price (in actual and potential contribution to foreign exchange saving and earning or import/export) on the other. The still more more methodologically agonizing problem of pricing is found in relation to traded and non-traded inputs and outputs. It is a well-known fact that in many parts of the Third World, major inputs (animal and plant waste) including labour and outputs (biogas and digested manure) are often non-traded goods without organized stable markets land are often obtained at zero private cost. Thus the perceived opportunity cost of these inputs and outputs for a biogas adopter may be zero, while from the nation's point of view it could be substantial. The use of world prices as "shadow prices" to overcome this problem brings the considerations of trade efficiency and distribution, raising many other critical questions while solving some.

(4) The conflict between private and social profitability or benefits raises some fundamental decision issues. What is

involved in a biogas project is its total impact on the economy, which cannot be readily identified and easily priced. There are a large number of indirect or secondary costs and benefits of biogas both at the private micro and the national macro levels."

The challenge raised by Stuckey, Smil, and Moulik is to develop a more sophisticated methodology for assessing the value of anaerobic digestion for developing countaries. The conference consensus was that the first step in this direction is to pay more attention to the nonenergy benefits of digestion--fertilizer production and improved sanitation and public health. Because of the energy crisis of the 1970s, energy production was viewed as the primary benefit of anaerobic digestion and often the only criterion by which it was evaluated. The distortion in this approach is apparent when one remembers that anaerobic digestion began as a waste treatment technology. The conference produced suggestions for improving the way in which energy production is valued and developing strategies for valuing the other benefits of anaerobic digestion.

ENERGY

In looking at energy production, two questions were raised that have not been adequately considered in the past: Will biogas substitute for current fuel or simply increase the amount of energy used by the rural poor? How does biogas compare to other alternative energy sources for rural people in developing countries?

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Household biogas systems are not not likely to replace other energy supplies. Most of the rural poor have so little affordable or available energy that they will readily find uses for additional fuel. Where fuelwood is in short supply, many people have alraeady had to cut back on cooking. Most have done without lighting, so biogas lights will not replace an existing energy source. In other words, in many cases biogas will not be replacing other energy supplies but improving the standard of living of the people. This makes biogas production for poor households more a social welfare than an energy program. And this raises another important consideration: who benefits? Household biogas systems do not benefit the poorest people. T. K. Moulik estimates that 75 percent of India's rural population does not have the resources to build or operate a household biogas digester. In fact, if those who can afford digesters begin collecting manure, it will mean that the poor who burn manure directly for cooking will have less available to them. For this reason, Moulik recommends the construction of community digesters that will enable the poor to take advantage of the technology. At any rate, most existing biogas systems do not reduce national consumption of conventional fuels nor improve the standard of living of the poorest people.

Placing a value on the biogas produced is also difficult because many of the people using biogas are outside the monetized economy. They now get their energy from wood, manure, or agricultural wastes that they do not pay for. Though energy analysts often assume that the hours spent gathering fuel are wasted and unpleasant, this is not always so. A survey in Tanzania, for example, found that the women who gathered wood found it a very enjoyable task and a social occasion. What might look like drudge work was actually preferable to staying at home or doing other chores. This changes how we would value the time spent collecting wood. Many participants suggested using "shadow prices" that reflect the value of the energy on the world market, but this is not an accurate reflection of the value of energy in the local economy. The assumptions made in evaluating biogas will determine the results. If one wants biogas to look good, place zero value on the work of the people who tend the digesters because they do not have the option of working for wages and value the biogas at the world price of oil. If one wants to make biogas look bad, value the labor at city wage rates and compare the energy value with free firewood.

Although it is a mistake to compare biogas value with free firewood, comparing the economics of digestion with reforsetation is necessary. It makes far more sense to do that than to compare biogas with world oil prices because rural people are not buying oil. By and large, they are using wood. Of course, one has to use a realistic estimate of the cost of growing, harvesting, and collecting wood. No one at the conference was prepared to discuss the relative advantages of reforestation and biogas promotion although these are the actual choices facing many countries. One must also take into account that other energy sources are often subsidized. The farmer will evaluate biogas on the basis of what he is paying for energy, not the world price. Government policy makers, meanwhile, should look at what it is costing them to subsidize the fuel and think if that money might not be better spent promoting the use of digesters.

FERTILIZER

In China, producing fertilizr was the primary motivation for the biogas program.. The Chinese have a long history of recycling animal waste to fertilize the land, and biogas systems fit perfectly with this practice. Chinese farmers were also buying commercial fertilizer and could directly substitute digester-produced fertilizer for the commercial product, realizing immediate cash savings. In this case, the slurry can be valued at the commercial value. This may not be the case elsewhere. Some people may not be using commercial fertilizer so there is no substitution. Others may not use the slurry from the digester so it has no value to them. In some instances, the farmers may actually be able to sell the slurry as fertilizer, which gives it very high value as an income producer.

This problem is complicated by the lack of empirical studies of the effectiveness of the fertilizer produced by the digester. Moulik quotes Chinese estimates that production increases 10 to 15 percent with the use of this fertilizer, but documentation is scarce. Field unit monitoring is necessary to accurately measure the value of the fertilizer, and we must recognize that this value will vary with location, crops, and farming practices. Several conference participants pointed out, for example, that volatile ammonia in the sludge evaporates quickly, taking with it valuable nitrogen. How the sludge is handled therefore determines how much nitrogen reaches the soil. Conference reports by Zohdy, et al., and El-Din, et al., indicate that work is being done on evaluating the value of biogas slurry as fertilizer, but that much more needs to be done.

SANITATION AND HEALTH

Measuring the benefits to sanitation and public health is the most difficult task. If anaerobic digestion replaces another form of waste treatment, the value is simple to calculate, but this is almost never the case with a household or community system. In most rural areas, waste is not treated and the value of waste treatment is therefore difficult to estimate. Measuring the cost of disease caused by pathogens carried by animal and human waste is extremely difficult. The variables to be considered include:

-the significance of the waste in causing disease

-the effectiveness of anaerobic digestion in making the waste safer

-the illness caused by handling the waste in operating the digester

-the cost to society of treating waste-related disease

-the loss to society in productivity and quality of life resulting from sickness

-the cost and effectiveness of alternative means of treating the waste

-the health effects of burning wood, agricultural waste, and manure, which will be replaced by cleaner biogas.

Once again, we are dealing with a social benefit as much as a commercial product and its value will differ greatly with each application. Even within a single country or a single province, the health and sanitation conditions, needs, and benefits will vary dramatically. Nevertheless, anaerobic digestion has been justified for its waste treatment value alone in the past, and this benefit must be part of any cost-benefit analysis.

FINDING NICHES

Implicit in this discussion of a methodology for evaluating anaerobic digestion is the assumption that a univeral value for biogas systems is unattainable. Unlike a diesel generator that will produce a predictable amount of energy at a predictable cost, biogas systems vary with each application. The purpose of the evaluation is to identify the niches where biogas makes the most sense, the places where anaerobic digestion best fulfills its potential as an integrated technology for producing energy, increasing agricultural production, and improving public health. The production of many outputs depends on the presence of many inputs.

Resources. A sufficient supply of manure is the first prerequisite for anaerobic digestion. At least three or four cows, or the equivalent in other animals, are required to feed a digester. Many rural households lack this basic requirement.

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But this assumes that the animals are kept in a confined area. If they are free grazing, manure is difficult to collect and more animals may be needed. The complementary requirement is water. Solid materials must be mixed with about ten times their volume in water for the digester to work efficiently. In many countries the water supply is the limiting factor.

Conditions. The disappointing production of digesters in the cold areas of China and Korea indicate that a relatively warm climate is necessary for year-round biogas production. In cold climates, an external heat source is required and this is only economic with larger systems.

Materials and know-how. Another crucial assumption about biogas digesters in developing countries is that they will be built and operated by local people with local materials. Buying a digester or even the materials raises the price beyond the reach of those most likely to use the technology. The Chinese digesters are built with local materials and skills for a cost of $400 for a 10-cubic-meter household system. The Taiwanese are able to build $100 bag digesters with cheap red mud plastic covers that are only available in that country. Most Indian digesters include a floating metal gas cap that must be purchased and raises the cost to $1,000 for a household system. And although cheap to build, the Chinese digesters have had trouble with cracks that make the digester ineffective. Better engineering could help, but German engineer Ludwig Sasse explained at the conference that a crack-proof digester is not possible. His solution was painting the inside with a latex paint that would stretch to cover the cracks, but this would mean buying the paint and raising the cost of the digester. Virtually all areas of the world lack the materials used by the Taiwanese for making plastic covers, and in Tanzania, for example, even concrete is hard to find. Most lack the skills and materials the Chinese use in building their digesters, and most lack the knowledge to operate a digester.

Economic_situation. Although inexpensive compared to some energy technologies, biogas digesters are still beyond the reach of most the people in the developing world. On the other hand, for many rural people who have entered the monetized economy, the value of their labor is so high that time spent minding a digester does not pay for itself. A change in government policy changed the economics of digesters for many Chinese farmers, and any farmer risks outgrowing the usefulness of a digester before he has reaped the benefits that would repay his initial investment. The economics can change again, however, for more prosperous operations. A commercial dairy or poultry farm might be required by law to treat its waste, may be able to sell the fertilizer, and may be able to substitute biogas for purchased fuel. In this case, a very promising niche exists.

Size. Different criteria must be applied to household and commercial digesters. The Chinese found that with their design there are diseconomies of scale--larger systems cost more per cubic meter to build and operate. The Indians on the other hand find considerable savings with larger systems. For this reason, India pays more attention to community systems, which are more economical and also allow the poorer farmers to benefit from biogas technology. At some point as size increases, it becomes economical to add an external heat source to increase efficiency. Raising the temperature from 15 C to 35 C can triple the output of the digester. Identifying the point at which this becomes economical is obviously crucial.

In addition to improved efficiency, large digesters are usually more reliable. Training one operator is easier than training many. With large systems, the help of a design engineer might also be affordable, and this can mean longer life and better performance.

Competition_for_inputs. The manure and water that go into a digester have alternative uses. Many people burn manure for cooking fuel or apply it directly to the land as fertilzier. If this manure is now directed to a digester, perhaps by the wealthier members of the community who were not using it before, the net effect may be a decline in the standard of living of the community as a few benefit. Water obviously has many essential uses, and people will resent seeing it poured into a digester when it is urgently needed for irrigation or livestock.

Need_for_outputs. The multiple benfits of anaerobic digestion account for the attractiveness of the technoloigy, but these various outputs are only valuable if they can be used. A poultry farm may have no use for fertilizer and not be able to sell it. A dairy may already be selling its manure for fertilizer and therefore does not have a waste management need. Some places may have a need for fertilizer but doubt the

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efficacy of digestion byproducts for that purpose. They could ignore the fertilizer and buy a commercial product. Some areas have an adequate and replinishable wood supply, and the people may be happy cooking with wood. They would not use the biogas and might not be able to sell it.

SOCIAL AND INSTITUTIONAL FACTORS

Having examined the technical and resource criteria for identifying appropriate niches for biogas plants, the next step is to examine the social and institutional conditions that are necessary for successful biogas development. Several conference participants argued that these considerations are the principal barrier to biogas technology diffusion. Undoubtedly, social and institutional barriers are significant, but they were too often used to explain why naive projections of biogas progress had not been achieved. Many biogas advocates ignored or underestimated the importance of the criteria discussed above. Rather than own up to their technical optimism, they lay all the blame on nontechnical factors. These can, of course, limit the use of biogas, but they become significant only after the primary technical and resource criteria have been met. At this time, these primary criteria have not been adequately understood or applied, so that the optimum niches for biogas development have not been identified. Assuming that a proposed biogas plant meets the primary criteria, the next step is to look at the following social and institutional issues.

<u>Divison of domestic labor</u>. If biogas is to be substituted for fuelwood, one must pay attention to who is going to work at

maintaining the digester. In many countries, women have responsibility for collecting wood. Will they be willing to manage a biogas digester or will handling of animal wastes be considered male work? If women will not manage the digester, will they assume other chores now done by men so that the men will have time to tend the digester? If a community digester is under consideration, who in the community will have the time to manage it, and how will that community service work be valued?

Taboos about handling excreta. While most people in developing countries are not squeamish about handling animal waste, one cannot assume that all are not. Attitudes can differ between men and women, among classes or parts of the country or religions, and among countries. In some countries handling human waste is unacceptable and therefore it cannot be used in a digester. This could mean that the potential health benefits would not be realized and that could change the economics of the system. Or if human waste is used, the people might not want to use the slurry as fertilizer.

Education. People must obviously know about biogas technology before they decide they want to use it, and public information programs can be conducted through state media outlets, agricultural extension agents, local officials, and many other channels. Government officials should be expert at identifying appropriate niches so that they can provide good advice to those who are considering the technology.

Even more important, however, might be the general education of the people. As Dr Harold ~~Howard~~ Capener pointed out, virtually all

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technology diffusion begins with the wealthiest and best educated segment of the population and gradually filters down to the poor and uneducated. Yet, these poor are the potential biogas innovators. People not accustomed to evaluating or adopting a new technology are not likely to change their habits suddenly. This willingness to take hold of a new technology will affect not only their willingness to build the digester but also their commitment to maintaining it. For this reason, in countries where people have a tradition of collecting and using animal waste, it is probably best to introduce anaerobic digestion as a refinement of an existing practice rather than as an innovation. And in all cases, one must keep in mind that innovation does not come naturally to the rural poor, particularly when they do not have a model to follow.

Financing. A biogas digester is a large capital investment for a poor farmer, and access to capital is not easy. Establishing a new institution to finance biogas is not likely to be economical or effective. One should look instead for existing institutions used by the potential users. Agricultural lending institutions could extend eligibility to biogas digesters, or the government could provide incentives to general lending institutions to issue loans for digesters.

Operation and Maintenance. As was noted earlier, biogas digesters are not that simple to operate. Those who are experimenting with biogas for the first time will need help not only with building the digester but with operating it. Smil estimates that in 1979 fewer than half and perhaps only one-third of Chinese biogas digesters were operating. Many countries reported similar percentages of operating digesters. No doubt in some cases there were bad designs that no one could help, but certainly in many cases some technical assistance could have put the digester back into operation. Because this is a new technology, no indigenous expertise exists. Whoever promotes the use of biogas digesters will also have to provide for continued assistance in operating and maintaining the systems.

Private Sector Interest. Several conference participants called for efforts to involve the private sector in biogas development. This has become a common call in discussions of technology transfer and diffusion, and it makes sense when there is a product or service to sell. Oil companies and the manufacturers of diesel engines should and do play an important role in promoting the use of diesel pumps for irrigation. With biogas for the rural poor, however, there is no product or service. Low-cost biogas digesters are only low-cost when they are built by the users. The cost of a commercially manufactured biogas digester is much too high. Virtually none of the 4 million Chinese biogas systems would exist if the farmers had to buy them. Likewise, these poor farmers are not going to buy maintenance contracts for their homemade digesters. And who would be foolish enough to offer them!

The private sector might play a role with biogas systems for large farms, dairy and poultry operations, and food processing plants. For these applications, a well-designed system with a maintenance contract might be a better investment than risking a do-it-yourself installation. Designing and building these digesters would most likely be an indigenous industry because the systems would still have to be less expensive than those sold in developed countries. The Maya Farms system in the Philippines, for example, uses much more manual labor than would be economically feasible in an industrialized country with high wages. In fact, such an indigenous private industry might be the catalyst for the success of commercial biogas installations.

CONCLUSIONS

The preliminary summary of the conference that was distributed on the last day acknowledges the lack of data for evaluating the economic viability of biogas and the limitations of the methodology for conducting the evaluation. Based on this realization the document recommends that:

> "Ultimately, decisions on the economic feasibility of biogas systems must be made on an individual national basis by developing countries in conjunction with the development of supportive economic policies (subsidies, financial support, etc.). The high cost and limited precision of economic analyses of individual site-specific applications of biogas systems indicates that countries should evaluate a limited number of representative sites to more closely define viable economic outcomes."

In spite of this awareness of the limitations of biogas assessment, the summary also claims that biogas can meet up to 50 percent of rural energy needs in some places. This is exactly what cannot be concluded. The upshot of the critiques of data and methodology is that we do not know what can be reasonably expected from biogas. Implicit in these critiques is the understanding that early assessments ignored many limiting factors and therefore grossly overestimated biogas potential. To propose any concrete figure for biogas energy potential, particularly one as high as 50 percent, is to miss the point of many of the conference participants, which is supported in the conference summary.

The summary does make one observation that did emerge from making a more sophisticated assessment of biogas potential: "Small household units (of about 10 cubic meters) appear to be less financially viable than larger community-size units (of about 50 cubic meters) or units treating wastes from industry or intensive animal feed lots due to economics of scale and smaller cash flows." The larger systems measured up better to the detailed criteria developed for defining niches.

The summary calls for improved information flow. It should be emphasized that assessment methodologies are as important as technical data in this flow of information. And like the technical data, the best methodologies are likely to be produced in the developing countries themselves.

This call for a reassessment of biogas potential should not be misinterpreted as a sign of failure. The technology should not bear the onus of naive assessment. Anaerobic digestion has an important role to play in developing countries as a source of energy, a producer of fertilizer, and an aid to sanitation and public health. Putting aside dreams of a biogas digester in every yard does not mean abandoning the technology. The prospects for larger systems may actually be brighter now. If policy makers are willing to stop looking for simple panaceas, they can begin to evaluate anaerobic digestion realistically as an important component of an integrated development strategy. The fading interest in energy as oil prices stabilize might turn out to be a boon for anaerobic digestion because it will enable people to see the value of the nonenergy benefits of the technology. Understanding and evaluating these benefits from the perspective of the potential user is the next stage in the development and diffusion of biogas technology.