Biogas Technology - Solution in Search of Its Problem

A Study of Small-Scale Rural Technology Introduction and Integration

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Abstract

This thesis aims to present and problematise perspectives of processes involved in diffusion of small-scale rural technology in Third World Countries. The focus is on processes that are initiated and upheld by organisations or governments, so-called induced diffusion processes. Diffusion of technology is viewed from two perspectives, (i) introduction of technology and (ii) integration of technology. The introduction perspective relates to how the technology is made available and accessible to the users. The integration perspective relates to the effects of the technology when it is integrated into the livelihood systems of the users.

The diffusion of small-scale domestic biogas units in India was studied. Secondary sources and interviews constitute the main source of information. In India a Government programme promoting biogas technology has facilitated the installation of more than 2.7 million biogas units in rural areas. The users of the technology are the women in the household. Even though this is acknowledged, women have had little influence on the development of the technology *per se*, and the implementation process. The integration of biogas technology in the user's (women) livelihood system raises a number of questions regarding how well adapted the technology really is to the local conditions.

The analysis in this thesis shows that the introduction of the technology has been successful, while the integration of the technology has been less successful in different socio-ecological situations. A distinction has to be made between practical experienced benefits, and potential benefits. While the local knowledge dimension is linked to the practical experienced benefits, potential benefits are based on knowledge from the global knowledge dimension. The gap between these knowledge dimensions makes identification of benefits, or problems that a specific technology solves a crucial issue in the diffusion process.

Keywords: Diffusion of technology, introduction of technology, integration of technology, livelihood, India, rural, biogas technology, energy, gender, knowledge, development, human ecology.

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Abbreviations

AFPRO	Action for Food Production
AICPB	All India Co-ordinated Biogas Programme
ASTRA	Application of Science & Technology to Rural Areas, Bangalore
BOP	Balance of Payment
DNES	Department of Non-Conventional Energy Sources
FYM	Farmyard Manure
GATE	German Appropriate Technology Exchange
GOI	Government of India
HRT	Hydraulic Retention Time
HYV	High Yield Varieties
IARI	Indian Agricultural Research Institute
ICAR	Indian Council on Agricultural Research
IIM	Indian Institute of Management, Ahmedabad
IREDA	Indian Renewable Energy Development Agency
IC	Internal Combustion (in connections to engines)
ICAR	Indian Council of Economic Research
ISI	Indian Standards Institute
IST	Indian Department of Science and Technology
KVIC	Khadi and Village Industries Commission
LPG	Liquefied Petroleum Gas
MNES	Ministry of Non-Conventional Energy Sources
MPCE	Monthly per Capita Expenditure
MTOE	Million Tonnes Oil Equivalent (12.6 TWh)
NABARD	National Bank for Agriculture and Rural Development
NCAER	National Council for Applied Economic Research
NGO	Non-Governmental Organisation
NPBD	National Programme on Biogas Development
NPIC	National Programme on Improved Chulha
NRSE	New and Renewable Sources for Energy
OPEC	Organisation of Petroleum Exporting Countries
PHU	Percentage Heat Utilisation
PRAD	Planning Research and Action Division
PV	Photovoltaic
R&D	Research and Development
RET	Renewable Energy Technologies
Rs	Rupees (Indian money, Rs 35≈US$ 1 in 1996)
SCRIA	Social Centre for Rural Initiative and Advancements
Teri	Tata Energy and Research Institute
TKW	Turn Key Worker
TS	Total Solids
UT	Union Territories

Preface

Rural small-scale biogas technology is fascinating. The input is composed of dung and water, resources that are both part of the rural livelihood. The output consists of both a volatile gas as and nutrient and mineral rich effluent. The gas can be used for cooking, decreasing the arduous task for the women of collecting fuel, and the effluent can be applied to the fields, which results in improved harvests. These aspects on the technology filled my mind when I went to India in 1994 to investigate biogas technology in practice (Gustavsson 1995). The conclusion I made was that many of the benefits described are only potential and will not be automatically obtained.

As a result of the trip questions were formed relating to why biogas had been chosen in India as an alternative energy technology, but also how appropriate the technology really is to the user in their own context. I was given the opportunity to pursue these themes further in a research project at the Human Ecology Section, Göteborg University. The project was initially focused on the choice of the technology, but this was soon shifted in favour of centre around questions regarding the processes involved in the diffusion of technology. Diffusion of technology as the main theme made it possible to discuss such issues as how to transfer technology from one place to another and facilitate this process.

Diffusion of rural technologies is a difficult task. Improved wood-fuel stoves, solar ovens, sawdust stoves, PV-systems for lights are a few different technologies where attempts for diffusion have been made. The results are all too often not very encouraging, even though there are notable exceptions. Even though the diffusion of biogas technology in India, as I see it, is one of the most serious attempts to diffuse a rural energy technology surprisingly little thorough analysis have been made. There is a lot of material on technical issues and general descriptions of the possibilities of biogas technology. Much can also be found concerning the biogas programme itself and about the processes of anaerobic fermentation. But little is found relating to the diffusion process. This study is an attempt to fill this gap.

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1 Introduction

This thesis is concerned with the diffusion of small-scale rural technology in Third World Countries. The focus is on diffusion processes that are initiated and upheld by organisations or governments, so-called *induced* diffusion processes (Cernea 1991). Large amounts of money have been allocated and large numbers of people have been involved in these types of projects. The aim of the thesis is to examine processes of diffusion using the biogas programme in India as the focus of the study. The main question posed here is; *has the introduction and diffusion of small scale, rural biogas technology in India been successful?* Even though India has had one of the most ambitious programmes worldwide to spread the technology, little synthesis can be found on the efforts and results from these experiences.

The main question is broken down into two underlying questions. The first question is concerned with the *introduction* of the technology. *Why and how was biogas technology chosen to be supported as an alternative technology in India?* By looking at the history of biogas technology in India an answer to this is sought. The second question relates to how the biogas technology is integrated into the users livelihood systems[1]; *is biogas technology an appropriate technology to the users?* A specific technology is examined in this study. The characteristics of this technology are put in focus and displayed in relation to the rural user's livelihood systems. The analysis touches upon issues such as how well adapted the technology is to the rural context and the specific livelihood system into which it will be transferred and integrated in. The livelihood system of the user(s) will have to change to some extent due to the *integration* of the technical device.

Transfer of technology as a tool to reach improved living conditions and livelihood is part of many development-projects and programmes. The process of spreading this transferred technology is referred to as diffusion of technology. A technical device can facilitate a solution to a certain problem. A new pump, for example, can make it possible to obtain water from underground. But transfer of technology is associated with several issues, not only related to technical aspects, but also to social and cultural norms and values. Technology is not functioning without affecting and changing people's way of life. From certain angles it is this change of life which is sought by the integration of new technology. When this change is perceived as an improvement to the former situation it is labelled development. If a new technology is transferred into a livelihood system this will have to change in certain respects. Some tasks will no longer be required to achieve the same results and other chores might be added in order to manage the new system.

1.1 Small scale biogas technology-The study

One of the most serious attempts to diffuse a technology to rural areas in a developing country has been done with small-scale biogas technology in India. In theory the technol-

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[1] Livelihood can be defined as *"a means for living, and the capabilities, assets and activities required for it"* (Collins 1991). This means that the livelihood concept more or less include everything that people need and do for their living.

ogy is well suited to meet people's needs[2]. In practice the technology will affect the user's livelihoods in a number of ways both positive and negative. In terms of installed numbers of units and years of use, biogas technology can be considered as one of the most mature biomass technologies (Hall 1993). At the same time there is an uncertainty regarding the results from the introduction of the technology, and regarding the benefits received in practice by the users.

A national government extension and development programme has given momentum to the diffusion process. In 1996 there had been 2,6 million units installed. Millions of people nation-wide had been involved and the daily life of many more had been affected. At present about 200 000 new units are installed per annum and the advocates of the technology argue that there is a potential for many, many more. The first large-scale biogas diffusion program was the All India Co-ordinated Biogas Programme (AICBP) which was launched in 1975. This programme was later transformed into what was called the National Programme for Biogas Development (NPBD). This last programme was launched in 1980/81 and is still (1999) in existence. The potential number of biogas plants is estimated to 12 million units (MNES 1996). This estimate is based on the fact that there are approximately 120 million rural households. Of these 10% are rich enough to own four or more cattle which is the minimum for having a biogas unit (Chandran 1980; Kishore 1996)[3]. Another estimate from 1987 comes to a potential of 19 million units (Kishore 1987). A so-called ultimate potential is set to 40 million small biogas units (Ramana *et al.* 1994a). This is based on available cattle in India divided by four.

The main instrument for diffusion has been subsidies for the farmers to cover some of the investment costs. In addition to this technical assistance, research, and information dissemination have been central instruments. The technology is aimed towards the rural populations. A biogas system is introduced to the individual rural household and the women are the main users and operators. There would probably not be many installed biogas units in India had it not been for the efforts delivered through these national initiatives.

The diffusion of biogas technology stands as the focus for this thesis. A number of studies have been carried out on the subject earlier[4], but it seems these studies are mainly concerned with the implementation of the programme rather than the impact and use it will have on the users livelihood situation. Here these two aspects are seen as <u>necessarily</u> interrelated to each other. The analyses of the diffusion process are taking the point of the departure in both of these aspects and from this lessons of experience can be drawn.

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[2] 'Theory' is here used as opposed to practice, i.e. it manifests a type a ideal picture or function.

[3] When interviews are cited in the text this is displayed by reference markers in *italic*.

[4] Among others see Moulik *et al.* (1975), Vidyarthi (1980), Kishore *et al.* (1990), Turner *et al.* (1994) or Dutta *et al.* (1997)

1.2 Structure of the thesis

The thesis is divided into nine chapters. Chapter 1 is an introduction including presentation of the study and a structure of the thesis is presented. Chapter 2 concerns diffusion of technology from the perspective of rural technologies in third world countries. A perspective for analysis is presented where the focus is put on *introduction* of the technology on the one hand and on the other on *integration* of the technology in the rural livelihood systems.

A discussion on methods and sources used in the thesis is given in chapter 3.

In chapter 4 the fundamental potential benefits from biogas technology are considered and discussed in brief. The aim of the chapter is to give an introduction to some of the driving forces behind the interest in the technology and behind the diffusion.

Chapter 5 is closing in on the aspect of *introduction* of the technology. To establish a better understanding of the rural energy scene a presentation and discussion of this is presented. A descriptive history of the development and dissemination of the technology is given in chapter 6. The history is tied together with some of the important events and processes that occurred during more than 50 years of biogas technology diffusion and development. A discussion of the results from the efforts and some of the problems that have been encountered is made.

In chapter 7, biogas technology's place in the rural context is discussed and reflected upon. The aim is to close in on the *integration* aspect of the diffusion process. A framework called 'user perspective' is created and applied on the biogas technology. The user perspective relates conditions for successful biogas operation to the livelihood situation for the users.

In chapter 8 a summary of the findings from the study is made. Four main themes are found. First, the focus is on biogas technology as an energy technology while many of its merits lie in other aspects. Second, the role of the user in the diffusion process is discussed. Third, some remarks on the results of the biogas programme are given. The forth part is devoted to look at why biogas technology was chosen to be supported in India.

Chapter 9 is a synthesis, aiming at bringing the lessons from the study back to the more general level on diffusion of technology. A discussion on implications between knowledge and the diffusion process, including the aspects of introduction and integration is made.

An appendix describing anaerobic digestion and principles for biogas technology is found last, along with a brief general description of the technology and appliances.

2 Diffusion of Technology: Potentials and Challenges

The diffusion of a technology includes a number of events. First a certain technology has to be selected for support and thus a choice has to be made. In case of planned projects other people than the users often make this choice. After selection there is a dissemination and extension phase. Creation of appropriate structures and structures of monitoring are used to control that the extension work will be carried out in according to plan. Standardisation is a tool to keep costs down and to control the quality of the system(s). The measures may, paradoxically, work against adaptation and technical development of the technology. There is a risk that technology that is uninteresting to the users is diffused. Technologies are often found to have undergone a process of technical improvements and development after some years of diffusion. A continuous development should ideally take place (Barnett 1990). This has in turn led to the analogy of evolution that favour networks rather than hierarchies and implies that strong feedback mechanisms are prevalent. The problem with this approach to diffusion is that the potential of standardisation and hence cost reduction is reduced, and the processes are no longer possible to control from a central position.

Barnett (1990) divides the theoretical discussion of diffusion of technologies in rural areas in third world countries into a number of historical phases. The early phase, around the 1960's, focused on the "social-psychological" systems examining the adopters and communication between these systems. One of the main neglected issues here was, however, the characteristics of the technology. This was later identified as an important factor and the focus shifted towards the needs of the user's. Along with this, the users participation in the diffusion process became a key word in the theoretical discussions on how to reach an efficient *induced* diffusion. Together with the participation aspect, the importance of adaptation of the technology became clear.

The discussion above shows that there are different dimensions on the diffusion process. A framework that can be used to analyse an already existing diffusion process is to analyse it in terms of *introduction* of the technology in society and *integration* of the technology in the users livelihood systems. The *introduction* aspect concerns basically the dissemination, and the extension work. It also concerns structures for feedback, monitoring, and planning. The use of the technology is basically measured through different feedback mechanisms in the extension structures. The central issue here is to give the users access to the technology.

For the user, the technology will become a part of the livelihood system. We can look at this from the perspective of how the technology is *integrated* into the users' lives. It is not so much a question of the physical technical device but rather the access to the technology, i.e. the possibilities the users have to utilise and benefit from it. In order for a technical device to be accessible for a user, input resources have to be available. There are also requirements on know-how, and certain economic conditions have to be met. Incentives for use will have to assured. Without meeting these requirements it will become more difficult to achieve an *integration* of the technology. These requirements, however, will not prevent an *introduction*. The new device will (often) be *integrated* into a context where some or all the services it provides are already provided by other technologies. This means that it will be necessary to compare it to the livelihood system already existing, in order to be able to say anything of the benefits that can be delivered by the technology.

The two aspects of the diffusion process can be seen as complementary to each other. A successful *introduction* may ease the *integration* and vice versa. They are not dependent on the other however, a technology might very well be efficiently *integrated* but not successfully *introduced*. The alternative that is supposed to be diffused might however be more efficient or be an improvement on the existing system. This means that often there will be something that the diffused technology can be compared to. In connection to the *integration* aspect of diffusion of technologies the context into where the technology is placed will become of great importance. This is not the case from the *introduction* point of view, as this aspect is more centred around questions concerning how to give people access to the technology.

Agarwal (1985a) argues that a number of analytical distinctions can made regarding rural technologies or innovations. These distinctions depend on what type of output the technology will create and what type of investment in the device that has to be made. Agarwall does not make the distinction between *introduction* and *integration* but the distinctions are basically concerned with an *integrative* aspect as it relates to how the technologies will function in the livelihood systems of the users - technologies are contextualised. The following distinctions are made (Agarwal 1985a):

1. Technologies representing private financial cost and yielding private production financial benefit (e.g. high yield varieties (HYV) crops, tractors)
2. Technologies representing private financial cost and providing private non-financial benefit (e.g. watches, radios)
3. Technologies representing private financial or non-financial cost and providing private financial savings benefit (e.g. biogas system in case of replacing purchased fuel or reducing use of chemical fertilisers)
4. Technologies representing social/communal financial or non-financial cost and providing an individual financial production benefit (e.g. irrigation canals)
5. Technologies representing social/communal financial or non-financial cost and providing an individual non-financial consumption benefit (e.g. piped drinking water)
6. Technologies representing social/communal financial or non-financial cost and providing an individual financial or/and non-financial consumption saving (e.g. contraceptives)

One category further can be introduced which represents:

7. Technologies representing private financial and non-financial cost and providing private non-financial (savings) benefit (e.g. biogas system in case of replacing gathered fuel (free of cost) and manure already used as fertiliser)

An economic investment has to be made, as the device has to be purchased. The device will however not produce any financial benefits or savings, but can deliver other non-economical benefits such as improved living or working conditions.

Depending on the user's livelihood system a, rural technology can fall under several of the above categories. From this we can conclude that even though the same technology is diffused it might be received by the users differently and hence making the *introduction* and *integration* of the technology shifting in character. Barnett (1990) argues that technologies representing a private financial cost and provides a non-financial saving benefit are the ones most difficult to diffuse (number 7 above). An investment has to be made even though there will be no direct economic return. Many of the small-scale energy technologies, like improved stoves and solar ovens, diffused in Third World countries fall under this category. Target groups for many of these devices belong to low or middle-income groups. Energy is mainly needed for cooking and the main part of this energy is covered through collected biomass[5]. Many users consider this resource not being linked to any direct monetary costs (Agarwal 1983; Hall 1993).

2.1 Strategies to achieve development

> *Development involves structural transformation which implies cultural, political, science and economic change. Development theory is therefore by definition interdisciplinary… (Hettne 1990).*

Development concerns change. To acquire change processes are needed. These processes are planned and that are the aim of development planning; to plan and to reach the intended goals[6]. When it comes to planning development, diffusion of technology becomes a central process. Technology available in one place can be transferred to another place and by this other people can benefit and initiate or increase a development process momentum. This transfer can be seen as a diffusion process where the technology is available in one place and then spreads to other places.

Development can be divided in terms of planned (or induced) development, and spontaneous development (Cernea 1991). I am here interested in development through planned or induced technology transfer or to be more specific through planned or induced diffusion of small-scale rural technology in third world countries. Elaborate planning is performed in order to achieve the desired goals of the development. The idea is often that the induced diffusion process, which always includes intervention in one way or another, shall undergo a transition and achieve its own momentum and finally end up as a more spontaneous diffusion process. Through this transition the project will continue even although intervention can be reduced to a minimum.

Under the overarching concept of development a number of different sub-groups to development can be found, for example rural development, sustainable development, or eco-development. These can also be described as strategies or policies that aim toward

[5] Biomass fuels are fuels that are derived mainly from plant biomass and includes both the raw form of the resources such as wood-logs and so on, but also converted forms, such as seed-oil and biogas (Hall 1993). A more detailed discussion on biomass resources and their use, see for example Ravindranath *et al.* (1995) and Hall *et al.* (1992).

[6] For further reading on development see for example Hettne (1990) or Esteva (1992).

creating development that solve a specific problem. For example, many of these strategies are concerned with resource depletion and improving the living conditions for the weaker sections of the society. When these strategies are implemented they aim towards taking these aspects in special consideration.

In each strategy a 'problem' is identified or considered to exist, which should be solved[7]. In order to solve a specific problem various technologies can be used. However depending on the type of development strategy that is adopted the solutions can vary. For example piped water connected to kitchens might not benefit people without permanent houses, while the same system but with taps in public places might do this. The latter would be a more appealing solution if the focus were set on development for the weaker sections of society. Thus it is possible to compare the different strategies in terms of development goals and means to achieve these goals. A brief presentation of the strategies relevant to diffusion of biogas technology will be done here. This exercise is intended to briefly summarise some of the important features of the different strategies.

Similar to 'development', *rural development* can also be seen as an over-arching development classification based on a spatial categorisation. *Rural development* is however also a development strategy with goals described by Chambers (1983) as:

> *"a strategy to enable a specific group of people, poor rural women and men to gain for themselves and for their children more of what they want and need… The group includes small-scale farmers, tenants, and the landless" (Chambers 1983).*

Rural development has been and is an important part of national Indian planning. About 74% of the total Indian estimated population of 960 million (1997) live in rural areas (Baru 1999; CSO 1999).

In the latter part of the 70's an *'integrated'* was put before rural development leading to a slightly different meaning of the concept. *Integrated rural development* should not only consider the specific groups of rural people, but should also consider (optimal) use and development of local resources (Subramanian *et al.* 1987). The distributional aspects of the development were in focus.

In the mid 70's to the late 80's two strategies for development, *appropriate technology* and *eco-development*, became more widely spread. Both of these strategies have goals connected to improved resource management and minimisation of negative environmental impact. Whereas *appropriate technology* is basically a means to achieve development, it has been closely connected to rural development and the aspects of improved resource use and hence often used as a strategy with a goal in itself. There are numerous definitions of *appropriate technology* but there are some characteristics that appear in most of them. Two of these characteristics are the use of indigenous materials and small-scale production (Dudley 1993). Definitions are often found to be quite vague in that they are not stating for whom they work of and what they supply. One definition for example states that:

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[7] Gass *et. al* (1997) argue that the problem-solving approach is a central notion of what is often referred to as a top-down development intervention tradition.

> *[Appropriate technology] is […]; a set of techniques which make optimum use of available resources in a given environment (Vaa 1993).*

The stress here is laid on resource utilisation, but nothing is said on whose resources or who is to chose which resources, although the management aspect is set in a central position. A critique of the technologies advocated under the umbrella of appropriate technology has been that they are sometimes seen as second rate by the beneficiaries and useful only as long as technologies preferred by the users are not available (Dudley 1993). The problems and solutions identified within the development strategy frame are not the ones identified or considered by the people. *Appropriate technology* has played an important role in pursuing a wider understanding of what technology really means and what it does to the users. Many of the technologies advocated in developing countries today are often referred to as appropriate technologies, for example improved stoves and biogas technology.

Eco-development is a development strategy similar to rural development but with an environmental focus. One definition can be found in Glaeser (1995b): "*Eco-development is a strategy based upon satisfying the needs of the poorest individuals in society, a strategy which brings about accelerated economic development without its attendant negative ecological impact".* Eco-development takes a strong position regarding the impacts development could have on the environment. The goal of this development strategy was not only found in improved conditions for the people, but how to achieve this without negative environmental impacts. The strategy was soon overshadowed as in the 1980's the strategy of *sustainable development* emerged on the scene.

Sustainable development gained immense publicity through the publication of the Brundtland Commission's report "Our Common Future" (WCED 1987). One often cited definitions of sustainable development is taken from this report and states that sustainable development is *"A development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs"* (WCED 1987). Sustainable development concerns not only local and regional problems, but also concerns global issues. The goal is to preserve the earth as a place to live on for future generations. The means to reach, or rather live by this goal, varies much. The concept of sustainable development has been closely attached to diffusion of renewable energy technologies[8].

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[8] *Renewable energy sources* (RES) refers to energy originating from resources having relatively short cycling times, i.e. flowing resources. These sources are often seen in contrast to the non-renewable energy sources, such as fossil based fuels and nuclear energy. However a renewable resource can very well become non-renewable if the utilisation exceeds the cycling capacity. RES started to be discussed more widely after the oil crisis and the publication of the limits to growth study (Meadows 1976). The more recent report from the Brundtland Commission (WCED 1987) also discussed the issue of the need for a transition from use of non-renewable to renewable energy sources. Technologies that use RES are often referred to as renewable energy technologies (RET). Examples on texts concerning RES in developing countries, see for example Foley (1992) or Kristofersson *et al.* (1986b).

One of the most exciting trends over the past years is the increased focus on participation by the beneficiaries, in the development process. *Participatory rural appraisal* (PRA) emerged (along with a number of other participatory methods) during the 80's and 90's as a reaction to this[9]. PRA is a means to achieve development, similar to for example appropriate technology. Today these techniques are thoroughly accepted. It should be pointed out that involvement of grassroots in the development process is a central idea in most of the development strategies discussed above. But while PRA techniques take (ultimately) its point of departure in the people's development needs, the strategies discussed earlier can, but are not forced to do this.

One central issue to consider here is what and whose 'problem' actually is pursued in a development project. It seems as if the development arena is self-generating in 'problems' while issues that really concern people are not identified or lies outside the mandate of the specific development program. Questions like safe drinking water supply and secure health service are questions that are often found to be more important to the people, than to meet questions relating to energy supply (McGranahan *et al.* 1993). At the same time the basis for the identification of difficulties varies between people, classes and gender.

2.2 Technology - some points of departure

The concept of 'technology', as it will be used here, relates to more than the physical device or structure. Technology, apart from the physical device, also includes cultural and social values, which are linked to the users' context. In some terminology hardware and software is used to differ between the device or physical artefact and the knowledge and relations the user will have to it. In computer science, where the terminology also is found, software is a separate part, developed for the computer hardware. This is hardly the case for many other technologies where the software is as much a part of the hardware as the hardware is a part of the software. The distinction in hardware and software is however not always applicable as the hardware and software are too tightly connected in real-life situations. There is no clear difference between the soft parts of a technology and the hardware.

A definition of technology taken from the economic field states that:

> *…technology can be defined as a combination of (i) physical capital (equipment, hardware, etc.); (ii) human resources and skills (human capital and labour); and (iii) intangible technological assets (logistics, organization, systems, etc.) (United Nations Conference on Trade and Development 1990)*

The categories fall to some extent under the hardware/software distinction but here also including surrounding systems and structures that function as basis for access, improvements of the technology. Taking the step to a more clear social science perspective of technology the concept tends to have its parts more integrated into each other. For example, Vaa (1993) argues that technology can be discussed in terms of everything

[9] For an introduction see for example Chambers (1994b; 1994c; 1994a).

pertaining to the transformation of inputs to outputs. This would mean that there are no clear limits to what is the technology and what is not, technology is defined through its service, or function rather than the physical device. Hence labour and social organisation becomes important as they are linked to the outputs and inputs of the technology.

I will briefly summarise how 'technology' is used in this text. Firstly it should always be seen as more than the physical structure. Secondly the context in which the technology is found often plays a central role in how the technology is used and performs, for example know-how and skills of the users are important aspects. This means that it can be difficult to discuss performance of a specific type of technology in general without connecting it to certain cultural and social conditions. This last aspect indicates that just because a technology works in one context it is not certain that it will work in another place or context, i.e. a technology depends on the context in which it operates. Diffusion of a technology is thus not a question of only to supply the technical devices to people. For successful adoption or integration of the technology, consideration has to be given to know-how, skills, and social and cultural aspects in the context where the device will be operated.

3 Methods and sources of information

The field that this thesis covers, ranges over themes such as the social structures for dissemination of the technology, technical aspects of innovation and operation, social and cultural aspects of use and management of the technology and also biological conditions for maintain an anaerobic digestion process. The interdisciplinary (human ecological) approach to the problem enables the researcher to use knowledge and information from various fields to create a synthesis. One example of this in the case of biogas technology is requirements set from a biological point of view on the quality of the dung in terms of chemical parameters such as carbon, protein, and fat content. At the same time physical aspects viscosity (water content) of the slurry also exist as well as social (and cultural) practices of cattle keeping and handling of dung. Keeping all of these aspects in mind when closing in on the issue of biogas use and management is believed to yield a better understanding of the situation.

A descriptive approach was used to close in on the main question; *has the diffusion of small scale, rural biogas technology in India been successful,* posed in this thesis. The question relates to a general understanding of the diffusion process. The approach made should be from a national perspective of the two aspects of diffusion, i.e. *introduction* and *integration,* rather than through case studies in a local area, something that has been done earlier (Gustavsson 1995). The *introduction* aspect relates to development, implementation, and extension of the biogas programme, and the *integration* aspect relates to the use, management, and incorporation of the technology in the livelihoods of the user's.

Written sources form the main information source for this thesis. These sources are combined with a number of interviews carried out with people in India that have played roles in the diffusion process. Various types of text-sources have been found, ranging from unpublished material and short articles to policy and evaluation reports. Much of the literature found on biogas for example is written as reports on projects or field works. In these reasons are given to why this or that happened and explanations to why this or that did not happen. The people involved in the monitoring are perhaps biased to a certain limit to what they believe the clients wants to hear in order to continue or receive new assignments or project funds. This makes the analysis of the results from these types of sources especially difficult (Chambers 1983; Dudley 1993). A critical reading of the available texts has been important to keep a high degree of validity.

A large number of texts related to the biogas technology were procured after extensive search in different databases. From these a selection have been made. Many of the publications found are concerned with some specific technical aspects of biogas technology, for example Khandelwal (1978), Sasse (1986) or Raman *et al.* (1989). Other publications focus on different aspects of the biology and ecology of anaerobic process, for example Temmes *et al.* (1987) or Kulkarni *et al.* (1990). These falls outside the scope of this thesis and has therefore only been briefly examined. Texts that do not concern the Indian experiences have to a large extent been excluded. However titles covering the technology in general has been considered. Experiences with biogas from countries on the Indian sub-continent such as Nepal, Bangladesh, and Sri Lanka have been taken into consideration.

Information concerning the experiences from China's biogas programme is quite rare but some is available. This information has been examined as the Chinese experiences have played a role in the assessment of biogas technology in general.

As a complement to the written sources, interviews were carried out during a field trip to India at the end of 1996. Some of the key-actors in the field of biogas technology introduction and dissemination in India were contacted and interviewed.

Interviews were carried out with Dr T. K. Moulik who has been involved in evaluation and monitoring of biogas technology over the last 25 years *(Moulik 1996)*[10], Dr. J. B. Singh former director of the NGO Action for Food Production (AFPRO) *(Singh 1996).* Dr J. B. Singh was one of the key-persons in AFPRO's biogas program, today he is with the consultancy firm South Asia Partnership-India. Mr A. Dhussa, Director at the Ministry of Non-Conventional Energy Sources (MNES), Government of India (GOI), was also interviewed *(Dhussa 1996).* An interview was also made with Dr V. V. N. Kishore at Teri in New Delhi *(Kishore 1996).*

To cover issues related to the practical side of dissemination and extension of biogas technology interviews were carried out with some people more involved with this. Mr S. Nathan *(Nathan 1996)* at AFPRO, and Mr M. Paul *(Paul 1996)* both at AFPRO, and involved in this organisation's biogas programme, were interviewed about AFPRO's work and their experiences with implementing a national biogas programme. The Director of the NGO Social Centre for Rural Initiative and Advancements (SCRIA) Mr S. Lal *(Lal 1996)* and Mr N. Sharma *(Sharma 1996)* were interviewed in Haryana. They are involved in practical development and extension of biogas technology. At this level the interviews became more case oriented but still some more general concerns were discussed.

The qualitative form of interview was chosen to enable the informants to give complementing information to themes that to some extent I already had information about. The semi-structured form of interview made it possible to follow lines of conversation that could not be anticipated before the interview. Every method has its strengths and weakness. In the case of the semi-structured interview each of the interviews will be unique and cannot easily be compared to another.

The interviews followed prepared themes, which were discussed with each of the informants; the first theme concerned how the informant looked upon the history of diffusion of biogas technology in India. The main ambition here was to gain a picture on how different people looked upon this process. The literature concerning the subject is rather vague and is usually more focused on the technical development than the diffusion process. The second theme was to close in on what the results from the efforts discussed in the first theme were. The last theme focused on possible lessons of experience that could be drawn from the diffusion of biogas technology. Each interview took 1-2 hours. All interviews, except the interview with A. Dhussa, were recorded on tape. During the interviews short notes were also taken.

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[10] When interviews are cited in the text this is displayed by reference markers in *italic*.

One aspect that has not been elaborated in this thesis is the multi-caste, multi-class social structures of Indian rural society. The point of departure of this thesis is a general analysis of the introduction and integration of biogas technology. The caste and class structures are much too case-specific to be counted for here. If an analysis of a case specific project should be carried out these aspects of the diffusion process should be taken into consideration.

4 Biogas technology - A sustainable, green, appropriate, gender aware, cost effective and just (energy) technology

There are a number of *potential* benefits that are usually mentioned as the rationale behind the choice of biogas technology. These potential benefits can be seen as driving forces for biogas introduction and can be divided into:

- Energy-related benefits
- Fertiliser-related benefits
- Health-related benefits
- Development-related benefits
- Economic benefits

At face value there are potential benefits on all levels in the society. The benefits are here considered at four levels: national-, regional-, local- and individual level. The national level accounts for India as a country, while the regional level is state, district and in some cases block depending on size. Panchayats[11] and villages account for the local level, while individual level concerns the person(s) involved with the use of the gas and management of the unit. It is normally the women of the households that are in charge of carrying out these chores.

4.1 Energy-related benefits

Biogas produced in a small-scale biogas plant is an energy source that can be accessed in rural areas[12]. The gas can replace different commercial fuels such as liquefied petroleum gas (LPG) and kerosene as well as non-commercial[13] fuels such as wood fuel, dried dung-cakes, and crop residues.

When biogas is an alternative to fossil based fuels it is, on a national level, considered to improve the balance of payments (BOP) since less oil products have to be imported. On a regional and local level, transportation and infrastructure for distribution of these fuels/products will not be required to the same extent. On an individual level the use of biogas will result in reduced monetary spending on fuel since biogas is made from dung and water, which are available for free.

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[11] Panchayats are local or city councils.

[12]Since cattle dung is the main feedstock for biogas production it is difficult to manage a biogas unit in areas where the households do not hold any larger number of cattle i.e. urban areas.

[13] The distinction between *commercial* and *non-commercial* energy sources is not based on, as one could mistakenly suspect, whether the resource holds an economic value or not. *Non-commercial* fuels are a general term that refers to fuels that is derived from plant and animal material (Paga *et al.* 1991). This means that the end-use can vary and that they can be sold and still be called *non-commercial.* Another category of energy sometimes seen is *Traditional fuels* which refers to the traditional practices and resources that have been used over long periods of time (Kaale 1990). Among traditional fuels fuel-wood, dried dung cakes can be found, whereas biogas is not.

If biogas is used to substitute for non-commercial fuels the picture will be different. On a national level we will basically find benefits from reduced deforestation since the pressure on land for wood is said to be reduced (Sasse 1990; Ramana *et al.* 1991). However, there are few signs, if any, that the pressure for wood on the forest would decrease through the introduction of biogas technology. One explanation is that the rural people themselves do normally not use living trees for fuelwood (Reddy *et al.* 1983; Dutt *et al.* 1993).

On an individual level the main benefit is the time saved on wood collecting which in some area accounts for many hours of daily work. In some areas wood is bought at the market and in these cases the benefit will be a reduced cost for the household. There may be less time spent on collecting fuelwood. But the 'saved time' benefit should be seen as a switch of chores where the new ones for operating the biogas unit are thought of being less than the fuelwood collection. Instead of spending time collecting firewood, time will have to be spent daily on getting water to the unit and mix it with cowdung to ensure the necessary input to biogas unit.

4.2 Fertiliser-related benefits

Biogas technology can change the management of the cattle dung and use of this resource as an organic fertiliser. The actual value of this benefit is however dependent on how the dung was used prior to the installation of the biogas unit. If the dung was used as a fuel and burned or just not taken care of, biogas technology will improve the management of biological fertiliser. On a national level the BOP and costs for subsidies to chemical fertilisers can then be reduced. On an individual level the expenditure on chemical fertiliser and soil conditioner might be reduced.

Several field trials investigating the value of the effluent as a soil conditioner have been carried out. The conclusions from these trials show that the effluent is a good fertiliser (Dahiya *et al.* 1986; Moawad *et al.* 1986), and it has even been proposed that the effluent holds better values than the farmyard manure (FYM) (Bhatia 1977). However, in farm practice the management of the slurry differs from those during the trials. The effluent is for example often dried on the ground, exposed to sunlight, which leads to diffusion of ammonium nitrogen to the atmosphere and denitrification of the nitrate. This practice will decrease the quality of the slurry.

If the manure already was used for fertiliser, the difference due to the installation of a biogas unit will not be very significant from a fertiliser point of view. There will of course be a change in handling of the resource, but there will be little or no economic or other effects in relation to the 'fertiliser' benefits.

4.3 Health-related benefits

The main health benefit is gained through the improved indoor environment. One of the most severe health problems in rural India is connected to indoor air-pollution (Smith 1993b). There are many designs of the traditional Indian *Chulha* (fireplace i.e. stove). A common feature among many of these is that there is no chimney attached to them (Sarin *et al.* 1989). The absence of a chimney makes the kitchens filled with smoke that affects the women and children who spend much time there. The high exposure to health damaging pollutants in the smoke are, according to Smith (1993a), associated with four major categories of ill-health:

- "Acute *respiratory infections (ARI) in young children*": Mainly pneumonia, which is the number one killer of young children worldwide.
- "*Adverse pregnancy outcomes for women exposed during pregnancy*": Smoking is a known risk factor and as many of the pollutants in tobacco smoke also can be found in biomass smoke there is cause to think there is a risk here as well.
- "*Chronic lung diseases and associated heart diseases in adults*": Tobacco smoking is the main risk factor here. However studies have, according to Smith (1993a) shown that non-smoking females cooking on biomass stoves have shown higher prevalence of this conditions than expected. Relation between reduced lung function and indicators of indoor airpolution from coal or biomass has been shown in several studies[14].
- "*Cancer*": Many chemicals known to cause cancer can be found in biomass smoke.

On a national level the main benefit will be from reduced spending on health care while on individual level improved health and lower susceptibility to disease will be positive aspects. The situation at the user level is normally that biogas is supplemented with another source of fuel such as wood or crop residues. Due to this, the smoke reduction will not always be as large as anticipated. The actual improvement in health for the user due to introduction of biogas technology has not been assessed.

There are also a number of sanitation improvements that are usually taken up as potential benefits of biogas technology. Firstly the stabilisation of the organic compounds through the fermentation process is believed to attract less flies to the dung heaps. There are some indications that flies would be less attracted to the fermented slurry (Dandekar 1980; ISAT 1997) but there seems to be little clear evidence for this. One side effect of the biogas technology is that handling of the dung will be more controlled, which could affect the fly population. Secondly there is a certain reduction of pathogens and parasites, which are found in the cattle dung, during the fermentation process[15]. As the feedstock is only from cows and bullocks there is not so much problems with animal-parasites. If human faeces or pig manure is used as feedstock instead, which is seldom the case in India, there should be more concern taken to ensure that the effluent is taken care of properly. There is however no such thing as a total removal of all parasites due to the anaerobic process.

4.4 Development-related benefits

On a national level the dissemination of biogas can be viewed as a rural development programme improving the situation for the rural population. During the end of the 70's,

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[14] See for example Smith (1996) for general discussion and Ellegård (1997) on health in connection to smoke exposure in urban areas.

[15] The reasons for this are two. First, the anaerobic bacteria reduce the available amount of prime substrates (such as fatty acids) to strive upon (Langley *et al.* 1959). Second reason relates to that pests are trapped inside the digester by sedimentation and viruses are aggregated to sludge particles (Ellegård 1990).

the energy situation in rural areas came into focus and a so-called rural energy crisis was identified (Makhijani 1977). Biogas technology was seen as a way for the government to improve the situation. Women, as the main users of the technology, would improve their livelihood situation. This aspect was given a central role in the propagation for diffusion of biogas. Another issue that gained attention was the employment opportunities created by biogas technology diffusion. Both masons and extension workers would be needed on a regional and local level in order to install units and manage the programme.

There are aspects of global concerns generated through biogas technology. The decrease in diffusion of greenhouse gases is one example. Biogas can be an alternative to fossil-based fuels, which affect the net amount of carbon dioxide emission to the atmosphere. Atmospheric methane is another gas contributing to the greenhouse effect. Leaking methane from biogas technology is, however, not likely a significant source for global increase of atmospheric methane (Khalil *et al.* 1990). The technology has been advocated as a renewable energy technology as well as a sustainable resource. A situation where non-commercial fuels in developing countries are replaced with fossil-based ones is not desired from the global-community.

4.5 Economic benefits

The economy of biogas technology is often brought forward as one of its main drawbacks on the local level[16]. Still, the potentials of the technology are often assessed in economic terms. The investment in a biogas unit will result in savings, mainly non-monetary, rather than earnings. This is the case both on a national level and on a local and individual level. There has not been any assessment concerning the actual economic impact of the diffusion of biogas technology. Nor are there any regional analyses of the impact of biogas technology. Due to this the actual economical benefits on these levels cannot be estimated. In the case of individual economic savings there are a number of assessments (ICAR 1976; Rubab *et al.* 1995; Biswas *et al.* 1997). Many of these are, however, only considering a theoretical potential, which is often quite different from the actual situation. For example the production of gas is fluctuating due to changes in input and seasonal variations.

4.6 Conclusion

One of the main features of the potential benefits is that they are only valid under certain conditions, for example one has to consider what type of fuel was used prior to the installation of the biogas unit. Biogas technology has the potential in theory to deliver considerable benefits to its users, but the situation in practice looks somewhat different as I have briefly touched upon in some cases.

A summary of the above briefly described potential benefits from biogas technology is displayed in a matrix below.

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[16] The economy of biogas technology is discussed in more detail in the section *Money: Earning money through saving expenses* on page 63.

	National level	**Regional level and Local level**	**Individual level**
Energy, repl commercial fuels	Improve BOP	Reduce transportation and need for infra structure	Reduced spending
Energy repl non-commercial fuels	Reduced cost for afforestation	Environmental impact	Less time spent on collecting fuel
Fertiliser, if manure not used prior	Improve BOP	Reduce transportation and need for infra structure	Reduced spending on fertilisers
Health	Reduced spending on health care	Increased labour availability & equality	Improved health
Development	Rural development Sustainable development	Create employment	Convenient fuel
Economy	n.a.	n.a.	n.a.

Table 1: Potential benefits from biogas technology

Even though all these benefits undoubtedly potentially exist, it is interesting to note that the biogas extension process has not, except in a few regions, attained a spontaneous diffusion. All of the alternative energy technologies that are advocated as solutions for rural people have to face the real life of these people and have to stand the test of reality. Do the nice colour brochures and wall charts promises stand true after a year or two? Does health improve, will the household expenditures decrease and will you be able to turn the valve and have your fuel each day? There is no clear 'Yes' to this question. Looking at the potential benefits that can be the results from the technology and comparing them with the results there is a gap. The potentials are to a great extent what is described in literature and also what is popularly spread as the image of the technology as well as what it can deliver to the user. When the device is placed in practical application the management and operation of the device will prove which benefits can be attained. This theory-practice gap is one of the problems of biogas technology but not unique for biogas technology. Similar gaps have been noticed in, for instance, the improved *chulha* case (Gill 1987).

5 Rural energy in India

> *"Our scientific and technological efforts have led to the development of a variety of technologies suited to the needs of our people. One of the most notable of these is bio-gas" (Srinivasan 1982).*

There are many reasons to why biogas technology came to be supported as an alternative rural technology by the government of India and other organisations. The aim of this and the following chapter is to look in more detail on the aspect of *introduction* of biogas technology and focus on why and how biogas became one of the most advocated alternative energy sources in India. Trends of energy utilisation indicates that commercial energy sources become more and more important, not only for urban areas but also for rural. The increased population and participation in the monetary economy to a higher degree can partly explain this transition. In this light biogas technology stood out as a good and sound alternative. It should be recognised that biogas is not an alternative for the many poor of rural India. There are requirements that have to be met by the household, in terms of number of cattle available (dung) as well as possibility to make an initial investment, which is quite substantial in this context.

5.1 The Indian rural energy situation

The energy scene has changed quite drastically over the years that biogas technology has been promoted in India, i.e. from the 1950's to the present. Even though it is argued that biogas technology should not be seen as solely a technology for energy supply, it is necessary to give a brief overview of the energy scene in India in order to put the biogas efforts in a context. Biogas technology has often been regarded as an energy-supply project[17]. The programme for dissemination of the technology is today found under the Ministry of Non-Conventional Energy Sources (MNES).

National development policy has for a long period of time, since 1960 at least, been directed towards creating an infrastructure for energy distribution and energy production of both commercial and non-commercial energy sources. The energy need of rural people is basically energy for domestic purposes and then especially for cooking. These areas have to a large extent been self-sufficient in energy, i.e. people have been dependant mainly on gathered non-commercial sources.

If, on the other hand, the energy used in goods, such as chemical fertilisers, were included, the picture of the energy use patterns would change, and the dependency of commercial energy sources would rise.

One of the indirect reasons for rising commercial energy use is the increased use of chemical fertilisers, as the processes involved in the production have a high-energy input. The Phosphorous (P) and Potassium (K) parts are normally mined, whereas the Nitrogen (N) part is extracted from the air in an energy demanding process. A rough estimate is that

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[17] See for example Bailey (1976), Kumar *et al.* (1977), Guldager (1980), Kristofersson *et al.* (1986b), Hall *et al.*(1992), or Sinha (1994).

the Nitrogen part is 5 times more energy demanding then the P and K parts (Sherff 1975). The production of the fertilisers is often made with different types of fossil based fuels (Ishiguro *et al.* 1995). Chemical fertilisers are further on an expense for the Indian government. Governmental subsidies are given to keep the price down (World Bank 1998). Their use also affects the national balance of payment negatively. It is in this light that biogas technology can be seen as both energy supplier, direct in the form of gas, and indirectly in the form of decreased use/need of chemical fertilisers[18].

Figures given for the use of non-commercial energy sources are usually quite unreliable because the information is to a great extent based on sample surveys, which is then translated into more general estimates. The ecological and socio-economic diversity makes it difficult to extrapolate such data to a good estimate. Field surveys with more detailed information on a specific area or case can then be used for comparing the estimates done from sample surveys. The figures on non-commercial energy vary much between different sources[19].

Looking at the use of energy in India over the past years it has increased from about 90 MTOE/year in 1953/54 to 370 MTOE/year in 1996/97. There are several reasons for the increased energy use. The increase in population is one. In 1950 about 360 million people lived in India whereas in 1995 there were about 930 million citizens, an increase of about 2.5 times (GOI 1992; World Bank 1997). Along with this an improved living standard for the average population in India, which has been taken place which is partly illustrated by the increased national GDP. Another reason for the rise in (commercial) energy use can be traced back to the increased demand of oil products for industry and transportation. The increase in energy use has taken place for both commercial and non-commercial fuels, from 90 MTOE in 1953/54 to about 370 MTOE in 1996/97 (GOI 2000). The ratio between commercial and non-commercial energy use has changed. The distribution between these sources has been plotted in Figure 1, indicating that the trend is towards increasing rates of commercial energy use.

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[18] The net output in energy terms from the harvest will decrease substantially through use of chemical fertilisers instead of organic fertilisers (Dahiya *et al.* 1986). On the other hand the net output in terms of production of food can be substantially increased through the use of among other things chemical fertilisers.

[19] More on the uncertainty of data and information on non-commercial energy use, see for example Teri (1998).

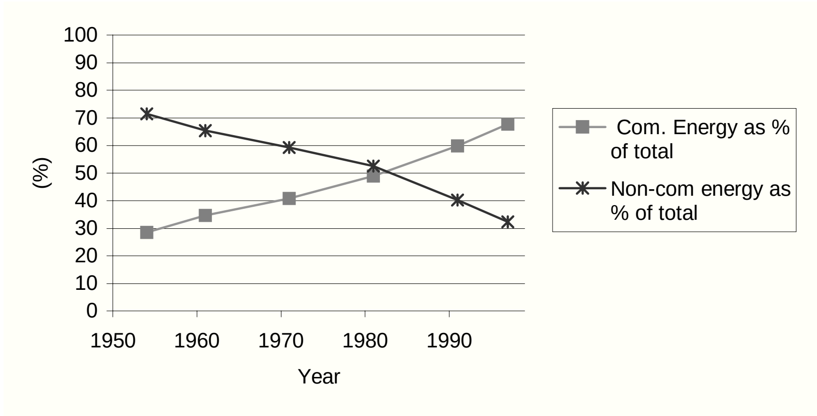

Figure 1: The change in use of commercial and non-commercial energy sources in India 1953/54-1996/97 (GOI 2000).

The domestic sector as a total accounts for about 40-50% of India's total energy consumption (Teri 1998). The distribution of primary energy sources in relation to both urban and rural households is displayed in Figure 2:

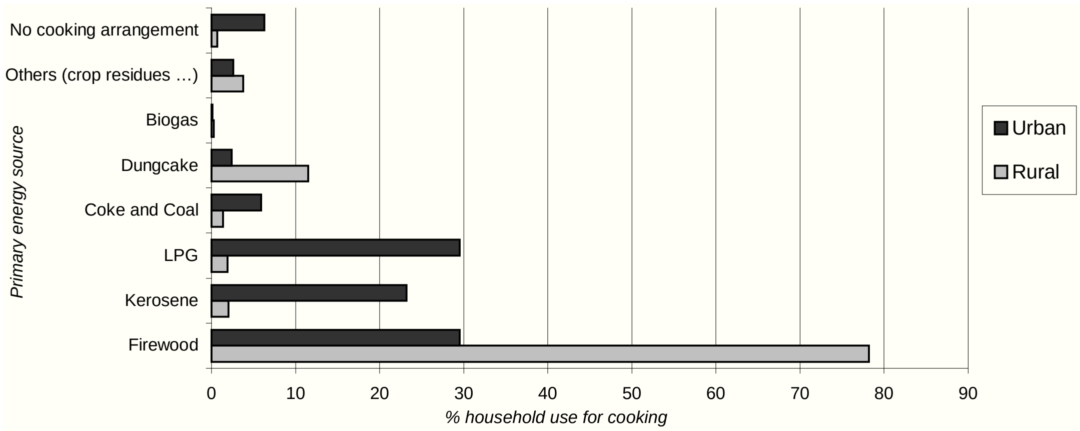

Figure 2: Urban and rural households primary energy source used for cooking (NSSO 1997, in; Teri 1998).

There are large differences between urban and rural areas concerning primary sources used for cooking. Whereas in rural areas firewood[20] is the most common source, in urban there is a higher use of commercial sources (gas and kerosene). The price of kerosene and LPG is regulated by government through subsidies (Thukral *et al.* 1994; Malhotra 1999). The access to these resources is severely limited in rural areas, mainly due to a weak infrastructure for distribution. The availability of the different resources plays an important role in deciding what resources that are used. Taking different areas of India as the point of departure and looking at the distribution of households that use of crop-residues, dungcakes, or firewood as their primary energy source these differences becomes evident.

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[20] Firewood refers to a number of different wood-based sources, including logs, branches, twigs, but also shrubs.

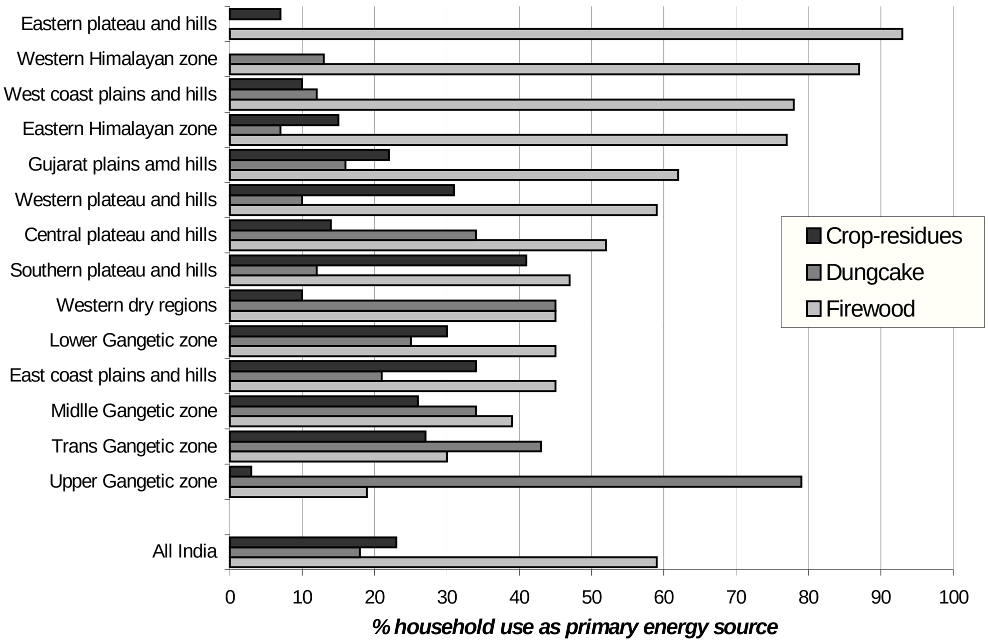

Figure 3: Use of non-commercial fuels indifferent regions of India (Joshi et al. 1993).

The wood-fuel crisis gained extensive attention from the mid 70's (Eckholm 1976; Leach *et al.* 1988; Murray *et al.* 1992). The crisis had its origin in the observation and assumptions that the de-forestation of Third world country's forests was caused by people's need for fuelwood. From this assumption and the empirical evidence that the forests were slowly vanishing led to a lot of policy decisions and development project concerning supply of fuelwood, supply of alternative fuels and protection of the forests (Leach *et al.* 1988). The picture became more complicated as it was later identified that fuelwood was only one factor in the deforestation process[21]. In the beginning of the 80's, for example, the use of fuelwood in India was claimed to exceed the natural production (Bowonder *et al.* 1988; Moulik 1989)[22]. Rural people were seen as the major contributors to deforestation, but they seldom use tree logs for cooking, rather shrubs and twigs. Trees are used for construction or sold at markets. Indications suggest that the main reason for deforestation is rather the use of fuelwood in urban areas, land expansion for industry and the need for construction material (Reddy *et al.* 1983; Chandrashekhar *et al.* 1987; McGranahan *et al.* 1993).

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[21] See for example Agarwal (1985a)

[22] It was estimated that in 1982 about 150 million tons wood was cut whereas the production from forest lands where a mere 15 million tons (Moulik 1989). The figures vary between various authors, but they all agreed that the extraction was far larger than the annual incremental growth. The trend of using more tree than annual growth is sometimes referred to as the wood fuel gap or gap theory (Leach *et al.* 1988). However there is little indication that the gap-theory actually holds true, or the de-forestation would be much more severe today than it is .

The fuel-wood crisis is what could be called a development narrative[23]. The deforestation due to use of fuel-wood as domestic fuel in rural areas is still a narrative that is used as reason for action. This is done despite the fact that there seems to be little evidence that this is a general cause for deforestation[24]. The use of parts of living trees can be found to some extent, but this will not affect the all-over picture of the weak linkages between deforestation and rural domestic use of fuel-wood. Leach and Mearns (1988) states that "*if all woodfuel use stopped tomorrow, deforestation rates would hardly alter*" (p9). Reasons for deforestation are other than related to fuel-wood use in rural areas. For a more comprehensive discussion on this see for example Ravindranath and Hall (1995).

The *energy ladder*, in Figure 4, illustrates aspects behind the transition from low-grade biomass fuels to more modern fuels (Leach *et al.* 1988). The theory should however be used with caution as it is in no way an automatic and mechanical transition that takes place. There are three main barriers considered to be influential in the transition process: cost of modern fuel devices, access to the resource/fuel and the price of the resource (Leach 1992).

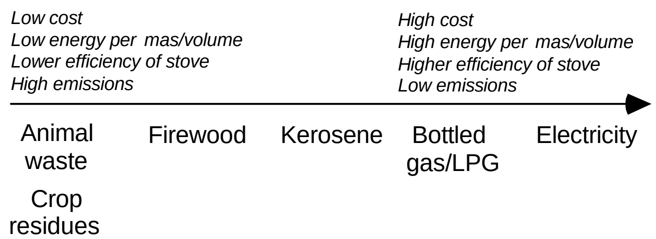

Figure 4: Energy transition and some characteristics of different energy sources.

The first barrier, the cost of modern fuel devices, is well established and identified as an obstacle for modernising the energy use. A strategy among the poor is argued to be to avoid 'lumpy' payments even though the total sum over time is higher. In the case where there is no money there are no alternatives given. The second barrier is the access to modern fuels. In many regions there is no infra structure to handle the distribution. This is the case in many rural areas where the constraints in access to energy are much higher than in many urban ones, like for example LPG in rural areas in India. This aspect could also be labelled security in resource supply which is identified as a central issue in the choice of a resource (Lichtman 1987). The last barrier concerns the fuel price. It is sug-

[23] A development narrative can be described as a short story, with some kind of explanatory content, in which there is a beginning a middle part and an end (Roe 1991; Hoben 1995). Even though a 'story' is argued not to hold truth any longer it can still retain explanatory and descriptive power to the storytellers and hearers.

[24] It should be pointed out that there are large local variations. It is certainly possible to find cases where deforestation is caused by the need for rural need of domestic fuels. In general, however, this does not seem to be the main cause for deforestation.

gested that this only affects the use of the resource when the device to use it is available (first barrier).

So where should biogas technology be placed in this scenario? If biogas were available in the house at a certain cost, without any need of other inputs, it could be placed somewhere between kerosene-LPG-electricity. Biogas from a quality point of view is very similar to these energy sources. But in practice production of biogas is usually linked to the operation of the plant. The operation of a biogas unit means that both labour and time has to be invested in order to get gas. Taking this into consideration biogas would instead be found *below* kerosene[25].

A diagram where the monthly per capita expenditure (MPCE) is put in relation to the primary energy source can visualise the differences in primary energy source use, Figure 5. The MPCE-value is a proxy to understand the well being of people and is basically a consumer price indexed value of people's expenditures (Teri 1998). A higher MPCE value indicates a higher living standard and a higher financial income.

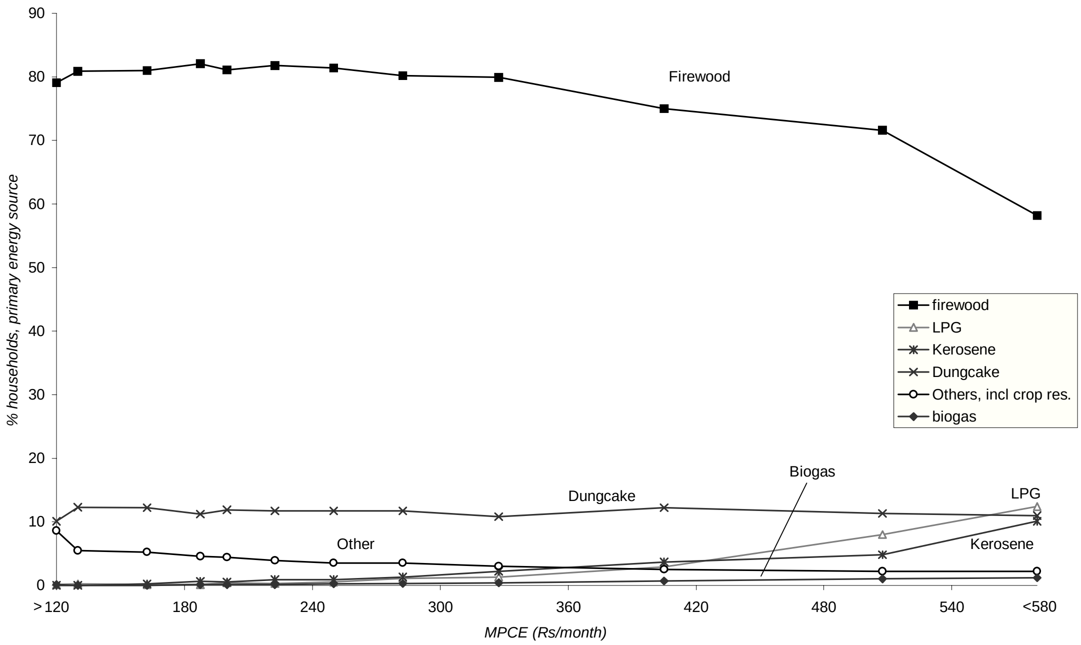

Figure 5: Relation between MPCE (Rs/month) and primary energy source in rural areas of India (NSSO 1997 in: Teri; 1998)

Among households with higher MPCE values more modern type of fuels, such as gas and kerosene, are used. It can also be noted that the category 'other' including crop-residues is decreasing with higher MPCE values. Crop-residues as an energy resource is from the perspective of the energy-ladder among the lowest ranked energy sources, while on the other hand LPG and kerosene are the resources ranked highest. Along with rising living standard transition to more modern energy sources takes place. Biogas is according to the

[25] See for example Ravindranath *et al.* (1995) or Dutt *et al.* (1993)

diagram slightly more used as a primary energy source among household with higher expenditures. Following the energy-ladder theory this could be explained by biogas attracting interest because it is perceived by the users as a more modern type of energy source and hence worth investing in. When it comes to biogas technology there are a number of requirements to be met in order to have access to the resource. One is to have access to about 50 kg of dung each day. Another is to have a permanent house as well as access to 50 litres of water each day. These requirements indicates that the household have a certain degree of wealth, so the explanation could also be that potential users of biogas technology is mainly found among the better-off households.

In many household multiple fuel are used. It is possible to use less-modern fuels in response to price for example. The person or persons responsible for domestic energy supply in the household are not making themselves totally dependent on only one source for energy. The energy ladder is biased towards economic factors, and what could be labelled infra-structural factors. The economy of fuel use should not be over emphasised as the parts above only act as barriers against a resource and technical device rather than facilitators of the same. Esthetical, social and cultural values of choice will become central when the first barrier has been overcome. These are however much more difficult to screen than the economic constraints and barriers discussed above. From the perspective of biogas technology a certain amount of money is needed in order to be able to invest in the unit. This money is at least equal to what is needed for buying the first LPG bottle.

6 Introduction of Biogas Technology in India

Biogas technology has a long history in India, stretching from the early 20:th century to today. The bulk of installed units have, however, been constructed within the last 15 years, and this process was initiated only when a number of designs, considered practical and appropriate for dissemination, were available. There was also a political foundation for propagating a large-scale diffusion programme administered on a national level. The history of biogas introduction is here divided into a number of phases, which are defined by occurrences and changes in society and programme developments.

-1950	-	First units constructed. Some research on the process and design
1950-1972	-	Industrial development of India and agriculture. First practical designs constructed, small projects, mainly one organisation involved, one design disseminated
1972-1975	-	Energy crisis attracts attention to the technology, start of national interest. Fossil fuel dependency identified. Indira Gandhi to power
1975-1980/81	-	National interest and research. National programme developed.
1980/81-1985	-	Initiation of large national programme relying on subsidies. Multi organisation, multi-design approach.
1985-1992	-	Improving designs, improving the organisation and results from dissemination
1992-1996	-	Decrease in subsidies, new structures of dissemination and extension

Table 2: Phases in the history of biogas technology in India[26]

It was first during the beginning of the 80's that a momentum was reached in the volume of biogas units. The technology as such had received substantial attention from researchers and development workers, both nationally and internationally, since the mid 70's. The cumulative number of biogas plants installed, and the annual new installation made, in India are displayed in a Figure 6.

[26] Similar division of periods of the introduction of biogas technology in India can be found in for example Moulik (1990a). There are some differences however. The importance of the political support for the technology is not taken by Moulik, but is here seen as a factor influencing the diffusion process. Other presentations of the history of biogas introduction in India can be found in for example Chawla (1986), Moulik *et al.* (1986), or United Nations (1984). These are, however, mainly focusing on development of the technology and to some extent a discussions of the institutional arrangements for diffusion of the technology.

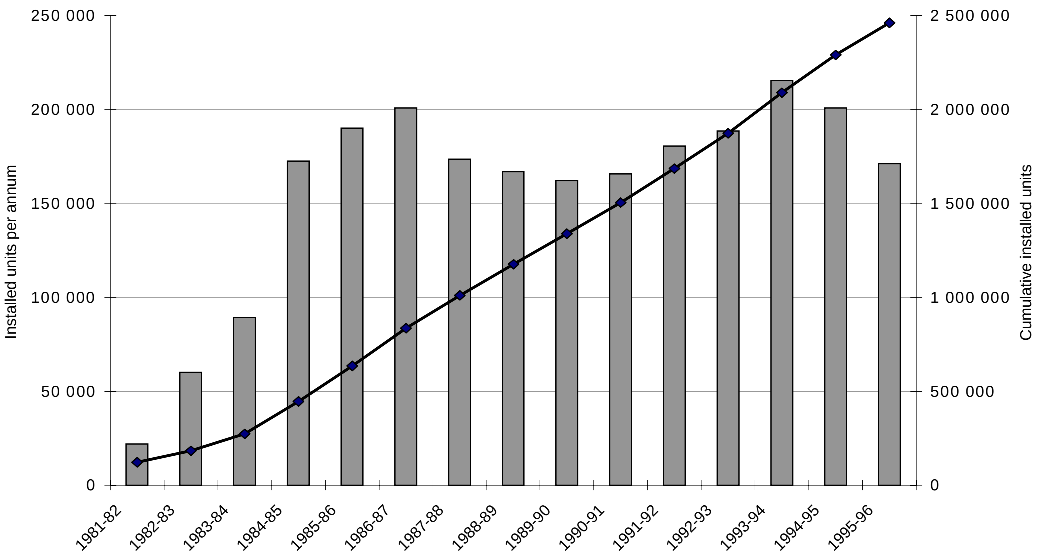

Figure 6: Number of installed biogas units (Ramana et al. 1994b; Teri 1998)

There are significant regional differences in the number of installed units between the various states and union territories (UT). Among the states with largest number of units are Maharashtra, Uttar Pradesh, Gujarat, and Tamil Nadu.

6.1 Early history, up to 1950's: First steps taken

The early years of biogas research and development can be said to start in the 1920's, even though some work had been done previously with biogas technology for sewage treatment[27]. In places such as the Indian Agricultural Research Institute (IARI) near Delhi[28], research on biogas technology was carried out. In Poona, near Mumbay (Bombay) Professor N. V. Joshi, who had earlier been at the IARI, worked with, among other things, designing a new biogas model which he managed and later patented (Chawla 1986; Singh 1996). One of the main research interests during this period was to better understand the process and conditions needed to get an efficient anaerobic fermentation process. What on

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[27] The first anaerobic biodigester that was installed in India is argued to be that in the Mantunga Homeless Lepers Asylum near Bombay, which should have been installed in 1897. It was primarily functioning as a sewage treatment plant but the gas was taken care of and used for lighting (United Nations 1984; Kristoferson *et al.* 1986a). This statement is on the other hand quite difficult to confirm. Chawla (1986) refers to a French publication by Mignotte (1952) in which a description on the first attempt for producing biogas from manure by biological decomposition is given to 1900. Meynell (1976) states that the leper colony digester was constructed in 1859. According to Sarkar (1982) the first biogas unit was installed in Dadar (Bombay) as a sewage treatment plant in 1937. The units discussed above are all sewage treatment works, which is slightly different from the household based biogas plants that are discussed here.

[28] One of the researchers at IARI at this time was Dr. S. V. Desai. He carried out laboratory tests on the cowdung digestion process aiming at finding principles that could later be used for design of a biogas digester (Singh 1974).

the other hand lacked at the time was a practical design of the digester that could be used by farmers. Another problem was to find reasons to implement it. Initially the attraction of the technology laid in the possibility to improve the utilisation of available manure as fertiliser, whereas the gas was seen as a by-product (Singh 1974). The use of dried dung cakes as fuel instead of using it as manure was also a factor encouraging further biogas technology development *(Singh 1996).*

During this time basically agricultural researchers were responsible for the development of the technology and it was considered important by the involved people to develop an indigenous Indian biogas design (Moulik 1990b). In the late 1940's a social worker within the Khadi and Village Industry Commission (KVIC)[29], Mr Jashbhai Patel, started to work on developing a biogas design that was different from the designs that had been developed thus far. His design was constructed with the digestion chamber placed below the ground instead of above ground. Another new feature was that the gasholder and the reactor were made into one unit saving both space and material. Further innovations of this design were the continuos flow system and automatic overflow when loading. It was also equipped with a scumbreaker that should prevent scum to enter the gaspipes (Singh 1974). The first unit of this type was installed at Osmania University, Hyderabad, in 1950 (United Nations 1984). The design was called *Gramalakshmi. Grama* meaning rural in Hindi and *Lakschmi* is the Goddess of wealth and prosperity in the Hindu religion. There is also a notion of the word *Grama* towards the Gandhian movement of rural development[30].

The installation of the first *Gramalakshmi* unit constitutes the end of the first period. Biogas technology had until then been more or less a mere research issue, but now an Indian design that could be disseminated in rural areas had been developed. It was, however, still far from being affordable to rural farmers.

6.2 1950's to 1972: Development of practical design

During the period from early 1950's to 1972, biogas technology was slowly attracting more attention, still mainly from agricultural researchers. Most important though, it was further developed and experiences on operation of units under practical conditions were

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[29] KVIC is a statuary body working with planning, promotion, organisation and implementation of programmes aiming at developing khadi (hand-sun and woven cotton goods) and other village industry activities. The wider objective is to build a stronger rural community. KVIC was established in 1957, by an act of parliament, and took over the work that previously the All India Khadi and Village Industry Board had been responsible for.

[30] In the Indian context, rural development is often discussed in relation to the development practices that Mahatma Gandhi proposed. For example the Gandhian concept of *antyodaya*, meaning real improvements for the poorest person is often connected to the integrated development idea. It might be questioned, however, how much influence these ideas have had on the development strategies and goals that are found in the national development planning. In the 50's and 60's the development policies were actually rather in opposition to what M. Gandhi desired, on the other hand, among development practitioners M. Gandhi's strategies seems to be more alive.

being collected. A very small number of units were constructed and this took place in certain regions such as Maharashtra and in the vicinity of Delhi.

The work of Mr Patel continued during the fifties and other institutions such as the Rama Krishna Mission in Calcutta and Khadi Pratisthan Sodepur in West Bengal did also develop new designs (Chawla 1986). Experience began to be accumulated from these projects. Indications were that biogas technology faced problems when integrated into the livelihood systems of the farmers.

A project implemented by IARI in the mid 1950's is discussed in an article by M. A. Idnani (1964)[31]. The project had installed twelve biogas plants in twelve different villages free of cost to the farmer. The first period of time after installation the operation was satisfactory but then the units started to malfunction. The reason for this is argued in the article to be traditions of living, and the means to overcome this is suggested to be education.

> *"…single demonstration gas plants in individual villages, however ably run, cannot arouse enthusiasm in farmers even when it is known that some of them have money enough to afford the installation. The type of experiments carried out in some villages in Gujarat and Uttar Pradesh, of installing several gas plants in each village involves the effect of concentration of efforts which is not obtained otherwise. It will not be long before other farmers who do not own a biogas plant in such villages are automatically embraced in the scheme by the sheer force of isolation in deriving benefits which others are found to be enjoying" (Idnani 1964)*

The reason for the farmer to adopt biogas technology is argued by Mr Idnani to be the benefits that would be the results from operation. The improved situation should thereafter give other farmers incentives to install and invest in their own plants. This can be seen in contrast to the experience gained, which did *not* lead to other people finding it attractive enough to use. The strategy of building a number of plants in each village in order to reach a critical mass, as is exemplified in the citation, seems to have formed the main strategy in India since the beginning of the diffusion process.

KVIC included dissemination of biogas technology in its programme in 1961, and this was a result of earlier field trials. The aim of including diffusion of the technology in KVIC's work plans was to spread it nation-wide (KVIC 1976; United Nations 1979). The Planning Research and Action Division (PRAD) of Uttar Pradesh took further national initiatives through the establishment of the research station in Ajitmal. This research

[31] Mr M. A. Idnani was another central person to biogas development at the IARI. He was together with co-workers involved in both laboratory and field tests of biogas plants. Concern was given to the fertiliser and soil conditioner aspects of the plant as well as best practice in the handling of the effluent (Chawla 1986).

station was later to become known as the Gobar Gas Research Station and one of the influential persons here was Mr Ram Bux Singh[32].

There were few signs of a rural energy crises at this time and within the rural energy field the main goal was electrification. The electrification of rural India took its start by the creation of the Rural electrification programme in 1950/51 (Sinha *et al.* 1991a).

The national development goals at this time were to bring India into development through industrialisation[33]. The rationalisation of the agriculture became central, since it accounted for the largest part of India's national income. A programme called Intensive Agricultural District Programme had been running since the early 60's. This programme was targeted to special areas and the aim was to get India self sufficient in grains which was seen as best done through intensified agricultural practice by certain farmers. During 1965-67 there were severe drought/famines in the northern parts of India, which acted, as alarm clocks for many politicians that the agricultural sector had to be modernised.

The so-called *green revolution* was initiated and through the introduction of High Yield Varieties (HYV) and chemical fertilisers an industrialisation of the Indian agriculture could take it start in 1965. The High Yield Varieties Programme was initiated soon after. The main breakthrough for the green revolution in India came at the end of the 60's when the HYV of Mexican wheat and HYV of Taiwan and Philippine rice were introduced (Wolpert 1993). The first harvests from these new varieties, displaying the possibilities that came along with modern agriculture, came in 1966 (Brass 1990)[34].

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[32] Mr Ram Bux Singh invented a vast number of different designs of which a number could have vegetable matter as feedstock. Other designs that were equipped with devices for heating of the digestion material in order to be able to improve the digestion process (Singh 1972; Singh 1974).

[33] The heavy industry strategy was instituted by J. Nehru and P.C. Mahalanobis and had its greatest impact from 1955/56 to 1965/66 (second and third five-year plans). The core of the heavy industrialisation strategy was to move towards capital intensive, fast paced heavy industrialisation, led by the public sector. The public sector would hold a central role as it would build the key industries and control the new modern industrial economy of India, while the private sector would only hold a complementary role in the mixed economy (Brass 1990). Chakravarty (1987) argues that an underlying thesis among planners at this time was that in the early stages of industrialisation the agricultural sectors should supply cheap food and cheap labour. J Nehru died in 1964 and his successor, Lal Badhur Sharsti, was in power to 1966 when he was succeeded after his death by Indira Gandhi (Gupte 1992). P.C. Mahalanobis was the principal architect of the second five year plan (Brass 1990).

[34]The rice yields increased substantially through the introduction of the HYV rice varieties. According to Tivy (1990) the average yield in 1950 in the tropics was 750 kg/ha, by 1970 the same figure had increased to 3,200 kg/ha. The increase was due to many factors such as reduced time of maturing. This made two crops per year possible, but the Green revolution was not the panacea for the agriculture (in the third world) which was hoped for. HYV species requires high inputs of herbicides, pesticides, and water. Tubewells can be a solution in the case of water, but establishment of these can result in lowering water tables in the area. Further on little, or no, account has been taken for the effects that herbicides and pesticides can have on people. However it is important to consider in respect to these issues that the yields has doubled or tripled

The green revolution emerged during a period of time when the oil price was low and the food scarcity was seen as the major threat of the future. The result was that the new farming practices and technologies were more energy intensive and relied (indirectly) to a higher degree on oil (Kumar *et al.* 1977). The oil price began to gain increasing importance through among other things the close link to chemical fertiliser production. Along with this efficiency aspects of the agriculture were given priority before the equity aspects (Natarajan 1987). Small and marginal farmers were not actually involved in the two major agriculture rationalisation programmes[35]. It was considered that the new technologies and practices of the green revolution should trickle out to these so-called non-progressive farmers.

Biogas technology was disseminated on a minor scale in the wake all of this, but, as said earlier, the target groups differed. On the one hand the industrialised farming practices spread were targeted towards the large farmers while biogas technology was more a rural development programme focused on small and medium farmers.

The end of this period is marked by two events: Indira Gandhi's ascent to power in 1972 and the effects of the oil embargo in 1973. Indira Gandhi was elected leader in 1966 but the period from 1964, when J Nehru died, to 1972 is marked as a struggle for political power (Kaviraj 1986; Taylor 1999). In 1972 Indira Gandhi won an election for her Congress Party with a clear majority of the votes which made her the pre-eminent leader of the country (Brass 1990). Consolidation of central power and the assertion of India's independence from the west is a central feature of the Indira Gandhi era (Wolpert 1993).

6.3 1972-1975: Increased interest for biogas in the shade of crisis

Indira Gandhi had a different strategy to development than her predecessors during the 50's and 60's. Indira Gandhi believed that technological self-reliance was the key for maintaining India's political independence towards the international community (Natarajan 1987). This strategy was to a large extent in line with what biogas technology apparently could offer. Poverty alleviation was another issue that was high on her political agenda.

In 1973 the Organisation of Petroleum Exporting Countries (OPEC) announced a cutback in oil production which was followed by the October 1973 Middle East War. The result from this was a quadrupling of the crude-oil international prices during the period 1973 to 1974. Oil and fertilisers accounted for 21% of the import to India by value in 1973, in 1974 this figure had increased to 35% (Moulik 1989). All of this happened at the end of

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which has made more food available. The Green Revolution was an answer to *national* food shortage and it gave a (short) breathing spell.

[35]The division of landholders in Indian official documents is often made in the categories of landless, marginal, small, medium and large farmers. Landless and marginal farmers hold up to 2.5 (1 ha) acres, whereas the small and medium hold 2.5-5.0 (1-2 ha) and 5.0-10.0 (2-4 ha) acres respectively. According to this classification large farmers hold land of more than 10.0 acres (Vidyarthi 1984).

the fourth five years plan when the fifth was already a draft. It can also be pointed out that during this time there were attempts made to establish a national energy policy.

The industrialisation and promotion of the green revolution in agriculture made drastic cuts in commercial energy consumption and chemical fertilisers impossible both from an economic and political point of view. The government was forced to take measures against the rising import bill. Industries had to initiate energy management programmes aiming at reducing wasteful use of resources. These programmes did not fall out very well as the response from the industry was instead of implementing energy saving measures, to install captive diesel generators, as there were subsidies available for these investments. Hence, little energy savings were made (Moulik 1989). The Indian Government also took policy measures regarding, among other things, transportation. The working lives of coal fired locomotives were extended, the electrification of the railway was at the same time encouraged. Gasoline prices were tripled.

Small and medium farmers' dependence on commercial fuels was low and thus they were not affected directly to such a great extent. But prices on commodities in general increased giving indirect effects. Due to the increasing prices all of a sudden 50% of the population could be found below the so-called poverty line (Hettne 1979). For the rural population, where many were subsistence farmers, the changes might not have been that important. But the important thing was that the country of India became poorer from global point of view, and that caused the government to take further actions to meet the problematic economic situation and further push for development.

As a measure against the rising oil import bill, the Government of India requested increased research on alternative renewable energy sources. This was a crucial step for the diffusion of biogas technology. Resources and attention, on a totally different scale than earlier, were given to the technology. The Indian Department of Science and Technology (IST) were among those, which initiated research programmes.

> *…after a long period of totally undeserved neglect, the future of biogas plants has, thanks to the oil crisis, become rosy (Prasad et al. 1974).*

Moulik (1989) made a similar reflection:

> *The emphasis and importance given to renewable energy technologies as additional sources of energy were perhaps among the most positive and determined responses of the Indian government to the first oil-shock of 1973, which carried the seeds of an alternative development model with a long-term sociopolitical, and economic impact (Moulik 1989).*

Still there was no infrastructure to implement larger biogas technology extension programmes. Skills needed to construct the units were, for example, not widely available. The high investment cost attached to the technology was considered another major obstacle for wide dissemination. Moulik *et al.* (1975) argued strongly for subsidies to compensate the farmers:

> *…if the farmers do not perceive the benefits in terms of gas in terms of the kerosene price equivalent, many of the smaller plants will not be*

> *able to fare better than competing investment opportunities. Therefore, subsidies will have to play an important role in promotion of small plants. (Moulik et al. 1975) pp 81*

It can be assumed that the authors refer to governmental subsidies, as the aim was to initiate a government programme. By introducing the need for national subsidies, biogas technology went from being a local rural development or in some cases a research interest, to politics. Hence decisions regarding biogas technology were lifted from the level of research institutions and regional development organisations, to a national- and political level as they were in charge of subsidies and other support measures. From this point on the decisions on whether or not to advocate biogas technology were made by politicians on a national level.

KVIC, which had remained the main body for the extension work, received some money for their programme from the Ministry of Agriculture. It was basically the KVIC-design that was to be diffused. This design was also sometimes referred to as either the Indian design, or *gobar*gas plant. *Gobar* being dung in Hindi. Up to 1974 there had been about 6,000 biogas units installed in India (Moulik *et al.* 1975; Kishore *et al.* 1990).

The end of the period is represented by two separate events. Firstly, the initiation of the All India Co-ordinated Biogas Programme (AICBP) which came to existence in 1975. Secondly, another energy crisis was "discovered", the so-called fuel wood crisis[36]. This energy crisis was supposed to hit the rural poor people and gained great international attention. All of a sudden the discussions of biogas technology became two-folded. Firstly to the increasing national oil import bill and secondly the fuel-wood crisis. Biogas could be a solution to both.

6.4 1975-1980/81: Getting in start position for nation-wide programme

By 1975 it was considered that there existed a well-tested technology and an infrastructure for carrying out nation-wide dissemination. AICPB was created with the aim to install 1.5 million biogas units by 2001 (Moulik 1989). IST was the main initiator but many organisations and institutions were involved, such as the IARI, PRAD, and the Indian Institute of Management (IIM). The main responsibility for the implementation of the programme was, however, held by KVIC.

The programme was in many respects in line with the development goals set up be Indira Gandhi earlier[37]. The technology was indigenously Indian; it would develop the rural areas and improve the situation for the people living there. It was also a response to the

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[36] See for example Eckholm (1976).

[37] During the period from 1975 and 1978 there was severe political turbulence which resulted in a state of emergency being declared by Indira Gandhi in 1975. The emergency continued until early 1977. In 1978 elections were held, Indira Gandhi and the Congress Party lost the election. The Janata party with Morarji Desai as the Prime Minister came to power. Even though Indira Gandhi and the Congress Party had lost much of the people's trust through the emergency they regained power in 1979 (Brass 1990).

increased oil import bill that India had experienced some years before. When the fuelwood crisis was identified it was considered, among many planners and policy makers, that biogas technology could be a solution to the problem. International organisations and donors were starting to show an interest in the technology[38]. Rural development and appropriate technology were attractive for development programmes[39]. Small-scale technologies were given attention as possible solutions to the limits of our finite resources (Lovins 1977) It was considered that dissemination of biogas technology was a potential way of improving the situation for rural people with relative small budgets.

In the meantime, there had been almost 7 million biogas units constructed in China during the period between 1973-78 (Qui *et al.* 1990). In China political attention had been given to biogas since the 50's and the practice was argued by the rulers to be well adopted to the livelihood systems of rural farmers and the political intention of the party. The main feedstock was pig manure and indications are that the main emphasis of the Chinese programme was to provide a good fertiliser, rather than the Indian emphasis that had more and more turned to the energy aspects of biogas technology. One of the lessons from China was that diffusion of the technology to a very large number of households was possible.

In 1978 the Gobar Gas Research Station in Ajitmal, Uttar Pradesh, came up with a prototype of a new design called *Janata* biogas plant, meaning public or people in Hindi[40]. The *Janata* design was similar in several ways to the Chinese fixed dome design, but one notable difference was there. The *Janata* design was not equipped with a manhole on the top of the digester, which was a common feature of Chinese designs. The manhole on the top made it possible to use other feedstock than manure, as feedstock that floated on top of the slurry could be lifted out. Floating biomass inside the digester can cause blockage of gaspipes as well as the digester volume is not used efficiently with reduced gas production as a result. The main advantage seen in the *Janata*- over the KVIC design, was the reduced cost for construction.

But why had not the *Janata* design, which was similar to the well-known fixed dome type that had been spread extensively in China since the 50's, been introduced earlier to the Indian biogas scene? There is no clear answer to this, but the drive to develop an indigenous Indian design had been strong since the start of biogas development in India. The KVIC design or Indian type of digester was long assumed to be better than the Chinese type from a technical point of view due to among other things the constant gas pressure.

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[38] One sign of the increased international attention given to biogas technology was the First International Symposium on Anaerobic Digestion that was held in Cardiff 17-21 September 1979. Further signs of this is that publications regarding small-scale rural biogas technology, targeted for an international audience, is starting to be produced, see for example United Nations (1979).

[39] Biogas technology has been referred to as the *"archetype appropriate technology"* (Ramana *et al.* 1994b) or in the title to the article by Theilen (1990) "Biogas-An appropriate technology for Third World Countries". It should however be noted that these references are from the 90's.

[40] For technical information and construction manual for this design see Myles (1985).

Also KVIC as the main body for extension of biogas technology in India was of course interested in disseminating their own model. The relation between India and China were not very good at this time. It had among other things resulted in war in 1962. These are some reasons to why transfer of technology from China could be problematic. Anyhow, by 1980 approximately 90,000 units had been installed of which only a small number were of the *Janata* type (Sarkar 1982; Ellegård *et al.* 1983).

Texts and articles on biogas production and utilisation began to be produced *en masse* and also spread publicly during this period[41]. Biogas technology was seen as a potential alternative energy source that could be beneficial for rural people and contribute to solving the energy crisis that India was facing. But there were some authors that argued that the technology, however well adapted, could not be seen as a general solution in rural areas as there were conditions to be met such as the need of capital investments[42]. The general ideas were however that some of these conditions could be solved through technical development and then make biogas an important energy source for rural areas. It is quite clear that the main argument of biogas technology became more and more centred on the energy aspect.

Towards the end of this period, 1975-1980/81, the biogas programme was integrated into the Government of India's 20-point program. The 20-point programme was launched the first time some weeks after the emergency had been declared on June 26, 1975. The programme promised to bring down prices, called for land reforms, the removal of the system of bonded labour, design laws declaring minimum wages. The programme had been a populistic response to the situation that existed at the time of the emergency (Hællquist *et al.* 1977; Hettne 1979; Brass 1990; Wolpert 1993)

6.5 1980/81-1985: Biogas technology crash programme initiated

The integration of the biogas programme into the 20-point programme made it a national development goal. As a response to this, the Government of India in 1981/82 launched an extension and development programme called National Programme for Biogas Development (NPBD). The Ministry of Agriculture was only to implement the programme. NPBD still exists and the goal, as it is presented today, is:

> *…providing clean and cheap source of energy in rural areas, producing enriched organic manure for supplementing the use of chemical fertilisers, improving sanitation and hygiene and removing drudgery of women (MNES 1996).*

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[41]In Vijayalekshmy (1985) it is assessed that from 1920 to 1985 there were more than 1,500 articles and texts available on biogas technology and processes. 70% of these were produced during the periods 1975-85. Some examples see (Bailey 1976; KVIC 1977; Khandelwal 1978; Dandekar 1980; Deshpande 1980; Srinivasan undated) and the special issue (no 33-34) of Economical and Political Weekly in 1977 including the articles (Bhatia 1977; Kumar *et al.* 1977; Makhijani 1977).

[42] See for example Bhatia (1977) or Ghate (1979).

Soon after the launch of the NPBD the responsibility for the programme was taken over by the Department of Non-Conventional Energy Sources (DNES) which had been created in September 1981 under the Ministry of Power (Sinha 1994). The already strong emphasis on energy was now settled as the programme was handled by a Department involved in renewable energy technologies (RET) *(Singh 1996)*. The other aspects of the technology, such as the fertiliser and health benefits, were still acknowledged as important features though. The NPBD was the main RET programme within DNES, followed by the National Programme on Improved Chulha (NPIC). NPBD held about 50% of the department's total budget.

The programme was designed to encourage the construction and dissemination of biogas technology mainly through:

- *Direct support* in the form of subsidy to the beneficiary if installing an approved biogas design. A turnkey fee is given to organisations, corporate bodies and approved entrepreneurs who construct biogas plants with a 3-year warranty.
- *Indirect support* in the form of training courses for users, turnkey workers/masons and representatives for organisations, and through support for communication and publicity activities.

NPBD was dependent on distribution of large subsidies to the household who installed a biogas unit. The high investment cost for the farmer was still present even though the less expensive *Janata* design could be chosen instead of KVIC model. A direct subsidy to the farmer was seen as a solution to this. Each state was given targets, depending on what they themselves thought were possible to achieve. Some organisations, like KVIC, were acting as an autonomous extension organisation with their own targets. The willingness to participate and push for the technology differed between the states. Maharashtra for example was one of the states that pushed intensively for the technology.

The strategy of the NPBD was described as a multi-agency, multi-design approach[43]. In 1981 there were two approved designs, of which basically one, the KVIC-design, was disseminated (Kishore *et al.* 1986). The extension work was mainly done through the different states and union territories development bodies *(Dhussa 1996)*, along with a few other bodies such as the KVIC. Each organisation works in specific areas and thus only one organisation is carrying out biogas extension area wise, i.e. the multi-agency aspect is only visible from the point of view of programme management. Concerning the different designs, the trend has been to include more types as approved designs in the NPBD. Normally one organisation will install only one type of biogas design. For the user there is no actual choice, but again, on programme and policy level there is a multi-design, multi-agency approach.

In 1984 AFPRO introduced their new biogas design called *Deenbandhu* biogas plant meaning "friend of the poor" in Hindi[44]. This design was approved for inclusion in the NPBD by the DNES in July 1986 (Singh *et al.* 1987). The *Deenbandhu* design was

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[43] See for example in Moulik *et al.* (1986) or Dutta *et al.* (1997).

[44] For more technical information on this design and for a construction manual see Singh *et al.* (1987).

claimed to cut the cost of installations even further. Actually it was not a new design, but rather a further development of the *Janata* type. The cost reduction was due to the use of some standardised pipes and a different construction technique. The design got a break-through, as it soon became the most popular design within the NPBD.

When Indira Gandhi was assassinated on October 31 1984, the Prime Minister post was taken over by Rajiv Gandhi, her son. Rajiv Gandhi believed that a more technology- and market oriented development strategy than his mother had advocated could modernise and develop India (Gupte 1992; Wolpert 1993; Tully *et al.* 1996).

The four years that had passed from the integration of biogas development in the 20-point programme as well as the initiation of the NPBD had resulted in a large number of installed units, about 400,000. The technology as such had proved itself as a potential rural technology, and resources allocated in the national budget for RET implementation and extension were increased. However the increased number of annually installed biogas plants made it important which an efficient extension organisation to implement the program. Moreover, the importance of high quality construction was identified as an important factor for successful implementation of biogas units. This leads into the next phase where the NPBD programme was revised to some extent and steps were taken to meet the problems of malfunctioning and non-operational plants.

6.6 1985-1992: Reforming the crash programme

During the period between 1985 and 1992, 160-200 000 biogas units were installed annually. This can be compared to the earlier annual installations between 1980 and 1984 of less than 90,000. Many of the units that were constructed soon after installation fell into disrepair or were simply abandoned. One of the measures taken by the DNES to meet this was to encourage autonomous bodies and entrepreneurs to take part in the implementation of the NPBD.

From the mid 80's a category of biogas extension worker acquired escalating importance for the dissemination under the NPBD. These, so-called Turnkey worker (TKW), were people (men) trained for construction of biogas plants. The profit for the TKW in the biogas venture was the government turnkey fee that was available for the trained and approved entrepreneurs. NGOs and other Institutions could also act as extension bodies, provided trained personal was available. Thus a transition to rely more on NGOs and TKWs for the extension work happened. A person constructing a biogas plant required special skills and training. Training was needed to an even higher extent in the case with the fixed dome types than with floating domes. Construction of the fixed-dome plant is done with bricks, plaster, and concrete, materials that are non-plastic which can cause cracks in the dome if the construction is not carried out properly. The cracks can be microscopic, but still cause gas to leak out. The inside of the dome is due to this painted with thick paint (which is plastic). A further measure was to advocate high quality construction materials to be used for the plants.

During the period between 1985 and 1992 the resources for RET diffusion and development in general was enlarged manifold. Comparing the budget allocation for New and Renewable Sources for Energy (NRSE) in 1988/89 (Rs 830×10^6 in 1981/82 prices) with that of 1980/81 (Rs $40x10^6$ in 1981/82 prices), the amount of resources allocated to this sector is enlarged by a factor 20. Other energy sectors did not experience the same spectacular rise in budget allocation[45]. NRSE stood, however, only for a very small part of the total net budget. Examining the figures on the budgets given for the whole five year period of the Sixth and Seventh plan show these differences in budget allocations.

	Power	NRSE	Petroleum	Coal	Total
Sixth plan (1980-85)	183.0 (164.9)	1.6 (1.4)	84.8 (76.4)	38.1 (34.3)	307.5 (277.0)
Seventh plan (1985-90)	379.0 (239.3)	6.6 (4.2)	160.1 (101.1)	71.2 (44.9)	616.9 (389.5)

Table 3: Expenditures in energy sector sixth and seventh plan (Rs x 10^9) (Sinha 1992)[46]. Fixed prices (1980/81) within brackets.

The increase in allocation of budgetary resources for RET dissemination and development and the increased rates of installed units during the preceding years certainly made the future for biogas technology extension look bright. For the NPBD this meant that a brave new goal was set to install 12 million units by 2001 (Sinha *et al.* 1990; Sinha *et al.* 1991b). This would mean that the total estimated national potential for biogas would have been met by this time. The international oil price was still a factor of central concern to the Government. Between November 1985 and end of April 1986 an inverse oil price shock lowered the price on oil. Due to rapid increase in consumption of foremost kerosene and diesel the easing of public expenditures that could have been the result of decreased oil price did not happen (Moulik 1989).

As time passed by, less interest was given to small-scale biogas technology from the international actors (donor organisations, international development agencies) with some exceptions. Dhussa *(1996)* argued that reasons for this could be that biogas technology had gone from the research and development phase to the extension and dissemination phase, a phase that attracted less international attention. On the other hand the many disappointing experiences yielded from international and Indian biogas extension programmes in the early 80's certainly played a role[47]. Indications from China at this time told that perhaps more than 50% of their biogas units had broken down or were not in

[45] The estimation is based on figures cited in Sinha (1992). These have been converted to fixed prices.

[46] It could also be noted that from 1980/81 to 1984/85 the budgetary subsidies given to fertilisers had rise by a factor two summing up to Rs $10.8x10^9$ (Chakravarty 1987). These subsidies are in themselves more than total budget for the NRSE sector. As biogas technology has potential to some extent lessen the need for chemical fertilisers this level can be useful to hold in mind.

[47] See for example Stuckey(1985), Kishore (1986), or Lichtman (1987)

operation (Kristoferson *et al.* 1986b)[48]. The implementation of the NPBD went on. Large numbers of units were installed and the strategy of heavy direct subsidies to the households for the investment, along with turnkey fees made the foundation. The state development organisation as well as both NGOs and TKW, who could make an income through installation of biogas units, carried out more a more of the extension work.

Two events make-up the transition from this period to the next. First, the economic crisis, which came to the surface in 1991 and led to, among other things, what is referred to the economic liberalisation of the Indian economy in 1992 (Kurien 1996). One of the results was that the Government of India was forced to drastically cut in fiscal expenditures. Second the transformation of the DNES into an own ministry, Ministry for Non-Conventional Energy Sources (MNES).

6.7 1992-1996: Uncertainties but continuos dissemination

In July 1992 DNES was transformed into a ministry called Ministry for Non-Conventional Energy Sources (MNES) The supply strategy that had been applied in the work when it was a department was still holding. In July 1993 this strategy was slowly transformed in order to try to pursue a more end-use oriented approach (Sinha 1994). MNES assignments were varying from biogas research and development, improved *chulha* extension and development over mini hydro and solar photovoltaic (PV) power to more institutional assignments such as the Indian Renewable Energy Development Agency (IREDA) (MNES 1996). The NPBD was still the largest project and constituted for about half of the budget. The ministry is divided into six groups relating to different aspects of RET:

- *Power group:* wind power, small hydro-, biomass-, and solar power
- *Rural energy group:* household biogas, improved *chulhas*, community biogas
- *New technology group:* hydrogen energy, chemical sources of energy, tidal energy, wave energy
- *Urban and industrial group:* energy from urban and industrial waste
- *Solar energy group:* solar water heaters, solar cookers, PV programme; small, and medium size
- Administration and co-ordination group

The biogas programme was restructured to include financial, research and extension bodies. An organisational chart of the NPBD is displayed in Figure 7:

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[48] These figures concerning the Chinese biogas programme are speculative. There is little information available concerning the performance and results in China in comparison to what is available on the Indian biogas programme.

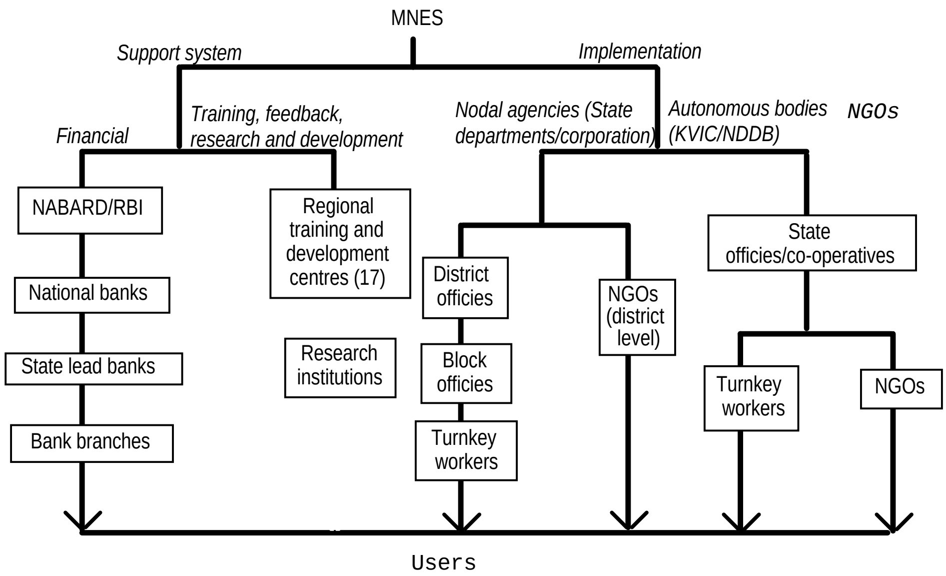

Figure 7: Organisational structure of the National Programme on Biogas Development (Ramana et al. 1994b; Dutta et al. 1997).

In the organisational structure in Figure 7 the government development workers are no longer present. Many local NGOs can support their other development programmes through biogas extension work as they are also entitled to the turnkey fees. It seems that people and organisations have experienced problems in obtaining the subsidies and turnkey fees when the instalment had been done. The reasons given are slow handling of the cases and a low confidence in the technology from the bank's branches (Turner *et al.* 1994; Dutta *et al.* 1997). It should also be noted that at the bottom of the structure the *users* are found, but the directions of the arrows indicates that there is little feedback from this group to other parts of the NPBD structure. This is of course not totally so. As part of the NPBD there is continuos monitoring of the progress from the different bodies, carried out by themselves or in some cases by autonomous bodies.

The concepts of both sustainable development and rural employment became increasingly linked to biogas technology in the 1990's. Biogas technology has fitted into the sustainable development discussion through among other things making the energy system in India less dependant on fossil-based energy[49]. Other examples is that biogas is found in discussions and suggestions for sustainable energy solutions for India (Sinha 1992; Sinha 1994; Naidu 1996; Raja *et al.* 1997).

Rural employment generated through biogas extension work had gained growing attention from the late 80's. In 1965 about 25% of the rural households in India received their major income from wages, in 1988 this percentage had increased to 40% (Ghosh *et al.* 1992). The figures are rough estimates on a trend that indicates that an increasing portion of the rural households and people have to rely more on wages for their livelihood. To

[49] See for example Rajvanshi (1995), Sinha (1992; 1994), Rady, (1993), Hall *et al.* (1993) or GOI (2000).

many of these wage-dependant households there are no possibilities to cultivate any land, as there is no land available. The formal sector of manufacturing and service do not expand in correspondence to the available excess workers (EIU 1993). One possibility is to do casual labour or to migrate to urban areas. Another way is to work in household industry and informal sector services, work that is insecure and paid with low salaries. Rural employment schemes have become increasingly important within national development, but many of the schemes implemented have not reached their aims due to lack of resources, lack of local decision making and low usability of the products produced (Ghosh *et al.* 1992). Biogas extension can be seen as a possible contributor to local employment[50].

All of this happened in the shade of the national turbulence due to increasing gaps in the balance of payment, political elections, and changes, as well as the assassination of Mr Rajiv Gandhi (in 1991). What did all this mean for the dissemination and development of biogas technology? As was the case in 1973, with the effects that arouse out of the oil embargo, people would find themselves in a changing surrounding.

From the perspective of biogas technology the main change was the cut in subsidies that came along with an aim to slowly phase them out. The people within the MNES assumed that a response to proposed cuts in subsidies should come in form of lower number of installed biogas units. However, this did not happen *(Dhussa 1996).* It seemed that there had been a certain momentum in the dissemination and that it more or less went on. The main reason for this is granted the more grassroots level extension work with TKW and NGOs. The structure of the NPBD had been almost the same since the initiation in 1982 but there had been a process where the extension work had slowly been turned away from governmental bodies to more and more rely on extension work implemented by organisations, TKW and groups working locally.

The total phasing out of direct subsidies that had been expected to happen in the near future put the light on the difference in subsidies for different fuels *(Dhussa 1996; Kishore 1996; Moulik 1996; Singh 1996).* It was argued that if the subsidies for biogas technology were to be levelled out, then the same had to be done with subsidies on other energy sources like LPG and kerosene. There are differences between the types of subsidies disbursed on these goods. To receive the subsidy for the biogas unit, the farmer himself has to make an application when the construction is done. In the case of commercial fuels the subsidy is already included in the price when purchasing the resource at the retailer. It is noteworthy that the discussion on subsidies on chemical fertilisers is not taken up, even though governmental subsidies are integrated in these retail prices as well.

In 1996 there were a total of seven biogas designs approved by the MNES. Besides the KVIC, *Janata* and *Deenbandhu* there were the *Pragrati* design, KVIC design with reinforced plastic dome, KVIC design with ferrocement dome and the *FLXI*-design.

One of the striking features at the end of this period is that biogas technology should after nearly 20-years as a government subsidised programme begin to act as a commercial

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[50] See for example Ramana *et al.* (1994a)

venture *(Dhussa 1996; Kishore 1996; Moulik 1996).* This puts the end of the transition period between 1992 to 1996 and we find ourselves at the present time.

6.8 Today and the future: Commercialisation, results and reflection

According to Dhussa *(1996)* there is quite a substantial difference between the different state boards on how much they want to push for biogas technology, i.e. how large targets they want to fulfil. This has resulted in a quite large spread between the different states concerning numbers of installed biogas plants. Maharashtra is without comparison the state with largest numbers of constructed biogas plants, covering almost 1/3 of the total number of installed plants. It can be noted that KVIC has it headquarters in Mumbai (Bombay) situated in Maharashtra and this organisation has been one of the leading actors in the development and diffusion of biogas technology. Uttar Pradesh, Gujarat, Tamil Nadu, and Andhra Pradesh follow Maharashtra in number of installed units. There are a number of small states that have not installed that many number of plants, among which we can find for example Bihar, Nagaland, Tripura (MNES 1996). However it should be noted that within these states there might be pockets where an organisation, or TKW, have implemented a relatively high density of biogas plants. The potential for biogas might further on not be that large in every region.

In the draft for the Ninth five year plan (GOI 2000) it is quite clear that the direct subsidies for investments in biogas technology is intended to be phased out. Among planners, biogas technology still has confidence, and the potential benefits as discussed in previous chapters are acknowledged. However the goals set up during the latter part of the 80's are abandoned. The goal is now rather to continue as before but increase the annual targets to install 1,200,000 units during the span of the Ninth Five Year plan. In the draft to this plan it is argued that the long-time central-sector run social programmes should gradually be transferred to state level. If this concerns the NPBD it would mean that MNES would no longer be responsible for the implementation of the programme.

The shift from subsidised national programme to commercialisation of biogas technology will put the technology to the test. There are very few if any biogas units that have not been subsidised in any way. There is also very little grassroots movement regarding innovation and development of the technology. The diffusion and extension process has thus far been a question not so much for the user as is indicated in the NPBD structure (Figure 7). When biogas technology has to compete with other technologies and bear its own costs, the comparison to other energy options will seem increasingly important and the users (or households) demands on sound and appropriate technology solutions will become a central concern. The services that can be obtained from biogas technology and whether or not people see these services as important in relation to other concerns are questions that have to be raised.

6.9 Problems of the future

We have come this far in the history of biogas diffusion and development in India without touching so much upon one of the most difficult question, i.e. the results. It has been mentioned that during the first part of the NPBD, 1981-85, quite some problems of malfunctioning plants existed. Further on we have touched upon some of the difficulties that were confronted in China with their massive propagation and diffusion of biogas during the 70's. There are, however, no clear and simple answers to what the results concerning the diffusion of biogas technology in India are. Numerous project evaluations have of course been made[51]. NPBD is continuously monitored in respect to progress of the programme and, similar is the case with more or less all biogas projects. The problem is however that it is often difficult to assess what the results really are. An illustration to this is given in Gutterer and Sasse (1993):

> *Nothing exact can be said about the proportion of plants which are out of operation in the project areas, since - as can be understood [!] - only functioning plants were "demonstrated" (Gutterer et al. 1993b).*

In a major study carried out in 1992 by the National Council for Applied Economic Research (NCAER) an estimate of the use of biogas plants installed between 1985/86 to 1989/90 was made. 3,600 villages spread in 251 districts and 27,000 units were monitored. It was found that on a national level 66% of the units were in use while there were significant regional variations (Ravindranath *et al.* 1995). A similar study carried out on plants set up during the period of 1992/93 to 1994/95 covering 5,165 plants in 727 villages in 18 states found that 87% were in use (MNES 1996). It should be noted however that these surveys only consider units that are not older than four years.

Another survey of the functionality of installed plants can be found referred to in Dutt and Ravindranath (1993). A survey of 4,108 biogas plants in Maharashtra showed that 36% of them were working. The reasons given for why the plant was not in working condition was 3% said it was due to technical failures. Other reasons given were; 29% lack of dung and in 16% there were difficulties in keeping a good process. In most cases, 52%, there was just a lack of interest in the technology from the respondents.

In the draft for the Ninth Five Year plan it is written:

> *6.314 … It is (…) necessary to quantify the benefits through this programme [NPBD] for fuelwood saving. In order to justify the biogas programme as the best decentralised energy source especially in rural areas, the economic cost is to be taken as the basis (…). Thus, detailed surveys need to be made for these programmes to quantify the economic benefits on the ground and also to make these programmes more effective (GOI 2000).*

The NPBD has existed for more than 15 years, and it is surprising that the above information does not already exist. An estimate of the cost of the NPBD in 1992 was that the Government of India had spent Rs 3 billion on the project (Lichtman 1992). In respect to other power and conventional energy related programmes this is quite small amount of money, but it is the major non-conventional energy programme implemented in India. It

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[51] See for example ICAR (1976), Gutterer *et al.* (1993b; 1993a), Turner *et al.* (1994) or Dutta *et al.* (1997). The most extensive survey is the NCAER (1992) study which has a national perspective. This study is further discussed in the text.

is moreover noteworthy that the point of departure is with all clarity from the energy aspect and that biogas is argued to be "the best decentralised energy source" (GOI 2000).

There is one big difficulty involved in what the Government of India is planning to do; quantification of fuelwood saving. Today it seems more and more clear that there is only very small, if any direct correlation between on the one hand fuelwood saving in rural domestic sector and deforestation on the other (Agarwal 1985a; Leach *et al.* 1988; Ravindranath *et al.* 1995). Hence introduction of biogas technology will have no, or a very small effect on deforestation. The issue at stake is quantification of the benefits implies that there are benefits to quantify.

We can assume that there will be a number of new surveys carried out regarding biogas technology in the years to come. One of the major tasks then will be to quantify the achievements from the NPBD. First thing here is to find out what the results really are. Questions relating to if the biogas units are in use or not will be insufficient. Information on the performance of the different units will also be required. As of today there is very little information on the actual performance in terms of amount of produced gas and quality and amount of effluent. Some exceptions exist, like for example Teri's surveys in Dhanawas, but these only concern a small number of plants[52]. A number of different laboratory and controlled tests have also been carried out, but there has not been any survey, to my knowledge, with a large number of plants looking at the actual performance over a longer time span and in different geographic zones. Further methodological problems will be faced such as how to monitor performance through asking people without encountering the same situation that Gutterer *et al.* (*op. cit.*) faced?

6.10 Introduction of biogas technology in India - Some concluding remarks

If biogas technology can stand up to its potentials it can, probably, make a real difference for rural people. At present little is known of the performance in general nation-wide and over a longer time span. As of today one of the major constraints to further interest in the technology is its history, as strange as it might sound. During the 80's there were many people involved in the extension and dissemination of biogas technology. The experiences from this time were often disappointments. The projects ended in failures and aims not reached. Much of information on biogas available is based on the experiences made in the 80's. Today many of the international organisations, with some exceptions, are hesitant of further work with biogas. The strong dependence on state subsidies can be seen as an indication that the technology cannot live on its own merits. Today the policy seems to be to slowly phase out the direct subsidies, which could be a step in the right direction to make the technology prove its merits. It is not clear that letting biogas technology compete on market terms will bring about increasing numbers of installed units. One important factor is whether or not this technology will compete on the same terms as for example LPG or kerosene, which have subsidised prices.

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[52] See for example Pal *et al.* (1996)

Looking at the history of biogas technology, many of the aspects that were taken up to advocate the technology in the past are still seen as valid arguments for the technology. The argument that biogas technology would meet the problems of deforestation is still seen as a valid point, even found in the Ninth Five Year plan. The same goes for the allegedly good quality of the effluent as a fertiliser and soil conditioner. We could call these 'dogmas of biogas technology' and they are similar to development narratives. During the years biogas technology has fit in the main stream development ideas. Biogas could be used for rural development in the 70's and also fit perfectly in the integrated rural development ideas[53]. When eco-development came along biogas was adopted as a perfect technology to achieve the desired aims[54]. From the appropriate technology side biogas technology can be seen as an almost perfect technology, easy to use and with high benefits, locally manageable and profiting the rural households[55]. In the late 80's and 90's when biogas technology could be seen as means to implement sustainable development[56].

Research on various aspects of biogas technology has throughout the history been carried out, but it was often hard to transfer to any practical use on the grassroots level. Technical innovation, like coming up with new designs, was basically done outside the conventional research institutions. The *Deenbandhu* model, for example, was an AFPRO innovation, and KVIC model was the innovation of Mr Patel and later taken up by KVIC. Even though there is one part of the NPBD, which is devoted to research, little seems to have come out of it. There is definitely a need for new innovations and designs within the field. Today basically one design, the *Deenbandhu*, is disseminated throughout the whole country. It is a 'one design fits all' type of approach. Development and diffusion of biogas technology has to a large extent been initiated by a group of highly educated scientist with backup from research and development infrastructure (Moulik 1985). This seems still valid to some extent.

Life in rural areas has changed during the years that biogas technology has been diffused, but little notice has been taken of this. In all the applications where biogas technology could fit it is mainly the potential benefits that have been considered. But I would argue that there exist few linkages between the potential benefits and practical experiences from biogas technology. Most of the argumentation relies on theoretical cause and effect considerations, which might not at all be valid in reality. Biogas can provide positive results if managed correctly, but it is not an automatic or mechanical process. In the next chapter, biogas technology will be analysed in relation to the user's livelihood system.

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[53] See for example Prasad *et al.*(1974) , Sinha *et al.* (1994), AFPRO (1992) or DaSilva (1980)

[54] See for example Thery (1981) or Glaeser (1995a; 1995b)

[55] See for example Theilen (1990) or ISAT (1997)

[56] See for example Sinha (1994)

7 Integrating biogas technology - Creating a user perspective

> *"His masterpiece [...] was the cement gas plant. The government gave a subsidy, cement, and technical staff, in order to modernise rural life. He patted the walls of the plants proudly and affectionately. Nagaraj felt he might soon bow before it, prostrate on the ground, and wave a camphor flame." (Narayan 1990).*

The preceding chapter described the history and use of biogas technology on a general level. We have discussed different actors, MNES, KVIC, the role of NGOs. In all this, however, one actor -the user- has not been found other then as a beneficiary of the technology. The actual extension and development work of biogas technology has not involved the users to any larger extent. Diffusion of a technology does not only mean to *introduce* the technology to the users but also for the users to *integrate* the technology into their livelihood systems. The aim of this chapter is to examine and discuss this aspect of *integration* of the technology.

Up to 1996 there have been about 2.7 million biogas units installed throughout India. These units are found in varying socio-political and ecological conditions. Each of the units is found in a unique context. An analysis is made here, where a general understanding of the livelihood situation is generated, which is then related to the conditions set by the biogas technology for operation and management.

There is an extensive work going on trying to *introduce* the technology to the potential users. At the same time there is a large number of household nation-wide that already use biogas technology on regular and daily basis. But in the case of biogas technology the choice of the technology has already been made. Therefore it is here not so much a case of looking at a context and then search for solutions that are appropriate, but rather to look at a technology and see how it fits into the user's livelihoods.

7.1 The user and biogas technology

One way of trying to better understand the changes on the livelihood system and changes for the user is to look at the technology, in this case the biogas unit, as a black box. You make an input to the black box and then, hopefully, you will get an output. If we apply this on the biogas plant we will find three inputs; dung, water and labour, and mainly two outputs; effluent and gas. What actually happens inside the black-box is not known in detail, other than input gives output.

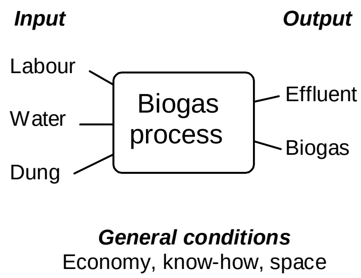

Figure 8: Black-box perspective on biogas technology[57]

What we have is basically a number of resources that have to be applied to the unit and as a result two other resources will come out. Depending on the way the inputs are applied we will have differences in the outputs. The two outputs will require that further input, of for example labour and technology, are made in order to benefit the user. Money is crucial in order for the household to get access to the technology, i.e. invest in a unit. There are, however, normally no direct monetary inputs in the unit in the day to day use and operation and hence no monetary inputs are considered here. The model displayed in Figure 8 has a strong physical perspective. One of the reasons is that the model is used to analyse the appropriateness of a technology in relation to the user's livelihood system. To further visualise this black-box model we can apply an interface between the user and the technology. The user can basically interact with the technology through the inputs. The black box is the inside of the digestion chamber.

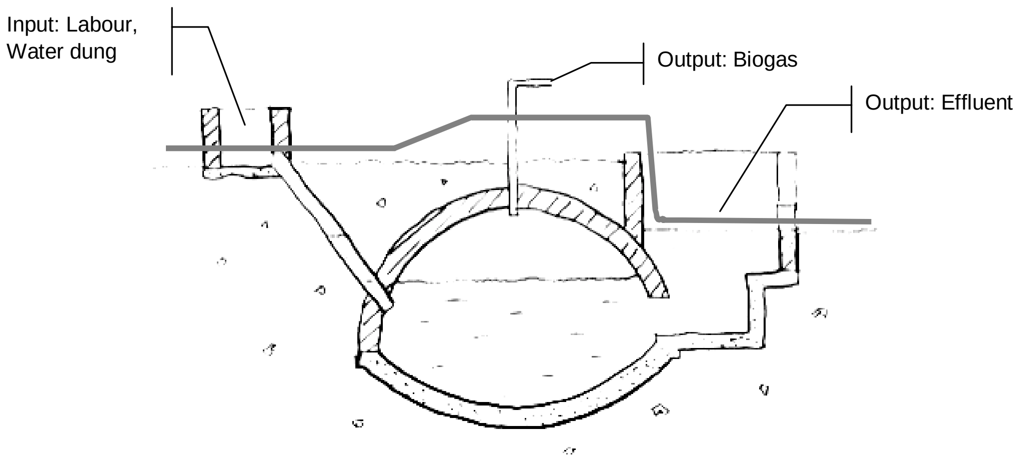

Figure 9: Interface between biogas technology and the user for a Deenbandhu biogas system

The inputs have to be managed, so do the outputs in order to be useful for the user. It will now be much more difficult to assign the potential benefits to the technology as the concern is now availability and access to resources rather than potential benefits from the

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[57] There are labour inputs associated with the management of the outputs as well. This is discussed further in *Labour: Operation and management takes time* on page 51.

technology. The benefits are supposed to be linked to the technology, but most of these are what could be called weak connections. Weak connections, as opposed to strong connections, are aspects that are not directly or strongly associated to a certain object or use of a technology (Roe 1991). In order to achieve these benefits it is not enough to just build a biogas digester but there will also be a change in the whole livelihood system of the user(s). While some chores, like fuelwood collection, might not any longer be necessary, new have been added, such as collection of water for the unit[58]. The biogas unit will be an alternative (or complement) to an already existing livelihood system. Other methods and technologies already provide most of the services provided by the biogas technology. A number of changes will appear where old (not necessary traditional) ways of doing things will be substituted with new ones. As an example the biogas stove will replace the *chulha*, something that will effect cooking practice and appearance in the kitchen. The basic service, to provide cooking heat is still provided, but there are both quantitative and qualitative aspects that differ.

The perspective discussed above will be called a user-perspective and applied to analyse biogas technology in relation to the livelihood system of the users.

7.2 Women, the user of biogas technology and the household

Women are generally the ones that clean the cattle sheds i.e. manage the fresh manure. They are further on the ones that collect the water and mix it with dung to make the input to the digester. Biogas technology have been introduced in India to supply an alternative domestic fuel for cooking, women normally do the cooking. This means that the operation and management of the biogas unit is a gendered issue. In the discussions on how the biogas plant is managed and utilised the concept of household fills a central role, even though it is mainly a technology concerning the women.

The household concept is widely used to display a social entity in a physical place. Economics is one of the fields in which the concept has been used extensively. The assumption is that a household is the unit for consumption as well as the unit where reproduction of human labour is assured (Wong 1984; Young 1992). The concept can however be defined in a number of different ways, each with its own strength and weaknesses, a number of common notions can, however, be found in many of these (Wong 1984; Moser 1989; Wolf 1991; Moser 1992; Young 1992; Working Group on Gender and Economics 1995). The household can consist of a family (social entity) but this is not always the case. People in a household do not need to be kin. The household is an abstract, constructed, concept that is used to display a group of people living/staying physically at one place. There is further on no such thing as a universal household strategy, or as it is sometimes called household rationality. A household strategy would imply that the household makes decisions to the best of the household as an entity. But the household as a unit of decision

[58] This is not be sneezed at: the water requirements for the operation of a biogas unit can result in substantial increase (in a family of four, 50% or more) in domestic water need, as will be discussed in more detail in *Water: A plentiful or scarce* resource on p 56.

and rationality is inappropriate. The household is made up of a number of persons whose opinions and meanings differ:

> *...evidence indicates [59] that the interest of women and men belonging to the same household do not always coincide and, in some situations, are even in conflict (Agarwal 1985b).*

Decisions made by one person in the household will of course affect the household as an entity (Krishnaraj 1989), and hence it is difficult to talk about individual decisions at all. But there is a difference between this and the existence of a household strategy. A household strategy would, as said earlier, imply a common goal, whereas this will not be the case in decisions taken on an individual basis within the household affecting all the members.

Biogas units are normally described as being installed in a household. The decision to make larger investment, such as the case of investing in a biogas unit, in rural areas is usually taken by the man in the household, or by the men in co-operation (Mencher 1989; Young 1992; Agarwal 1997). On the other hand the women (including girls) of the household are the main persons responsible for the household domestic chores relating to water collection (for the domestic use), cooking and collection or preparation of fuel (CSE 1985; Jain 1996; Kulshreshtha *et al.* 1996). When there is a biogas unit installed in a household, the women will become the main managers and users of it. The technology has the potential, however, to bring a number of improvements to the situation of the women, something which is acknowledged. But as often is the case with unpaid domestic work of the women and children, it is not visible in the discussion on development and economics (Benería 1992; Evans 1992; Elson 1995; Jain 1996; Chambers 1997). For the case of biogas technology the gender aspect of for example the work load and resource utilisation has been more or less invisible. In most contemporary development projects the aspect of gender is considered. One example is the AFPRO biogas project (Turner *et al.* 1994; Dutta *et al.* 1997).

Even though women are identified as the main managers and users of the biogas plant the implications of this, like targeted action and including women in extension and development, is not highlighted in the NPBD-programme to any greater extent. One of the reasons for this could be that the approach made to encounter the user is through the household. In doing this the household as an entity will become the unit for consideration and hence place for decision making, management and operation of the biogas system. In an analysis of the technology the women, i.e. the user, should be put in centre, instead of having the household as the point of departure. Biogas technology could be seen as a gendered technology in the same sense as for example stoves.

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59 See for example Agarwal (1985b), Mencher (1989), Young (1992) or Collins (1991).

7.3 Inputs, outputs and general conditions in order to access the potential benefits of biogas technology

Biogas technology will transform three inputs, labour, dung and water, to two other resources, biogas and effluent. Apart from the biogas unit three additional general conditions have to be considered, economy, know-how and space.

Inputs	Outputs	General conditions
- Labour - Dung - Water	- Biogas - Effluent	- Economy - Know-how - Space

Table 4: Inputs, outputs and general conditions for biogas technology

To obtain a good and efficient process there is need for a steady operation of the plant where each day dung and water is mixed and poured into the digestion chamber. This input is of vital concern not just in order to obtain any outputs but also to obtain high quality outputs. There is also a certain amount of labour that has to be invested into the process. The descriptions of the inputs in the different biogas manuals are usually made in the form of a short workplan on how to manage the technology.

Not very surprisingly it is the two outputs that are focused on when the benefits of biogas are presented in texts and by people involved in the extension of the technology. But in order for these outputs to benefit the user(s) they have to be properly managed, something that needs both knowledge, labour (time) and to some extent also equipment.

A number of more general conditions have to be met by the user and on the place where the unit is physically located[60]. These do not necessarily affect the day to day use and operation of the biogas unit. The first condition here concerns economy, which can be divided into two different aspects; (i) the economical conditions in order to be able to invest in a biogas unit, displayed as investment cost and (ii) the economic rationality in investing in biogas technology for the farmer. The second general condition relates to know-how and knowledge of the use and operation of the technology. The operation of a biogas unit will not be part of any local knowledge and hence the know-how has to be transferred along with the technical device. Third comes the requirements on physical place to install the unit, as well as the feasibility for biogas production from a climate point of view, i.e. average temperatures, rainfall. In the following parts each of these aspects will be discussed in more detail from a user-perspective.

7.4 Inputs

Three different resources, labour, dung, and water constitute the inputs to the biogas units. Each of these is in turn associated with a number of aspects such as use and management of the technology that might affect the all-over picture of the technology.

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[60] Construction material and appliances such as the biogas stove are not considered here. The extension organisation or person provides these items.

Labour: Operation and management takes time

A user-perspective analysis of biogas technology should take its start in the differences in labour and workload that will be the result of the integration. For the users, whom we know as the women in the household, the main benefit can be found in a reduced workload. Potential time saving can be made through the substitution of one chore, for example of wood collection, to the operation of a biogas plant. The input of work in order for the unit to work properly is however not negligible. Different estimates on time-allocation for management are available. One estimate states that the daily maintenance and loading of the unit is stated to take approximately half an hour to an hour per day (ICAR 1976; Fulford 1988). Another estimate is based upon the digester volume, which says that approximately 7-10 minutes per m^3 digester volume (van Buren 1979; United Nations 1984). This would mean that for a *Deenbandhu* model, 2 m^3 biogas/day, which has a digester volume of 7 m^3, a daily 50-70 minutes is needed.

Another aspect of time, which is important here, is the qualitative aspect; i.e. is managing the biogas digester hard or easy work. This cannot be assessed other than through asking the user about their own experience of the work. Each day the unit will be loaded with water and dung that have to be brought to the unit and mixed, normally by hand, and then poured into the digester. The outputs from the biogas unit, (effluent and gas) should also be managed, which require further input of labour (time). The women in most rural areas traditionally handle dung on daily basis when cleaning the cattle sheds and so on, but this management will grow substantially through the integration of biogas technology. It is one thing to spray your front yard with a mix of water and cowdung to make it nice and neat, but another thing to mix water and dung for half an hour every day. There will be new chores concerning dung handling included in the daily routines. The amount of dung will be the same, but time spent on managing it will increase. The traditional use of water and dung mixtures for spraying the front yard is used as an indication that this part of the management of the biogas unit is not a problem (Gutterer *et al.* 1993b). I believe that the descriptions that the women do not object against handling of dung, such as is described in are not valid. There are large differences between handling of smaller amounts and the daily 100 litres that will be the case with the biogas unit.

> *After this [the putting of dung and water in the inlet pit] the slurry has to be thoroughly mixed. Just stirring the slurry with a stick or hand is not sufficient. All lumps have to be broken by hand to make a slurry of good consistency (Kishore et al. 1987) pp 39.*

Some available data on time allocation have been compiled into a table.

	Hours/day, household	**Hours/day for biogas unit**
Water collecting	0.78 (Batliwala 1983)[1] 0.36 (Jain 1996)[2] 0.30 (Jain 1996)[3] 1-4 (CSE 1985)[4] 1.5 (Rajabapaiah *et al.* 1993)[5]	The amount of water needed in the household will be increased 50% due to the biogas unit[8]. 0.5-6 hours/day
Wood collection	1-3 (Bowonder *et al.* 1985; Bowonder *et al.* 1988; Agarwal 1997)	n.a.
Manuring	n.a.	n.a.
Managing biogas unit	-	0.5 (ICAR 1976) 0.5-1.0 (Fulford 1988)
Cooking[6]	4.3 (Ravindranath *et al.* 1997)[7] 2.5 (CSE 1985)[4] 2.28 (Batliwala 1983)[1] 2.0 (Dutta *et al.* 1997)	One standard meal takes 30-40 extra minutes on biogas stove compared to traditional wood stove (Ravindranath *et al.* 1997).

1 From ASTRA (1981), "Rural Energy Consumption Patterns–A Field Study", Indian Institute of Science, Bangalore

2 Rajasthan (all ages, men 0.01 h/day)

3 West Bengal (all ages, men 0.02 h/day)

4 Secondary sources: various studies

5 Pura village, before installing community biogas plant for supplying electricity and running water.

6 Time saved due to less time spent on cleaning vessels as well as time saved in cooking is considered further in the section *Biogas: Use and access.*

7 From Shailaja and Ravindranath (1990), Women and rural environment in Saldanha (ed) "Karnataka State of Environment Report IV". Centre for Taxonomic Studies Bangalore

8 Further discussed under the section *Water: A plentiful or scarce* resource.

Table 5: Time allocation for different chores related to the management and operation of a biogas unit. Compilation from different sources

The time allocation data presented in Table 5 is by no means static, as there are large seasonal variations for example. In the case of fuel wood collection the access to biomass differs between seasons and collections habits might vary as well (Bowonder *et al.* 1985). During periods of intensive agricultural work, like harvest, time can be allocated to harvest rather than fuel collection. During these periods, alternative fuels can be used or a reserve can be used which was established during times of less workload. Water availability varies as well in relation to seasonal variations.

The operation of the plant requires attention on a daily, weekly, and yearly basis. Each day the unit is supposed to have an input of a mix of water and dung. The input to the unit should be steady and not vary from day to day. This is in order to keep a steady flow through the unit. The slurry, which will come out of the plant, should also be taken care of in an appropriate way. On a weekly basis the digester tank should be stirred with a bamboo pole in order to avoid scum formation, and formation of layers inside the digester. On a yearly basis the different devices should be investigated and, if broken or malfunctioning, attended to and replaced. Every five years *Deenbandhu* and *Janata* plant plants should be emptied and the digester chamber investigated for cracks from the inside and thereafter repainted (Singh 1972; Myles 1985). For the KVIC type, the dome, if made of mild steel, should be repainted and investigated for rust.

The time it takes for water collection, bringing the dung to the digester, and the mixing of these two is usually not assessed in information material on biogas technology. Obviously the time this takes varies highly between regions which can be seen in Table 5. However, that changing time allocation due to operation of a biogas plant might not be a negligible increase in work time. As this will mainly concern the women of the household, who are already under a great workload, it seems especially important. The time the operation and management of a biogas plant requires should be assessed and compared to the previous situation. In areas where water and stables are close to the unit and wood is scarce less time will have to be allocated to secure an energy supply. In Dutta *et al.* (1997) it is argued that by using biogas, less time is needed collecting firewood. Households without biogas make an average of 39.7 trips per year, each taking 9.1 hours. The ones with biogas, on the other hand, make 30.7 trips, each taking on average 5.2 hours. However the time allocated for water collection, slurry handling, and operation of the plant in general is not included.

A striking thing concerning time allocation is that a number of authors, for example Vijayalekshmy (1985) and Fulford (1988), argue that the time saved by adopting biogas technology is not a valid argument for extension. Reasons given are that there are always other things to do, and in certain areas where unemployment exist, people do not have much else to do than collect fuelwood.

Dung: A resource with several alternative uses

In order to obtain the biogas, biological material is needed. In India dung from *zebu* cows or buffaloes have been the main feedstock for generating biogas. Several trials and projects have been carried out where other types of feedstock, such as weeds, leaves, or husk have been applied. There has not been any widespread use of other feedstocks than dung in India. New biogas designs might very well be more adapted and the situation might change[61]. Another biological material that has been discussed as a possible feedstock is nightsoil/faeces (Prasad *et al.* 1974; Anonymous 1981; United Nations 1984). There are different opinions on the applicability of this but generally it seems there has not been any wide spread use of nightsoil as supplementary feedstock, even though subsidies have been available. Reasons given are that there are taboos against use and handling of human excrement's (ISAT 1997) and to cook food on the gas (Rajabapaiah *et al.* 1993) but in some areas this does not seem to be an obstacle (Dandekar 1980).

In order to be able to benefit from biogas technology the access to dung will have to be ensured. In the extension work, the normal procedure is to look at how many cattle the farmer has, and through this an estimate of the available dung can be made. There are large variations between different authors on the number of cattle required to ensure a

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[61] See for example Lichtman *et al.* (1996)

sufficient supply of dung for the biogas digester. Estimates of cattle requirements for a 2 m^3 biogas/day unit from various sources are compiled to a table below:

No of animals	**Note**	**Reference**
2-3 heads of cattle	In (KVIC 1977) it is stated in one sentence that the cattle should be *"stable-bound grown-up animals of medium size"* pp 14	(KVIC 1976; KVIC 1977)
3-4 bullocks or cows (Bangladesh)	From (Islam 1985; Hoque *et al.* 1993)	(Biswas *et al.* 1997)
3-4 heads of cattle		(Ghate 1979)
4 heads of cattle	Less than 5% of all cattle owners are considered to have four animals.	(Prasad *et al.* 1974)
3-5 cattle		(Moulik 1990b)
5 cattle or 3 buffalo		(Myles 1985) annexure J, table XIII
4-5 cattle or 3 buffaloes		(United Nations 1984)
5 cattle		(United Nations 1979)
4-6 cattle		(Vivekananda Kendra 1993)
7 adult bovine animal		(Ramana *et al.* 1991)
4-10+ cattle	Depending on state	(Kishore 1987)
Enough, mark on inlet pit	*"The best way to ensure proper feeding is to have marks...in the mixing pit indicating i) level of fresh cowdung and ii) level after mixing with the requisite amount of water"* pp 39	(Kishore *et al.* 1987)

Table 6: Estimated need of cattle to ensure enough dung for 2 m^3 biogas/day. Compilation from different sources

The general understanding in the extension work is that there is a need for the household to have about 4 to 5 cattle, which seems reasonable if the cattle are well fed and kept in stables.

The number of cattle required for the installation of a biogas unit depends on two factors; how much dung that is produced by each cow/bullock *and* how much of this dung that is collected. Bovine cattle are considered, in very general terms, to generally produce 11 and 12 kg of dung (wet) for cattle and buffalo, respectively (Gaur *et al.* 1984 in; Motavalli *et al.* 1994). When the animals are used in the farming as draught power or out grazing, they will not be kept in stables. As a consequence much of the dung is spread during the day and not collected. An example of dung production by cattle in Orissa can be found in Gutterer *et al.* (1993a)[62]. In Orissa a *zebu* cow produces approximately 5 kg dung per

[62] There is no mentioning in Gutterer *et al.* (1993b) to what region in Orissa the figure on dung production is valid for.

day. This suggests that 10 cattle are needed. If the cattle are grazing, about half will be available at the stables (Motavalli *et al.* 1994). This means that roughly 3 kg/day and animal is produced, almost 17 cattle are needed to ensure the required amount of 50 kg dung/day. Ravindranath and Hall (1995) states that a buffalo will produce 3.6-6.4 kg dung/day, cows 2.4-6.9 kg dung/day and cattle 4.6-10.4 kg/day. Another estimate is presented in Motavalli *et al.* (1994) where buffalo daily dung production is given to 3-4 kg/day and cattle dung production to 3-7 kg/day.

The number of cattle a household/farmer owns is often related to the amount of land he cultivates[63]. Biogas technology has been claimed to benefit only the better off farmers. Mr A. Dhussa at MNES clearly states that the NPBD is not a poverty alleviation programme and as such it can not be too much concerned with these issues *(Dhussa 1996).* NPBD is aimed towards spreading biogas technology to potential users, users who are defined by their possibilities to access the technology. On the other hand for NGO and grassroots development organisations this is a dilemma, as they are usually concerned especially with the poorer groups.

Little is said in the literature on the dynamics of cattle keeping, and the resulting problems in relation to biogas production. One reason for this could be that if it were stated that to be able to produce 2 m^3 biogas/day through biogas technology at least 10 cattle would be needed the technology would be assessed differently. The potential of biogas units in India would decrease substantially and hence the impact and resource allocation should have to be reconsidered. For the government to subsidise such a technology would seem difficult due to the already strong position these households can be supposed to have, due to the number of cattle they hold.

Sanitation benefits from biogas technology are often brought forward. One of these concerns the reduction of parasites and bacteria in the process material[64]. Intestinal parasites, often endemic in rural India, survive to a certain degree the relative short detention time and low digestion temperature which is the case in the small scale type Indian biogas plant. This should be considered in those cases latrines are connected to the biogas plants (Fulford 1988; Ellegård 1990; Rajabapaiah *et al.* 1993). Further on the breeding of flies is assumed to be decreased in the effluent in comparison to normal practice FYM management (Subramanian 1977; Turner *et al.* 1994). It seems that this effect from integrating biogas technology into the livelihood system is to a great extent based on observations and reactions from users. It should be pointed out that a biogas unit

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[63] There are of course differences to this correlation, but it can act as a rule of thumb.

[64] There are two directions here. First the reduction through anaerobic treatment in general, for example Fitzgerald (1979), where the focus is put on reduction rates of different pathogens and parasites in general. The point of departure is often the existence of pathogens and parasites and then an examination and analysis of reduction rates and factors that affects these processes. Second direction is on sanitation, i.e. latrines, in rural and semi-urban areas, for example Anonymous (1981) or Engel *et al.* (1977). Here the starting point is on improving sanitation in rural areas in which biogas systems can be seen as small-scale treatment plants for municipal waste. The reduction rate of parasites and pathogens is seen as a fact.

will require a more controlled management of the manure, which might be the actual cause for the reduction of flies.

Water: A plentiful or scarce resource?

Operation of a biogas unit will require not only a daily input of dung, but also a daily input of water. There has been little attention given to this input, some exceptions can be found, for example Dandekar (1980), Foley (1992) or Kishore (1994). The point of departure in manuals and descriptions of the technology is that water and dung availability should be ensured in order to install the biogas unit in the first place and will *de facto* be no problem. Water scarcity is, however, an escalating problem in many regions of India (GOI 2000). In many rural areas the situation is rapidly changing due to, among other things, increased irrigation of land through pumpsets and tubewells that can make the groundwater table to go down, resulting in less water available in the normal water collection places. Irrigation can also mean that water resources are monopolised in the sense that water will be owned by the person/farmer that arranges the irrigation facilities.

Tapped water is very seldom found in rural housing. Water is collected and brought home in buckets from wells, pumps, streams, ponds, or communal taps. There is a variation in how much domestic water is needed/used due to among other things availability-, distance-, and practice of collecting of water. Water collection and the handling of the dung is a women (and children) chore (CSE 1985; Jain 1996; Kulshreshtha *et al.* 1996).

A figure used for planning says that as a rule of thumb 40 litres of water per person and day is *needed* (United Nations 1989). The daily use of domestic water use has been estimated in another source to 25 litres per day and person (Myers 1985). An empirical example of water use can be taken from the Pura village in Karnataka. In 1977 each person used 17 litres of water per day. For the women to bring home daily water for a household of four (68 litres) 1.5 hours every day was needed. As part of a community biogas programme taps were supplied inside the village. This caused the water consumption in the homes to increase to 26 litres per day and person (Rajabapaiah *et al.* 1993).

To achieve an efficient and well managed anaerobic digestion process the dung has to be mixed with water. The slurry should be like *"thick pea soup"* (United Nations 1984) which means that about one litre of water is added to every kg dung. If the input of dung is set to 50 kg/day then approximately 50 litres of water is needed. If too much water is added the retention time will be reduced and gas production will decrease as a result[65]. If on the other hand to little water is added there will be a tendency for division in layers inside the reactor, which can cause operational difficulties, such as clogging.

The increased amount of domestic water that is needed due to the operation of biogas technology is evidently not negligible. Water use at home may rise with 50% or more due

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[65] The retention time gives a relation between the input per day and the volume of the digester chamber. The Hydraulic Retention Time (HRT) is a *design* parameter that states the relation between input and digester chamber. Typical HRT values are 30, 40 and 55 days. Digesters with HRT values of 30 and 40 days are designed for areas with warmer climate.

to the operation of a biogas unit at the household. A biogas unit should be operated on steady basis with daily loading of the unit. Variations between days should be avoided as this will result in decreased gas production. Loading of the biogas unit is done on one occasion, usually in connection to cleaning of cattle sheds. Water will be needed in relation to this, which means that the water has to be fetched in advance. For the biogas system the input of water (50 litres for 2 m^3 biogas/day plant) should be done on one occasion. Compared to other domestic water needs, such as cooking, the water can be brought home throughout the day, as there is seldom need for large quantities of water at once.

7.5 Outputs

There are basically two outputs from the biogas system; (i) the gas that is produced through the anaerobic process and (ii) the fermented slurry, the effluent. Both of these resources can be beneficial to the user/household if managed properly.

Biogas: Use and access

The gas produced in the biogas plant can be used for different purposes, but it is as a cooking fuel that biogas has attracted the main attention. One of the aims of NPBD is to provide a clean energy source for cooking. The other uses are for lighting, it is also possible to power an Internal Combustion (IC)-engine.

When a new stove is integrated into the livelihood system of the women, a number of changes will appear. These changes will differ, depending on what type of stove that was replaced (we can assume that there is always a stove to compare with). The stove fills a central function as it is used to prepare the daily food. Use and operation is closely linked to a number of aspects that should not be forgotten in the analysis of biogas technology. Curing of food (Jiggins 1994) or as a giver of taste (Idnani 1964) are both functions of a stove that will influence use of the technology. In rural areas different fuels are often found supplementing each other. Cooking is therefore usually not dependent on just one type of fuel, for example only dungcakes or only fuel wood. The biogas will be used in the same way, i.e. supplemented with other fuel(s).

One of the problems of biogas technology refers to insecurity in the gas supply from the plant. Security in supply of cooking energy is a central issue in the users preference of cooking energy (Gill 1987; Lichtman 1987; Jiggins 1994). One concern raised by users is that of the insufficient gas production (Dutta *et al.* 1997). Reasons given are for example lack of sufficient feedstock, few numbers of cattle, or different types of mechanical problems such as crack in the digester and broken equipment. But other factors will also influence the biogas production, such as cold climate, improper management, or operation. The *Deenbandhu* model is designed to hold approximately 1/3 of the estimated 'daily requirement' as gas storage. This means that a 2 m^3/day unit can store about 0.7 m^3

biogas[66]. This amount equals very roughly one hour stove use. The storage will be filled before next meal is prepared, assuming that appropriate input and conditions are met. If the conditions are not met there will be less gas available and hence back-up energy sources will be needed.

In the case of the biogas technology there are a number of concerns related to the security aspect. One is the difficulty to assess the amount of gas stored in the unit. Different types of gadgets have been developed in order to make this possible, but it seems that these are not disseminated to any extent. Comparing this situation with what is at hand if using for example wood fuel or dried dung cakes, these resources can be stored and hence make it possible to assess available resources. Indications suggest that cooking practices and food preparation will change if there is a fuel shortage. Fuel conservation practices will emerge and food that needs less preparation will be preferred for preparation (Agarwal 1985a; Brouwer *et al.* 1997).

The biogas stove can be made quite efficient in terms of heat utilisation. This can be assessed in different ways but the usual measure is the Percentage Heat Utilisation (PHU) value[67]. The standard biogas stove is claimed to have an efficiency of about 45% (Kristoferson *et al.* 1986a; Ravindranath *et al.* 1997), whereas the traditional stoves are normally claimed to have PHU values ranging from 15-22% (Dutt *et al.* 1993). A PHU value is not static or definitive. A high value can very well be obtained under certain controlled conditions while under other conditions the assessed value can be hard to reach, hence it is important to remember that the PHU varies. One of the side effects due to high efficiency of the stove is that there will be less heat spread from the stove. This means that in warm climate, where the traditional stove would create high temperatures in the kitchen, less heat will be spread and temperature kept down. On the other hand, in cold

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66As an attempt to reach the poorer people with the biogas technology AFPRO designed a 1 m^3 gas/day unit. This design can hold half the daily gas output in its storage. A more recent design called *Konoark* is designed to hold 50% of the gas production even for a 2 m^3/day unit (Mohanty *et al.* 1999).

67PHU values are but one way of looking at the efficiency of stoves. These values can be of a number of types, monitored in laboratory or under more realistic conditions. The efficiency of the stove also differs depending on the type of food prepared, but then the whole cooking system is examined rather than just the stove. The PHU values are often measured through boiling a certain volume of water. A formula for calculation of PHU is displayed below:

$$PHU = \frac{m_w(T_B - T_i)C_p + m_e H}{m_f B}$$

PHU = value between 0 and 1
m_w = initial mass of water, kg
T_B = Boiling temperature of water, °C
T_I = Initial temperature of water, °C
C_p = Specific heat of water, kJ/kg, K (4.18 kJ/kg, K at 18°C, 1 bar)
H = Latent heat of evap. of water kj/kg
m_e = Mass of evaporated water, kg
m_f = fuel used in the test, kg
B = Lower heating value of the fuel, kJ/kg

areas (and seasons), when the heat from the stove is a welcomed contribution in the kitchen, a biogas stove will contribute much less warmth than a traditional stove. Similarly the emission of light from a biogas stove is less than from many traditional *chulhas*.

The efficiency of the stove does not tell so much about cooking time, it is merely a relation between input- and useful energy. The time it takes to cook, i.e. net time the stove needs to be utilised, is a central aspect from the perspective of choice of technology (Batliwala 1983; Gill 1987). A table that shows the differences in time spent for cooking has been compiled by Ravindranath *et al.* (1997).

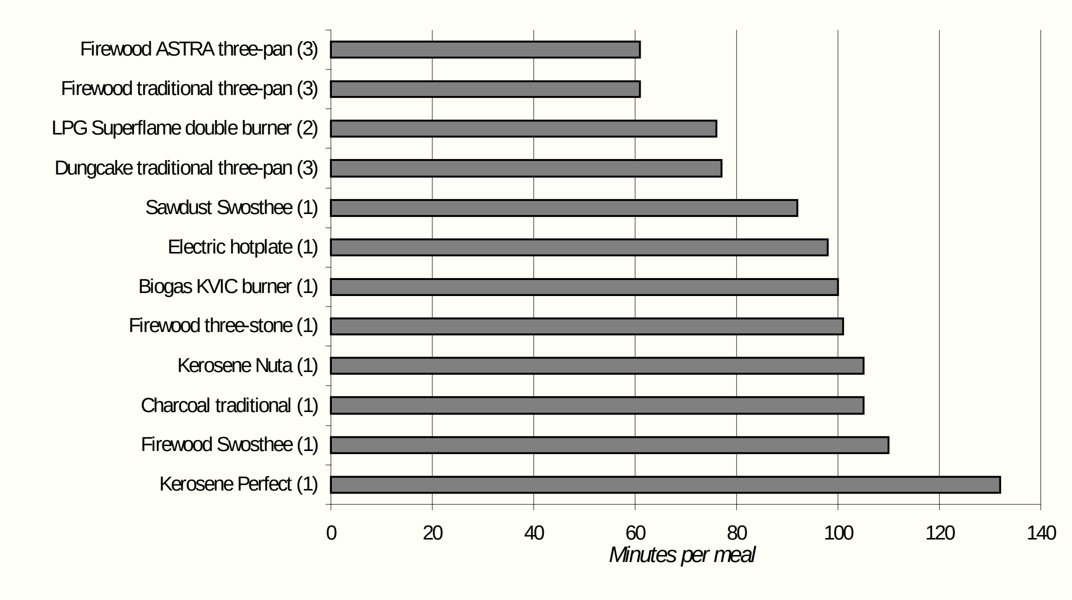

Table 7: Mean time required to cook the standard meal (Ravindranath et al. 1997). Numbers within brackets indicates number of cooking holes or burners.

The comparison of cooking time required for preparation of a standard meal between traditional firewood, three-pan stove, and conventional biogas stove suggest that the traditional stove will require less time. The differences between the stoves are quite substantial, from 60 minutes on woodstove to 100 minutes on biogas stove. The meal prepared consisted of several dishes so in the case of the one-burner biogas stove the cooking had to be done in a series while for the three-pan stoves a simultaneous preparation could be done. These results stand in contrast to for example the view in Dutta *et al.* (1997) or Turner *et al.* (1994) where it is argued that time will be saved due to the use of a biogas stove. This could be true in cases where enough gas is available and there are enough burners for preparation. If we assume that there are at least two meals prepared daily, differences in preparation times will be almost one and a half-hour[68]. The modern device that seems to be most attractive from Table 7 in relation to time requirements is the LPG Superflame. The main barrier for the LPG to spread in rural areas is that there is no infra structure for distribution in these areas and hence people will not easily be able to

[68] We assume households that can afford a biogas unit also afford two meals per day.

get hold of gas. It is though the preferred fuel by people *(Kishore 1996).* Improved *chulhas,* which seem to be favoured in respect to cooking time, are often equipped with more than one cooking hole. It should be pointed out again that just because cooking time is short it does not mean that the stove is energy efficient.

The attention given to the qualitative aspects of cooking with biogas is not considered in detail in the material about biogas technology, even though it is one of the main reasons for disseminating it[69]. When it comes to improved *chulhas* the aspect of how the user perceives the stove is considered important (Gill 1987; Sarin *et al.* 1989; Dutt *et al.* 1993). The biogas system should be analysed in the context in which it can be found i.e. the rural homes, as well as in the in the way it is operated.

Even though the gas is mostly used for cooking there are other end-uses for the gas. Lighting is one of these and another is fuel for an IC-engine. Of these the lighting is probably the most common. Compared to fuel for cooking, lighting is often done with commercial fuels, such as kerosene, which means that there will be an economic gain in any 'home-made' fuel. In areas where there is still no electrification, biogas light could be a solution. Examples of cases where the gas produced is actually only used for lighting can be found[70]. In practice it seems to be lot of work, as well as investment, just in order to be able to get light. In cases where gas is available for cooking or other purposes lighting will be a good additional service from the biogas technology.

Biogas fuelled engines can be used for different purposes. One of these is for irrigation pumping. If the gas should be used for this purpose, the biogas plant needs to be constructed at the farming site(s) rather than at the home (Bhatia 1990). A large capacity biogas plant is needed for the storage of the gas as the output will be needed intermittently (Kishore *et al.* 1986). Large plastic bags to hold the gas are sometimes referred to as a solution to the problem of moving the gas from one place to another[71]. In India this approach is not found.

Effluent: High or low value?

Women are normally responsible for cleaning cattle sheds. Women are the ones that will be responsible for the daily operation and management of the biogas unit. When the biogas unit is loaded with fresh slurry, effluent will be pushed out of the digestion chamber and should be managed properly. It is not clear who will be responsible for apply the effluent to the fields.

The effluent from the biogas unit holds value both as a soil conditioner and organic fertiliser. If the farmyard manure (FYM) is not taken care of, or used for cooking fuel, an improved resource management can be obtained by integrating a biogas unit in the

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[69] The stove that is used in the biogas system for example has been more or less the same model since mid 70's. There is a definitive lack of interest given to the utilisation aspect of the biogas and especially in the case of biogas for cooking, the most common utilisation.

[70] See for example Dutta *et al.* (1997), or Jash *et al.* (1999).

[71] Se for example United Nations (1984)

livelihood system. The fertiliser benefit has been claimed to reduce economic spending both for the farmer (Biswas *et al.* 1997) and for the nation (Moulik 1985; Sasse 1990).

The value of the biogas effluent as a fertiliser has been discussed since at least the mid seventies. KVIC claimed at that time that the nitrogen level in the effluent was actually higher in the effluent than of the unprocessed matter (KVIC 1976; KVIC 1977) This view was spread and taken up by Indian Council of Economic Research (ICAR) (Bhatia 1977). However this stand has been much disputed, as it is not at all clear that the effluent holds these qualities (Chawla 1986).

The content (in absolute terms) of nutrients and minerals in the manure will not change to any great extent due to the fermentation process. Compared to FYM, nitrogen, potassium, and phosphorous found will be found in the effluent in forms that are more easily absorbed by plants. A conversion of amino-acids and proteins to ammonia, and soluble ammonium compounds takes place. Organic material, in the form of dead bacteria, will also be produced. This is, however, a theoretical value of the effluent.

In order to obtain any benefits the management of the effluent is critical. First, the quality of the effluent is dependent on how the fermentation process has proceeded in the digester chamber and what the inputs have been. If good quality stable manure has been the input, the output will improve compared to if poorly fed, grazing cattle's manure is used as input (an effect of the difference in N-content). Second, how the effluent is treated after it has left the digestion chamber. In order to ensure that the loss of nutrients is kept at a minimum, measures have to be taken to collect the leachate water and avoid the effluent from drying in the sun. As the dung is mixed with water to ensure an efficient fermentation process, the effluent that will come out of the digester will hold a quite low dry solid content (about 8% TS). Much of the nitrogen will be found in the liquid part of the effluent. Loss of nitrogen will be the result if the effluent not taken care of properly. If it is dried in the sun, the heat will make the nitrogen diffuse to the air as ammonia and bacteria can cause denitrification in the presence of air. Almost all of the nitrogen in the effluent can evaporate to the atmosphere through these processes (Chawla 1986; Moawad *et al.* 1986). The liquid part, containing much of the nitrogen, might also run off as leachates into the ground.

The method for handling the effluent that has been advocated in India is to apply the effluent to a compost pit together with other biomass and wastes. The compost material can thereafter be used where soil conditioning and fertilisers is needed. The dry solid content will increase and hence it will be more easily handled. The compost will, if designed and managed properly, ensure that a high degree of the minerals and nutrients can be preserved. In the manuals produced by AFPRO on *Deenbandhu* biogas plants, and the *Janata* biogas plants it is merely stated:

> *"This [the compost pit and the operation of it] is a mandatory requirement"(Myles 1985; Singh et al. 1987).*

At AFPRO's biogas research and training facility in Aligarh outside Delhi there are several demonstration biogas digesters. There is also a series of half-constructed biogas units that display the different stages in the construction process. It is striking, however, that there are (end of 1996) no compost pits or composts showing how this part of the biogas technology should be designed and operated. Cutting of the production costs of the biogas plants has since the 1950's been one of the major development tasks. It has been noted that the designs are altered in the field to reduce the installation costs[72]. Examples of such 'improvements' are exclusion of the compost-pit, outlet-pit cover, change the iron pipe to a plastic or rubber hose and omit the water evacuation system on the gaspipes. Loss of quality of the effluent, an increased vulnerability to mechanical failures or increased risks for accidents by people and animal falling into the outlet pit are possible results from this. It should be pointed out that this is something that is not supported in manuals on construction of biogas units.

A number of experiments have been carried out in order to find out the value of the fertiliser[73]. The results from these tests indicate that the effluent from a biogas digester is at least as good a fertiliser as the FYM and chemical fertilisers. The conclusions from these experiments have however been disputed (Chawla 1986), as the methods for evaluation are questionable. In some tests the same amount, in absolute terms, of nitrogen is applied from both chemical fertilisers and from biogas effluent. This is then compared to the results given by a non-prepared area. The result from this basically shows how plants can assimilate the nutrients from the different sources, not so much on the value of the effluent as an organic fertiliser. If the biogas digester is fed with manure from well-fed stable cattle, the effluent will be different than if the input of dung is from grazing working cattle. Another point is that the handling of the effluent affects the fertiliser value of the end product applied to the fields. Due to this, results from testing in laboratories are difficult to transfer to practical use.

In China, the management of the management of the effluent has been reported to work well, but in India it has been less successful. It has been argued that the reason for this is the lack of tradition in composting in India (Moulik 1985; Fulford 1988). There seems to be little evidence for this suggestion however. FYM is acknowledged as a valuable soil conditioner and fertiliser in rural areas. Barnard *et al.* (1986) argue that compost practice is well spread all over India and Bangladesh and that this would be something that has traditionally been the case. The management of the slurry seems not to receive adequate attention from the extension organisations. If the traditional practice of the handling of manure has to change and that the fertiliser benefits are seen, as of central value to the technology, then it would seem important to stress this aspect. If well managed, the effluent could actually prove to be more profitable for the farmer than the gas.

7.6 General conditions

To gain access to the technology a number of general conditions have to be met by the user. These conditions are linked, on the one hand, to the user and the household where the unit will be installed, and on the other hand to the environmental conditions where the unit will be placed.

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[72] See for example Turner *et al.* (1994), Dutta *et al.* (1997) or Gustavsson (1995)

[73] See for example Dahiya *et al.* (1986) or Moawad *et al.* (1986).

Money: Earning money through saving expenses

One of the most discussed aspects of biogas technology is the economic dimension. The question discussed is whether or not the technology is economically viable (Bhatia 1977; Kumar *et al.* 1977; Stuckey 1985; Moulik 1986; Lichtman 1987; Kishore *et al.* 1988; Kishore *et al.* 1990; Joshi *et al.* 1992; Biswas *et al.* 1997). It is generally agreed that economic calculations on the use of biogas technology will be connected to a number of uncertainties. The technology can very well be economically viable under certain conditions. For example in cases where the use of chemical fertilisers can be reduced and a bought domestic fuel is replaced by biogas the technology might very well be economically viable. But this is under special conditions. Of course the operational conditions must also be conducive, such as sufficient input of dung, water and labour.

For the individual the installation of a biogas unit represents a substantial investment. A compilation of some estimates of the total installation cost is presented in the table below:

Type	Size (HRT)	Price (Rs)	Year	Indexed price (Rs)*	Reference
KVIC	n.a.	5,965	1986	8,750	(Kishore *et al.* 1990)
KVIC	40	6,300	1988	7,850	(Khandelwal *et al.* 1989)**
KVIC	40	11,700	1994	7,950	(Ramana *et al.* 1994a)
Janata	55	11,500	1994	7,800	(Ramana *et al.* 1994a)
Janata	55	4,600	1988	5,750	(Khandelwal *et al.* 1989)**
Janata	40	3,420	1983	5,900	(Myles 1985)
Deenbandhu	40	6,800	1994	4,650	(Ramana *et al.* 1994a)
Deenbandhu	40	3,550	1988	4,450	(Khandelwal *et al.* 1989)**
Deenbandhu	40	3,250	1987	4,450	(Singh *et al.* 1987)

*Indexed to 1990 levels: Whole sale price index, manufactured goods: 1981/82: 100, 1986/87: 129, 1987/88: 139, 1988/89: 152, 1989/90:169, 1990/91:190, 1991/92:214, 1994/95: 290 (estimated) (EIU 1993)

**In (Rubab *et al.* 1995)

Table 8: Total cost estimates for construction of KVIC, Janata, and Deenbandhu biogas units.

The investment can also be seen in relation to subsidies available from the Government of India. In 1988/89 the subsidy levels were ranging from Rs 4,410 to Rs 1,550 depending on (Moulik 1990a):

- Type of unit that should be installed (dimension)
- Category the household belongs to (scheduled caste scheduled tribe, marginal farmer etc)
- Area where the unit should be installed (hilly areas, plains etc)

The subsidy levels have decreased to some extent. In 1996 the subsidies ranged from Rs 3,200 to Rs 1,800 depending on region and category of household (MNES 1996). State banks ensure that bank loans to the farmers are available to cover the investment cost. In each state a bank has been assigned by the MNES to ensure soft-loans. These banks act under the automatic refinancing scheme offered by the National Bank for Agriculture and Rural Development (NABARD). The automatic refinancing scheme means that these banks will receive a fixed proportion, ranging from 70-86%, of their disbursement from NABARD (Ramana *et al.* 1994b). There is however limits for this refinancing depending on the targets in each state. One problem for the farmer is that the biogas unit itself is usually not accepted as collateral as it does not produce any revenue according to the bank (Turner *et al.* 1994; Dutta *et al.* 1997). The subsidies are paid from the state governments after receiving the application and inspecting the unit. It seems that the disbursement of these subsidies can, in some states, take a long period of time[74].

If the user-perspective is applied on the analysis of the economy of biogas technology, a number of questions emerge:

1. Does the substituted fuel represent a cost or not? The case is easy if commercial fuels are used. LPG and kerosene have to be purchased and a cost can be identified directly, but for non-commercial fuels such as fuelwood or dungcakes it is more difficult. The possibility to assign a shadow-price to it is tempting. A market exists, at least in urban areas, and this can stand as basis for a price. But fuel-wood in rural areas consists to a great extent of collected twigs and brushwood, which is not the same thing as the sold fuel wood. It becomes even more speculative when crop-residues are taken into consideration, as these resources do not hold any economic value.
2. How to assess the value of the effluent? Referring to the discussion on the value of the effluent as a fertiliser it is clear that it is not as simple as to only convert the effluent to FYM or chemical fertilisers. Further on, if the FYM is already managed and taken care of properly, the integration of a biogas system will not make too much of a difference in relation to economic gain on fertilisers.
3. How should benefits, like less smoke in the kitchen and improved BOP, be evaluated at the user level? These aspects do not hold any direct economic value even though they (however rarely in the case of the BOP) might be identified and appreciated by the women, i.e. the users. The approach to this varies but in most analysis these aspects are put as general benefits that should be accounted for as general improvements, but are not economically measurable. Insecurity in fuel supply will also

[74] See for example Turner *et al.* (1994).

be found here. Many of these non-measurable factors are related to the women's situation.

4. How to assess the value of work hours? The integration of a biogas unit in the livelihood system will result in change of daily chores. Less time can be spent on certain tasks. Labour input in the operation and management of the biogas unit will, however, be required. The actual changes and results due to the integration of a biogas unit will be case specific.

One of the conclusions that can be drawn from this is that the only clear economic saving is if biogas substitutes a commercial fuel and effluent can replace chemical fertiliser. As shown earlier, only a minor part of the domestic energy use in rural areas is commercial. Other economic profits will be vague and difficult to calculate. Hence the economic rationale behind biogas technology is mainly in saving expenditures rather than earning money through the technology. In general there seems to be more willingness among the farmers to spend money on things that can generate income, than investing in a biogas unit *(Kishore 1996)*. While farmers favour bank loans, banks are reluctant to do so for investments in biogas units. We can conclude that the economics of biogas technology will fall under the category, discussed earlier, that represents private financial and non-financial cost and providing private non-economic or economic (savings) benefit. These features of a technology are known from experience to be problematic when trying to transfer technologies (Barnett 1990). The main instrument to make biogas technology more economically viable to the farmers has been to make subsidies available. Through subsidies the monetary investment has been reduced.

The investment in a biogas unit has payback times of about 5 years[75]. The payback time is only valid if valid only when there is an appropriate price tag on fertilisers and domestic fuel. These payback calculations are further on based on the assumption that the units are operated at 100% load. In practice biogas units are seldom found to be operated at 100% efficiency or load rate (Dutta *et al.* 1997). This results in less output in terms of both effluent and gas, and hence the savings of chemical fertilisers and commercial fuel will be less.

Subsidies are, as mentioned earlier, given in arrears and there are fixed levels depending on the farmer's holding of land and to what class he belongs. Through the introduction of the *Deenbandhu* model the cost for a biogas unit became relatively low. If this cost could be reduced further the subsidy would cover more or less the whole investment. The TKW or an NGO can promote a technology with a number of potential benefits at a low or no cost. The more biogas units the TKW or an NGO can construct the more turnkey fees they obtain. Extension workers and organisations are often involved in other development fields as well (Fulford 1988). Indications are that farmers are persuaded to invest in a biogas unit in order to receive other assistance. NGOs have been able to finance other development projects through turnkey fees received from extension of biogas system.

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[75] See for example Biswas *et al.* (1997), Moulik (1985) or DaSilva (1980)

Turnkey fees will, however, not be paid unless the TKW or NGO gives a guarantee period of three years maintenance to the farmer (Turner *et al.* 1994)[76]. All failures that are due to construction faults will have to be covered by the TKW or the NGO at his own cost, minor repairs will, however, be paid by the farmer (Ramana *et al.* 1994a). The payment of the turnkey fee is made only after a certificate of the installation has been issued. In some states, the payment to the TKW or NGO is made in a series with the last one at the end of the period. There are also states where the turnkey fee is only received after the guarantee period is ended. This means that extension organisation needs to have quite some monetary resources in order to be able to pursue their task.

An aspect that has gained increasing attention in the discussion of the biogas programme is what vested interests there are in connection to the technology *(Dhussa 1996).* From being relatively dependent on the state rural development bodies in the 1980's, a transition to a greater reliance on NGOs and TKW as extension bodies has taken place. TKW and NGOs were seen as a way to reduce failure rates and to increase the number of installed plants, even though the subsidies and funds were reduced.

The NPBD is the renewable energy technology (RET) extension program that has received most resources over the past years in India, but compared to other power and energy programs it is only a minor program. The impression that the programme to a great extent is a way to subsidise development operation through the turnkey fees other than the diffusion of a RET is close at hand. The farmer needs only to invest small amount of money, provided he gets his subsidy. The extension organisation or TKW will be able to sponsor their activities or earn their living. In this, the user, i.e. the woman, is forgotten. She will have a new device that can ensure the domestic cooking energy. However know-how is needed which is not at all clear that she will be able to attain.

Women's know-how: The key issue?

There are a number of tasks and issues related to a successful operation of a biogas system. To be able to meet these, new know-how has to be attained. The daily operation of the plant, including loading and mixing slurry, needs daily and steady attendance by the user. There is no traditional or local knowledge that can explain the system. Know-how has to be transferred along with the physical unit in order for the user to operate the plant.

The *integration* of biogas technology into the livelihoods of the rural people will lead to a number of changes in the daily life. The women are the main users of the technology and despite this, they are not involved to any greater extent in the initial steps of obtaining a biogas unit. In a survey carried out in Orissa it was concluded that it had been the men that wanted biogas to be installed at their homes in the first place (Gutterer *et al.* 1993a).

The people involved in construction and extension work on the local level are mainly men. There are no rules against women working with biogas as extension workers but social

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[76] In order to avoid that turnkey fees are paid for non-existing plants each new unit should be inspected by a block level official, 5-10% of the new plants should be verified by a district level official, and last, 1-5% of these units should also be inspected by the state level officer (Ramana *et al.* 1994b)

and cultural norms works against this being done[77]. There have been quite extensive efforts, from especially the NGO community, to engage women in the extension work. Women's role in the biogas extension work, in those cases women are found, is not as constructors but rather as motivators (for biogas technology) at village- or NGO/organisational level. The main reasons given for not engaging women in the extension process are the extensive travelling involved in the work (Dutta *et al.* 1997), and that a good deal of the construction work is not practical for women in saris (Turner *et al.* 1994). However, women in India are often found working at construction sites or road building with heavy lifting and carrying, dressed in saris.

Exclusion of women seems to be due to other reasons as well. For example, extension workers and constructors of biogas units have to be trained and approved in order to be able to construct units that are awarded turnkey fees and governmental subsidies. A prerequisite for the training as a biogas mason is previous masons training, something which very few women have. This mason training is done in 17 (in 1996) different training facilities spread nation-wide (MNES 1996).

The issue here is not that women are unable (not permitted) to construct biogas plants by themselves, but rather the difficulties for the woman user to attain correct information on how to operate, benefit, and maintain the unit. The transfer of know-how from the male extension worker and the women operators is problematic. Dutta *et al.* (1997) noted that extension workers normally interacted with men, husband, or son, from the household concerning operation and usage aspects of the biogas unit. The women, who are the operators and main users, will depend on someone passing this information on to them and that this person can explain about operation and management of the unit. A criterion for attaining an efficient process is correct maintenance and daily inputs. Certain knowledge is needed to utilise the biogas stove efficiently. Ingredients should, for example, be prepared before cooking, i.e. lighting the stove, to ensure a more efficient use of the gas, and the flame should be adjusted in correspondence to the heat required due to the same reason. The women do not generally possess this know-how, as they are not in position to obtain first hand information from the local experts, i.e. the extension workers.

Space and location: Where and how

The biogas unit has to be physically located someplace. When the selection of location spot is done certain aspects should be considered.

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[77]One example of the exclusion of women in the construction and installation of biogas systems is apparent if looking at pictures of construction and construction sites in some of the literature on biogas technology. All the pictures in Kishore *et al.* (1987), Singh *et al.* (1987), Myles (1985) and Vivekananda Kendra (1993) display men working with the biogas unit. In some cases men are found loading the units. One notable exception is found on the cover of Dutta *et al.* (1997). Comparing with some of the booklets available on improved Chulhas, more or less every picture includes women. See for example Sarin (1984; 1989). See also Subramaniam (1994) for discussion on stoves and gender aspects.

- The biogas unit should be placed at a short distance from the kitchen and from the cattle sheds, in order to keep the distance for carrying dung short, and minimise pressure drop in pipes.
- There should be no trees close to the biogas unit. This is to avoid mechanical damage caused by roots, but also to avoid shading from trees.
- The biogas unit should be placed in such a way that mechanical damage caused by cattle can be avoided.
- Due to the risk of leakage of liquids from the unit, it should not be placed near any wells.

The space requirements depend on the size of the unit. A 2 m^3 biogas/day biogas unit requires approximately a circle area with a diameter of 7 meters. This does not include space requirements for compost pit. Rural villages in many parts of India tend to be compact, implying that it is not always easy to find a suitable spot to construct the unit.

The biogas technology in the form that has been developed and propagated in India has been on a relatively low technical level. There are few items of the units that are specific for biogas units. Concrete, bricks and steel pipes are things available in most towns. The exception has been the mild steal gas dome on the KVIC-design, which has to be produced in a mechanical workshop. The local availability of resources is seen as a positive feature of biogas technology[78]. But what does locally available mean in this context? On the one hand it could mean accessible locally, but it could also mean locally produced and processed. In the case of biogas, steel pipes, concrete and so forth are needed, items that have to be brought in from the outside. These items are available through the market but are not locally produced. Even if materials that were locally produced were available, they might not stand up to those quality standards that are required (Kishore *et al.* 1986).

There is furthermore an absolute need for skilled masons in order to be able to guarantee the performance of the unit constructed. In order for the farmer to receive subsidy a certified mason should construct the biogas unit. These masons are not always found in the local community. The biogas technology trained masons will also do other masonry work along with biogas construction, work which is often more profitable. Dutta *et al.* (1997) also argue that these masons, who will also act as TKW and hence educate the operator (or the person representing the household), are not too well aware of issues concerning maintenance of the biogas unit. It is not clear that the biogas masons could be seen as a locally available resource[79].

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[78] See for example Myles (1985)

[79] Deconstruction of biogas units is a chapter not considered in literature, which is not strange as the technical life of a biogas unit if well managed is long. The construction is however made below ground so there is not that much visual offence by it, but these constructions impose a certain risk of accidents. The biogas unit might in some cases be a more permanent structure than the living house as it is made of high quality concrete and bricks.

7.7 Conclusion

The users of biogas technology are mainly women. Even though this is quite evident and also acknowledged within the NPBD, the interface between the extension work and the user, i.e. women, is generally through the men in the specific household. This can partly be explained by cultural and social norms concerning women co-operating with men coming from outside the family. The stronger economic power that the men represent, in comparison to women, could also be a reason for this. Men are more attractive to confront as the technology needs relatively high financial inputs.

Time allocation for management and operation of the biogas unit will depend on the context in which the biogas unit will be integrated. There will certainly be cases where time is saved, but there is no clear evidence that there would be any decrease in workload for the women, what will happen is a shift in chores.

The direct subsidies for installing a biogas unit are likely to be slowly phased out. It will no doubt be important to look in further detail on what is required to use biogas technology in an efficient way. Experiences of diffusion of innovations in general indicate that innovations that do not have a direct financial output are the ones that are most difficult to diffuse. To many households' an investment in a biogas unit will result in non-financial savings benefits rather than financial savings or production benefits. In richer households more commercial primary energy sources are used and hence the economic rationale behind biogas i strengthened.

It does not seem that biogas technology is an appropriate solution for everyone. It requires inputs to function properly that can be hard to find in many regions. Water requirements, for example, can be substantial. Many of the potential benefits of biogas technology on a user level seem hard to realise in practice. The effluent must, in order to be a good fertiliser, be managed properly, something that seems not that common. The biogas unit is designed to produce a daily amount of gas, which should satisfy the requirements of the household. The gas amount will, however, require good conditions and proper management of the unit or otherwise the gas amount produced will be less. It would not be too surprising to find that the produced gas will not meet the requirements, and hence need to be supplemented by other sources of energy.

8 Diffusion of small scale biogas technology in India- Learning from experience

Biogas technology can be found all over India today. Only 20 years ago the technology was only spread and available in a few states. The diffusion process seems to have been highly successful, but still, although large sums of money have been allocated to the programme, only about 25% of the estimated total potential number of biogas units in India has been met. It is central to acknowledge that there is a vast number of perfectly functional biogas units all over India. There are many women and other household members benefiting from the technology through better working conditions.

The aim of this chapter is to close in on some specific conclusions from the study on small-scale biogas technology. I would like to bring forward four themes from the biogas experience in India. These are (i) the energy focus that has been applied to biogas technology, (ii) the user-perspective and the interactions they (the women) have with the technology, (iii) the results of the biogas programme and (iv) why biogas technology has attracted attention.

8.1 Theme 1: Biogas technology and the focus on energy

There are a number of potential reasons, as we have seen, to why biogas could be advocated for the purpose of development in rural areas. However the energy aspect seems to have been the overarching driving force for diffusion in India. The diffusion of biogas technology has had a quite clear top-down approach. Actors found at national and state political level, along with actors found in organisations and institutions on high posts have played major role in making diffusion of biogas technology in India possible.

In the early history the main reason for dissemination of biogas technology was the fertiliser benefits, rather than the energy aspects. The energy potential was seen as a positive by-effect. But biogas attracted attention after the first oil crisis in 1972/73. At this time it was seen as a potential rural energy source that could avoid increased fossil fuel dependency in rural areas. The value of the effluent as soil conditioner and organic fertiliser became now largely a side effect to this. The initiation of the AICBP was accompanied with the identification of the so-called fuel wood crisis. Now, reasons for diffusing biogas technology became even more directly energy related. To avoid deforestation in rural areas, and through this limit erosion hazard, it was believed biogas technology could be disseminated and supply rural areas with an alternative energy source which would alleviate these problems. As additional benefits, there could be improved resource use and better living conditions for the users.

The energy focus was further settled when DNES took over the responsibility of the national biogas programme, NPBD, from the Ministry of Agriculture. The Department later became a Ministry, displaying the impact it had had, but also the political attention it had received. It has been argued that the technology only becomes viable if taking all of its benefits into account *(Dhussa 1996)*. This might in fact be one of the weaknesses of the technology. One of the success stories that can be found in the literature on biogas is the community biogas plant project in Pura village. The community biogas plant supplies gas to an engine that pumps water the community so tap water is available. This has been the result after the traditional community biogas plant where gas should be distributed to the inhabitants, had failed. Quite some resources were put into the project through both studies of the performance and money for the operation. It came to the point where the choice stood between either closing down the plant or to change the approach of operation and utilisation. Instead of gas for cooking, tap water inside the village became the service distributed from the biogas system (Hall *et al.* 1992). This suggests that the attention given to biogas as a purely domestic energy resource might not be the right approach. The technology that is diffused in India is basically an energy service that can supply heat that can be used for cooking purpose, and to some extent also light. The above example from Pura displays one of the concerns here; biogas technology in the form that is diffused today, cannot easily pump water or be used for a TV-set, even though this might be a preferred service by the users.

Biogas technology is not a technical fix that fits everywhere, there are people that have to operate and manage it. All too often this is forgotten and biogas is seen from a strict technical point of view, stating a number of criteria that will have to be fulfilled in order to benefit from the operation. But if these conditions can be met, or how they will be met, in practise is not so much elaborated on.

8.2 Theme 2: Biogas technology and the users - the women

The main users of biogas technology are the women. They will operate and manage the plant, and they will also be main users of the gas. Even though this is well documented and identified in documentation of the technology and by the people involved with implementation of biogas projects, women are not visible in the diffusion process. As main beneficiaries, the women should get adequate training in operation and management of the technology. This is not easily achievable today, due to, among other things, the structure of extension organisations, whose staff mainly consists of men. The men hold the economic control in the households and they will normally be responsible for the investment decision. If the women are acknowledged as the users they should also attain proper training for operation. But the male extension workers are reluctant to give training to females, as cultural and social norms work against this[80]. Several attempts have been made to meet this problem through for example forming of women's groups, or introducing female trainers[81].

There is surprisingly little attention given to the labour input and the impact the biogas units really have on the livelihood situation. Most information found in project reports and evaluations is in terms of number of constructed units, how many were found functional, and usually some brief discussion on the impact. The actual improvements given by the technology, compared to the situation before installation, are seldom assessed. The improvements could, if assessed and contrasted to the rural livelihood systems, form

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80 It should be noted that the women may very well be reluctant to receive training due to the same reasons.

81 See for example Gutterer *et al.* (1993a) or Dutta *et al.* (1997).

strong incentives for advocating biogas technology. An analysis of biogas technology should take its point of departure from the reality and needs of the women.

It is evident that the top-down approach and subsidised programmes applied in the biogas programme in India has gained results in terms of number of installed biogas plants. The approach is manifested through the structure of the programme, the way of screening results and channelling resources. A number of more decentralised features such as the TKW and NGO as the ones that are doing the actual extension work exist. The structure of the programme, however, admits relatively little freedom concerning the extension work. For example funding is based on certain features such as numbers of installed plants of a certain type. It seems that the main instrument to screen the progress and results from the programmes are through the annual numbers of installed plants. The structure of the programmes does not enable the users to influence the higher hierarchies. In the case of the NPBD there are a number of levels between the extension organisation and the steering committees. The users are found on the levels farthest away from the decision-makers. For example, research has to a great extent concerned issues that have had little to do with practical applications in rural domestic contexts. MNES have, however, had ambitious plans concerning research, but when research has been carried out the results have often not benefited, or been relevant to the users. The technology as such, as well as equipment, is almost the same today as in the beginning of the 70's.

The dissemination of biogas technology in India is argued to have a multi-design and multi-agency approach. This is perhaps correct from a national point of view, but looking from the user's perspective there is usually only one design to chose from and one contractor. Contractors are assigned a special area to operate in. These contractors are only trained in construction of one type of design[82]. In fact, today there are not many units constructed that are not of the *Deenbandhu* type. From a national level perspective the multi-design, multi-agency approach is valid, but not from a local level perspective.

Biogas technology is aimed towards rural groups. Especially women can potentially receive benefits from its implementation. It seems of great concern that the resources allocated to this programme are really used in an effective manner. Today there is a fairly high number of plants that are not in operation. At the same time it seems the economic viability of the technology for the farmers is low. If biogas technology holds all those benefits it is argued to have, it would be most contra-productive not to disseminate the technology. If, on the other hand, this is not the case, resources for biogas dissemination should be considered for other purposes that could really benefit users.

8.3 Theme 3: Monitoring the results

There is a lack of reliable information on the performance and the effects of the efforts to diffuse biogas technology even though the biogas programme is monitored in several

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[82] It is argued by Polak (1992) that the concentration on *one* design is a prerequisite for a successful project. "*The [Deenbandhu] design is standardised and proven. Its construction is easy and since it is the standard model, faulty construction due to puzzled masons is an exception"(Polak 1992).* This statement seems quite contrary to the multi-agency, multi-design approach.

ways. The different organisations involved in extension work carry out surveys, some research is carried out examining different aspects of biogas systems, and there are government bodies monitoring and inspecting the progress. For example a government officer (at least block level) should inspect and confirm each new biogas unit. Quarterly updates are made of the progress and distributed among the responsible officials. Assigned targets of number of new plants are also followed up and tendencies for not being able to meet the targets are monitored. Targets and displaying numbers of installed plants seem to have grown a big issue in the NPBD. It would not be totally wrong to talk about a *target oriented* approach to development. Reports on numbers of installed plants are delivered on regular basis, each state has its target, and each organisation and TKW gets own targets. The absolute number of installed units seems more important than the performance of the plants, once installed.

Biogas extension has become more than just a way of reaching development for the users. It has also become a way for development organisations to finance other development projects through the turnkey fee, as well as for TKWs to create an income. The beneficiaries from the NPBD are not the only direct users (the women) but also the organisations and TKW involved in extension work. The turnkey fee is a strong incentive to construct units for the extension worker or organisation. Together with the shrinking number of household that fulfil conditions for biogas establishment, this could very well lead to compromising on telling the farmers (men) about the actual performance and conditions of the units. The units might then be installed in households where the conditions of the number of cattle are not met, or where the water supply is not adequate during periods of the year. There are guarantee periods but those concern basically whether or not the biogas unit is functioning from a technical point of view. Training and promoting use of construction materials of good quality has lead to good technical functionality, while functionality in terms of whether or not the unit is 'in operation' is not known.

There is no easy way to monitor the performance of the unit. Performance can be looked at from a number of different angles; social-, technical-, economical, and environmental performance are some. But there are also methodological problems involved. The input of dung and water can be measured quite easy, but when it comes to amount of gas, it is not enough to know the volume but the calorific value should also be assessed. Both are difficult to measure. In order to collect information on all of the above aspects, surveys over longer periods of time should be carried out, and compared to similar situations without biogas technology. By assessing the performance and results, a target group for biogas technology could be better defined. Today this target group is basically households that own 4-5 cattle but this seems not to be an adequate categorisation. A proper assessment of the long-time performance of the biogas programme in India could give important indications of what the target group of the technology is. Is biogas technology for example accessible also for the not so well to do farmers, something that is claimed occasionally[83]?

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83 See for example Khandelwal (1990)

8.4 Theme 4: Why biogas technology?

The diffusion of biogas technology in India can be seen as one of the most serious efforts of induced diffusion of a rural small-scale renewable energy technology worldwide. However if we only consider renewable energy in rural areas as such, there are a number of resources that are much more widespread than biogas, such as the use of dried dung cakes or fuel wood.

Biogas technology has been seen, I would argue, as a technical fix to a number of problems that has been identified by development workers. It is a fairly basic technology, which has fit perfectly into the different rural development strategies that has been advocated in development over the years. It has been applied as a solution to a number of different problems that has been identified in recent years in development work. Biogas technology has been identified as a possible solution and reasons for *introducing* the technology has been easy to find. The technology can improve harvests, as well as health status of women and men. Sanitation in rural villages will be enhanced due to less flies are attracted to dung piles and so on and so on. The technology can even fight illiteracy, as free light can be provided during the dark hours, which in turn can enable people to practice reading. The reasons for advocating the technology are numerous. Reasons for the users to *integrate* the technology in their daily life is not that easy to assess. There seems to be an assumption among implementation and extension organisations that *introduction* of a good technology, such as the biogas technology, will automatically lead to its *integration* and improvements[84]. It will not however.

One characteristic feature of the biogas programme has been that it has had a low, if any, own diffusion momentum, i.e. spontaneous diffusion of the technology. More or less all biogas units in India are built with subsidies and large efforts have been put into advocating the technology. An extension apparatus is needed for diffusion. Biogas technology's place on the so-called energy ladder, is not at the top, but rather low. Biogas is today not one of the alternatives that people seems willing to invest in by themselves. Biogas as a source of domestic energy is an option to many rural households, but this only as long as access to other types of fuels does not exist. In some panchayats in West Bengal and Kerala a demand for biogas installations exists *(Moulik 1996).* In general, however, people still need to be convinced about the technology, even though it has been around for 15 years.

8.5 Biogas technology-Solution in Search of Its problem

There have been more than 2.7 million biogas plants installed in India. What are the results from the diffusion? In terms of impact on deforestation little can be said, but the suggestion is that biogas technology, as it concerns a domestic rural fuel, only have had a marginal, if any, effect on the cutting of trees and deforestation in general. Another potential benefit of biogas technology, is less dependency on chemical fertilisers. The need for domestic fuel might result in a use of dried dung as fuel and through this a demand for chemical fertilisers will increase. The fertiliser aspect seems to be one of the most benefi-

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[84] See for example the citation by Idnani (1964) on page p 29

cial for the farmers. But the manure is normally taken care of and clearly identified as a useful fertiliser and soil conditioner resource, so in many cases there will not be any direct improvement of the management of the FYM and hence reduction in use of chemical fertilisers. Concerning health improvements, improved BOP to due biogas diffusion little can be said with certainty, as these have not been assessed. So why has the diffusion process proceeded if the results are so uncertain?

Biogas technology was early found to be *a good technology* by people responsible for rural development extension work. By 'good technology', I mean, that it could meet a number of problems that were faced in the rural development process. Examples of such issues are use of cattle dung for fuel instead for fertiliser, deforestation in rural areas (thought to be due to domestic fuel need) or high and increasing imports of oil. Biogas technology could be seen as a patent solution to most of these. By *introduction* of the technology, fuel could be obtained, organic fertilisers and soil conditioner could be applied to the fields rather than chemical ones, and then of course the living conditions in rural areas could be improved.

I would also argue that Mrs Indira Gandhi has played an important role in deciding to diffuse the technology on a national scale. The inclusion of biogas extension in the 20-point programme, in 1981, gave the diffusion momentum as it got political back up on a very high level. Government funds and resources were as a result allocated to the dissemination and extension work. To argue against the technology meant arguing against the highest political leader(s).

It shall be remembered that biogas technology has proved to work and function well (under certain conditions)! For educated people, responsible for decision making in extension and development organisations as well as government and state bodies, this was a very attractive solution. *There is no doubt that there are vast potentials, but there are conditions to be met in order to achieve them.* The *introduction* of biogas technology in India has to a great extent been based on the notion that it is a good technology that could meet a number of difficulties confronted in the rural context. Biogas technology has been diffused as a technical fix to a wealth of problems. However, the essence of *integration* has been given little attention.

Even though it was assessed that biogas technology would influence the livelihoods of the users (already in the late 60's), this has not been given much attention. People have had to adapt to the technology rather than the opposite. From extension organisations, research institutions and governmental bodies, there have of course been field trials and development work. Attention has also been given to the issue of social changes and lack of appropriateness of the technology to livelihood conditions of the specific site, this does not seem, however, to have influenced the view of biogas technology to any extent. Biogas technology is managed and operated by the women in the household but it is the men who are in control of the decision of installing a biogas unit. Women benefit from improved working condition such as reduction of smoke in the kitchen, less drudgery in collection of fuelwood. But there is need for labour input in the operation of the plant, i.e. water collection, mixing of input slurry, which might result in that little has been won in terms of time through the use of biogas.

9 Synthesis - Large-scale diffusion of a small-scale technology

The Indian biogas experience is an illustrative case of a large-scale induced diffusion process of a technology. It is doubtful if the technology should have found its way to the users without the efforts and resources allocated by the government. The main question of the thesis was whether the diffusion of small-scale biogas systems in India had been successful or not.

The distinction between *introduction* and *integration* of a technology has been made here in relation to the diffusion process. If first considering the *introduction* aspect it can be stated that even though the potential number of biogas units in India has not been reached a vast number of installations have been made. Infrastructure for extension work has been created and awareness about the technology has been established among many people. There have also been efforts to facilitate a process of innovation. Innovation is needed to adapt the technology to varied conditions and problems met or encountered in the diffusion process. It seems however that this has mainly concerned actors on higher-levels in the structure; academics, and researchers and not so much on grassroots level *(Moulik 1996).* Exceptions, such as innovations coming from NGOs exist like the *Deenbandhu* design, but in relation to resources given to implement research and create innovations within the field, the results have not been that encouraging. Looking at this *introduction* process, it is striking that little critical examination has been carried out the actual results from the technology in practice have been. There are, without doubt, complex systems for keeping records on constructed units and their functionality. However, the feedback is based on the diffusion of the structure rather than diffusion of the technology meaning that the actual performance and results from this will not be visible. It seems as almost taken for granted that as soon as the device is on spot the sheer existence of this splendid technology will make people use it, even though benefits in practice are far from the potential ones.

Successful *integration* of the technology into the users livelihood system is not something that will follow from the fact that the users have access to the device. A perspective called 'user-perspective' can be applied to analyse the interface between the user and the technology. An assessment of the required interactions in form of inputs, outputs, and general conditions can be obtained and reflected to the livelihood systems of the users. The relatively high water requirements, for example, will emerge as a problem, in areas where there is water scarcity. The same applies in areas where there is no scarcity of woody biomass for fuel. In these cases the problem, which is meant to be solved, i.e. the lack or scarcity of cooking fuel, is not prioritised or seen as a problem. The incentives for investing time and labour in the operation of the technology must be found elsewhere. As we have seen there is also a requirement for input of dung to the unit. The required number of cattle is said to be at least four. This is, however, the minimum number when the cattle is well fed and the total amount of dung can be collected. In reality cattle are kept in stables only during night and are often found to be poorly fed. About half of the daily produced dung will be available for collection and use in the biogas unit, thus increasing the required number of cattle.

The design of the extension program with turnkey fees might to some extent be considered contra-productive. The direct beneficiaries of biogas diffusion are not only the users, but also the TKW and the various extension organisations including NGOs. The more installed plants, the more turnkey fees the extension worker/organisation will receive. This can act as an incentive to install plants to households not meeting the requirements of the technology. This beneficiary group will receive direct financial benefits from the technology. They will receive a turnkey fee, employment and possible business opportunities will be created. This can be seen in contrast to the users and farmers return from the biogas unit, which to a great extent is saving benefits and indirect returns. The *introduction* aspect seems to have gained more attention than the *integration* aspect, even though they are interrelated to each other.

Driving-forces behind the decisions to introduce biogas, what has here been called potential benefits from biogas technology, are associated to what is referred to as global knowledge. Global knowledge[85] is often contrasted to local knowledge[86] (Blaikie *et al.* 1997; Sillitoe 1998a; Sillitoe 1998b). The differences between local-, and global knowledge are not distinct but there are some notable differences. While global knowledge often can be seen as fragmented and abstract, local knowledge is holistic and contextualised. Local knowledge is to a great extent passed on informally, while global knowledge is usually transmitted formally. The potential benefits from biogas technology can more or less exclusively be linked to the reign of global knowledge. For example the need to reduce the oil import bill relates to discussions in national economics, and the same goes with the need to reduce the use of chemical fertilisers. The rural energy crisis, identified by scientists working in the field, was linked to exploitation of biomass resources for domestic fuel use in rural areas, something that has later been re-evaluated. Health benefits from biogas technology are linked to both the local and global knowledge dimension. Global knowledge can assess the reduction and decreased risk of respiratory problems, while the local knowledge tells about fewer difficulties with running eyes for example.

For the diffusion process to gain momentum the potential benefits from the technology have to become real for the users, i.e. the gap that exists between theory (global knowledge), and practise (local knowledge) must be bridged. Adapting the technology to the needs of the users, or adapting the livelihood system of the users to the technology can do this. This is not an issue of transferring only knowledge, but to actually try to assess the context in which the technology will be *integrated*. One important issue is that the potential benefits should be possible to reach or attain. From this study study it is possible to see that during the diffusion process a number different crisis and development strategies have emerged, and biogas technology has been seen both to be able to solve the

[85] Also sometimes referred to as scientific knowledge, western knowledge or formal knowledge (Blaikie *et al.* 1997).

[86] Also sometimes referred to as indigenous knowledge, informal knowledge (Blaikie *et al.* 1997),

problems and fit in the development strategy. For example the fuel-wood crisis was linked to diffusion of alternative energy sources and through this to biogas technology. The same goes for the oil crisis and press for reduction of imports of chemical fertilisers and oil products.

It is possible to divide the features/benefits into three categories. First there are the features and benefits that can be found in practice and part of local knowledge. Second there are the potential benefits based on global knowledge. The last group consists of dogmas of the technology that may not have so much to do with either of the two other groups. Dogmas of a technology are benefits, associated with a specific technology and based on disputed or even rejected theories[87]. In the case of biogas technology an example of practical benefit would be the absence of soot on pots after cooking, which is one result from cooking with biogas in comparison to fuelwood. Improved harvest due to use of effluent from a biogas unit is a potential benefit, which might not always be obtained in practice as suitable conditions and proper management of the effluent is needed. A dogma of biogas technology could be the argument that biogas technology should reduce deforestation.

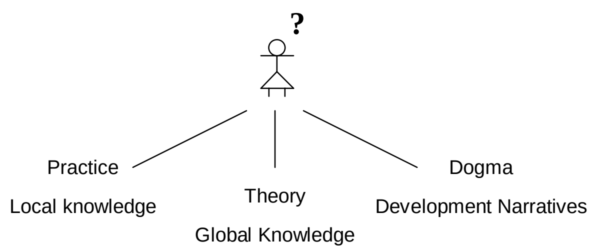

Figure 10: Practice-theory-dogma (and women)

Dogmas of a technology have much in common with the idea of development narratives. The dogmas of the technology have a strong explanatory value and can give an impetus to the diffusion of the technology, while they may only be partly true. These dogmas are further on not easily changed or deconstructed. It is perhaps not so surprising that dogmas will exist in a diffusion process, and especially within a large-scale diffusion process such as the biogas technology diffusion. While the top-down approach to diffusion leads to results in terms of installed devices and a relatively high possibility to a rational approach, it is difficult to achieve efficient feedback structures from the users to the higher levels, i.e. the structure will not easily change. The actual results in terms of concrete changes in livelihood system from the diffused technology are not known in detail. This can be put in contrast to the more bottom-up strategies where the actual results should form the basis for the continuation of the diffusion process. On the other hand this process will become more divergent and the possibility for rationalising is less, with higher costs for introducing the same number of devices as a result. In the case of the top-down approach the *introduction* aspect of the diffusion takes primacy over the *integration*, while in the case of the bottom-up the integration aspect is more important.

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[87] See page 45.

From this study it is possible to draw the conclusion that the strategy applied for dissemination and diffusion is of central concern for the programme. Diffusion of biogas technology in India was based on a top-down approach. Top-down approaches are marked by, among other things, centralised decision-making and technical solutions to problems (Biot *et al.* 1995). Structures for decision-making, planning, and dissemination can be established through bureaucratic measures, i.e. *introduction* of the technology, but it is difficult to achieve structures in this context that will make the diffused technology work in the users context, i.e. *integration* of the technology. If it works, the closest explanation at hand is that the technology filled a space in the livelihood situation of the user, rather than that an appropriate bureaucratic introduction structure had been disseminating the technology.

It seems evident that the *introduction* aspect of the diffusion process has been successful. A vast number of units have been installed, and the ambitions that have been set up have usually been met. Limits to number of installed plants are to a great extent set by the resources given for subsidies. This means that it is still an induced diffusion process. Concerning the *integration* of the technology into the users livelihood systems, the technology seems to fit perfectly in some cases, but not very well in other. The requirements set by the technology are strict and could be difficult meet in many areas. There is also the issue of problem definition. In many cases the biogas technology can be a solution to problems that are not looked upon, by the users, as very acute or even existing.

A question that is seldom asked is for what problem, and for whom, biogas is a solution? The rural energy crisis has been brought forward again and again as a reason for biogas extension. Similar is a need for decreasing the import of oil and chemical fertilisers. But these are issues mainly conceived by politicians not by the people who are the users of the technology. There is for example little evidence that the rural energy crisis is something that women, if comparing to other needs, prioritise. Lack of education and safe drinking water are normally seen as more acute than lack of energy. Many of the features of biogas technology could be attained through other solutions, such as improved *chulhas* for cooking or PV-systems for light. The strategy to let the users clearly define their problem in a specific context, and thereafter look if technological solutions are available to meet the identified issues not to have been applied. In the case of the Indian biogas programme a certain programme has had the goal to implement biogas plants, rather perhaps than to solve a certain specific issue. As MNES today works more along an end-use strategy this would surely be possible to attain today. It appears better to focus on one problem with a good solution, rather to solve more or less all problems with second rate solutions. The question is; to which problem is biogas technology really a good solution?

Appendix I: Biogas Technology: Process and Technology

The description made here is an introduction to the biological processes involved in anaerobic digestion[88]. Understanding the processes inside the digester is useful in order to the realise conditions to be met in order to achieve an efficient anaerobic process. The appendix also includes a brief introduction to biogas technology in general.

The anaerobic process

Anaerobic processes are among the oldest on earth, actually older than those involved in the photosynthesis. The methanogenic bacteria are found all over the world, but live only in environments where no, or very small concentrations, of oxygen is present.

In the early history of earth the atmosphere was hostile, from our human perspective, and no oxygen was present. The methane bacteria could live and breed, as their metabolism was dependent on the absence of oxygen, but presence of carbon dioxide and hydrogen. As time passed the methane bacteria became dispatched to environment where oxygen was absent. It can now be found in the bottom sediment of lakes and in marshlands for example. The intestine's of animals and insects is another place with suitable conditions for the methane bacteria, The anaerobic process is generally characterised by small heat emissions per unit decomposed substrate (McCarty 1971). This is in contrast to the aerobic processes where large heat emissions per unit decomposed substrate take place. A higher efficiency in terms of taking up acetate and short chain fatty acids can be obtained.

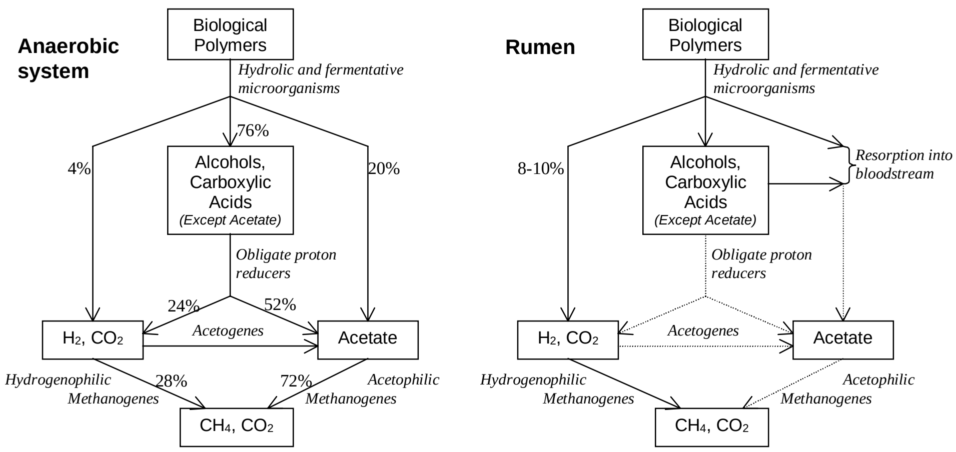

Figure 11: Substrate flows in anaerobic systems (Temmes et al. 1987)

The system in 'A' represents an anaerobic system in for example a biogas plant, whereas the 'B' system displays that inside the rumen. As can be seen the methane production is much higher in a biogas plant than inside the rumen. A highly schematic figure of the process that takes place in a biogas plant can be made:

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[88] *Anaerobe* - without oxygen present, *Aerobe* - with oxygen present.

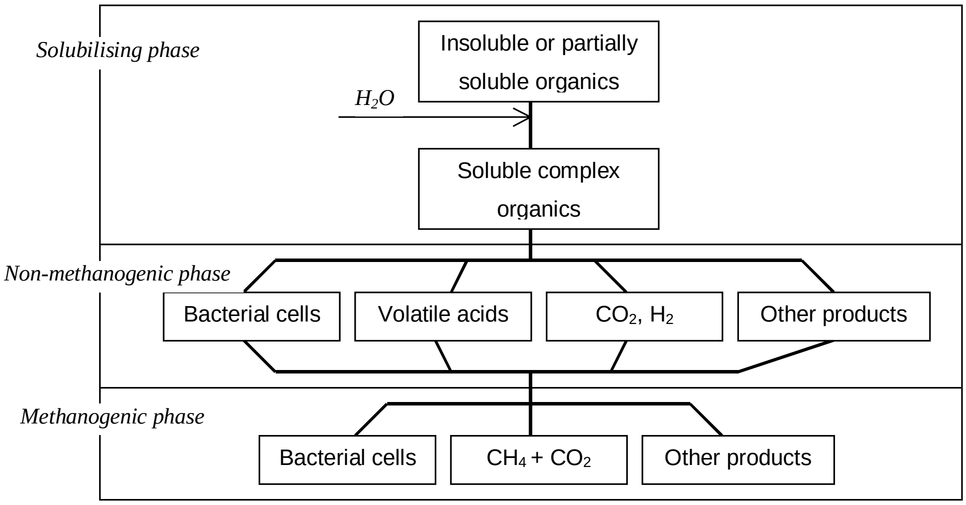

Figure 12: Principle scheme of anaerobic fermentation (Chawla 1986)

As seen in Figure 12 there are basically three different phases[89] (Engel *et al.* 1977; Pfeffer 1979; Chawla 1986; Fulford 1988):

1. Solubilisation. Facultative microorganisms (organisms that uses oxygen if available otherwise they use other digestion processes) act upon the organic substrates. A hydrolysis is taking place[90] in which polymers are converted into soluble monomers. These monomers are the substrates for the second phase.
2. Non-methanogenic phase (acidification). The now dissolved organic substrates are reduced from their incoming state to soluble simple organic acids (mainly acetic acid, CH_3COOH).
3. Methanogenic phase (methanogenesis). Methane bacteria reduce the soluble organic compounds from second phase to methane and carbon dioxide. There are two ways the bacteria works. Either they ferment the acetic acid to methane and carbon dioxide, or by reduction of carbon dioxide to methane by using hydrogen gas or formate which is a product of other bacteria.

In the process the amount of oxygen demanding material is reduced which results in a stable end product in comparison to the input (Chawla 1986).

The anaerobic bacteria's that are involved in the last step are strictly anaerobic, *obligate anaerobic*, and will not work properly if there is oxygen present. However it seems that the main bottleneck in the process is the solubisation of the organic polymers (Barnett *et al.* 1978; Temmes *et al.* 1987). So if the main objective is to keep an absolute oxygen free environment than the initial phase will be less efficient. The facultative microorganisms will have better environment for growth and improve the solubisation phase (Hughes

[89] Some authors divide the process into basically two phases; liquefaction and gasification stage, see for example Bell *et al.* (1973) or Vijayalekshmy (1985).

[90] Hydrolysis is a double decomposition reaction involving the splitting of water into its ions and the formation of a weak acid or base or both.

1979). Another characteristic of the process is the symbiosis between different groups of microorganisms. Different groups of bacteria are involved in the different stages.

These bacteria are sensitive to heat changes. According to Fulford (1988) a temperature variation in the slurry over a day of 5°C can cause the bacteria to stop work which will result in a build-up of organic compounds from the second phase (acetic acids mainly) which can cause the unit to go sour.

Normal conditions under which a biogas plant is operated, as well as the equipment gives the possibility to maintain condition where mesophilic organisms can work. The mesophilic anaerobic digestion process has its optimum at a temperature round 30°-35°C. The process slows down and finally stops at temperatures below 10°C (Barnett *et al.* 1978; Ellegård *et al.* 1983; United Nations 1984). If the plant is constructed below the ground, as well if the digester volume is not made too small, the temperature can be kept quite stable. Depending on local climatic conditions it can, however, be too low.

The basic content of biogas is methane (CH_4) and carbon dioxide (CO_2) which is found in different proportions depending on; input to the system and what the condition during the fermentation process are. Traces of hydrogen, sulphur, ammonia and oxygen can also be found in various degrees relating to feedstock and process. The sulphur is in the form of hydrogen sulphide, which is a poisonous and corrosive gas[91]. Typical values of biogas composition according to different authors is:

Methane (vol.%)	**Carbon dioxide (vol.%)**	**Other**	**Source**
50%	50%	traces	(Chawla 1986)
55-70%	30-45%	1-2%	(Myles 1985)
65-70%	30-35%	traces	(Meynell 1976)
58%	42%	traces	(Fulford 1988)
65-85%	30-35%	traces	(Singh 1974)
50-70%	30-50%	traces	(Engel *et al.* 1977)

Table 9: Composition of biogas

One of the problems of using cattle manure as feedstock is that much has already been digested inside the cattle's rumen, which result in less gas can be obtained per weight unit. In general it can be assumed that 30-40 litres biogas/kg dung can be obtained. These figures are mean values over 40-50 days of fermentation.

Dung from cattle and buffalo are easily digestible, since it already contains the bacteria, carbon, and nitrogen needed for digestion. Cattle in India are often poorly fed, due to reasons such as grazing under difficult conditions. This can result in that the dung is of low quality from a biogas production perspective (due to mainly lower content of N in the food). One factor to reach an efficient process is to ensure steady C/N ratios[92]. The nitrogen is mainly needed for cell formation in the microbiological processes. Lack of nitrogen

[91] Normally H_2S will not be found in biogas where cow and buffalo manure from poorly fed cattle is used.

[92] See for example van Buren (1979).

during the process can limit the formation of cells, and too much nitrogen on the other hand can result in formation of ammonia toxicity in the slurry. According to Barnett *et al.* (1978) the focus on the C/N ratio is over emphasised and should only become interesting for applications for specific industrial feedstock. The biogas basically consists of methane and carbon dioxide. These can be found in different compositions depending on the feedstock. The higher methane concentration the higher energy content will the biogas have. The composition can be calculated using Buswell's formula[93]:

$$C_nH_aO_b + (n - \frac{a}{4} - \frac{b}{2})H_2O \rightarrow (\frac{n}{2} - \frac{a}{8} + \frac{b}{4})CO_2 + (\frac{n}{2} + \frac{a}{8} - \frac{b}{4})CH_4$$

Equation 1: Buswell's formula for calculation of methane and carbondioxide content in the output biogas

Water is needed for sustaining the process but the amounts needed in conventional designs are more for technical reasons. Whereas the actual need of water is about 1-2 litres of H_2O/m^3 biogas, the technical need is about 25 litres/m^3 biogas.

Using anaerobic digestion for human service

A vast number of different designs have been brought forward by researchers NGOs and Institutions as potentially good designs[94]. Many of these have never found their way to the large public. A figure displaying two of the designs that are promoted in India today can be found in Figure 13.

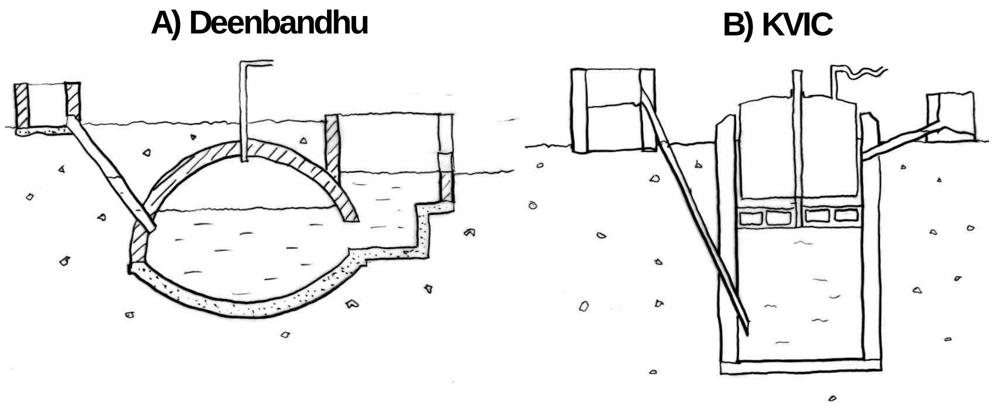

Figure 13: Principal design schemes of A) Deenbandhu and B) KVIC biogas plants

The designs found can be placed within three main categories:

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[93] See for example Meynell (1976) or Lettinga *et al.* (1993)

[94] See for example Singh (1974), KVIC (1976), Myles (1985), Kishore *et al.* (1987), Singh *et al.* (1987), Lichtman *et al.* (1996) or Mohanty *et al.* (1999).

- Floating dome designs
- Fixed dome designs
- Bag designs

The difference between the three concerns is basically how the gas is stored; in a dome, inside the digester chamber, or in a bag. In the floating dome designs there will be a constant pressure, depending on the weight of the dome. In the fixed dome types the pressure will be shifting depending on the difference in slurry level inside the dome and outside. During the use of the gas the pressure will drop. In the case of the bag digesters the pressure will be created through putting a weight on the digester bag. This weight will decide the gaspressure.

There are three designs that have had more impact in India than all others. These are KVIC design, *Janata* design, and *Deenbandhu* design. The Government of India has approved these designs, along with four more, to receive governmental subsidies within the frame of the National biogas programme.

The KVIC design is occasionally referred to as the Indian design or gobar-gas plant. There are two problems with the KVIC-plant. First the relatively high investment cost, and second corrosion on the mild steel gas dome. The fixed dome designs were disseminated in China since the early 50's. During the 70's there were millions of units installed in rural China. In the late 70's a slightly modified version of the Chinese design was developed in India and called *Janata* biogas plant. The *Janata* plant was further improved in 1984 and christened *Deenbandhu.* There are differences in how to build the unit and also some changes in man-whole placements. Through these adjustments a further cut in costs could be achieved.

There are two setbacks of the fixed dome designs. First the quality of the masonry both from material and construction skill has to be high. This is due to that there will otherwise be a high risk for small cracks in the dome where the gas can escape. Second is changing gas pressure which is due to that the gas is build up through the difference in slurry level between the inside and outside of the digester chamber. When gas is used the gas volume inside the digester will decrease and accordingly the gas pressure will drop.

Even though not widely disseminated the bag design Flxi should also be brought forward. The advantage of these plants is that they are ready at delivery so the only work is to install the pipe. Another advantage is that they can be put on the ground meaning that ground conditions will only play a minor role, something that is important in regions with much rock in the ground or high water tables (Kiwitt 1993). The disadvantage is that they are quite expensive in relation to both the fixed dome and floating dome types. By putting the units above ground the risk for mechanical damage seems to rise.

Biogas appliances

The calorific value of biogas is about 20 MJ/Nm^3 (4,700 $kcal/Nm^3$) (Myles 1985). Due to the relatively high concentration of CO_2 in the gas, the energy content will be relatively low in comparison to for example LPG. It is possible to purge the gas of CO_2, but there are no cheap or simple solutions available for this. Even though the biogas can be used for many purposes, such as illumination and fuel for internal combustion (IC)-engines, it is as a cooking fuel that it has gained main attraction.

In India there are ISI-marked stoves available that should ensure a high thermal efficiency. There are both one and two burner stoves available. The homemade stoves that are mentioned in the more general manuals, such as van Buren (1979) or United Nations (1984) are not found in India. Stoves for domestic use are found using biogas in the range of 200 to 900 l/h (Fulford 1988). The rate of gas that can be used is dependent not only on the stove but also on the length and dimension of the pipe from the digester. The limiting factor is usually found in the insufficient gas production.

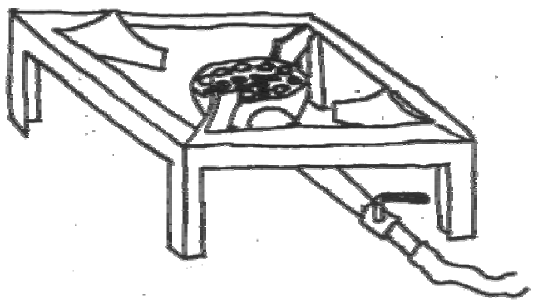

Figure 14: Biogas stove

The gas has also been used for lighting purpose. Gas lamps of mantle type are available. Typical gas flows are 90-180 l/h. According to Fulford (1988) biogas lamps are "inefficient, expensive and need regular service", but they are easy to use and give a good light. A biogas lamp can be an important development in areas without electricity. There are reports on biogas units that are used only for lightning (Dutta *et al.* 1997).

The gas can also be utilised in an IC-engine. There are engine models available for the use with biogas, these are usually of a dual-fuel type (20-30% diesel is mixed with the gas). In case spark plug engines are used there is no need for any admix. Even though the engine technology is well developed from a technical point of view the use of biogas technology difficult for this purpose. This is due to a number of reasons. First gas is needed under relatively short periods of times under which a relatively large amount of gas is needed. The normal designs do not have large gas storage capacities so there will be limited run times. Second, engines are usually not usually needed in the vicinity of the houses so it will not be possible to use the digester for both engine and domestic energy (Bhatia 1990).

Small Scale Biogas Systems in Other Countries

Small-scale biogas plants have been installed in many countries, but so far it has mainly been in China and India that mass installations have been initiated. Below a very brief presentation of some country's efforts to diffuse biogas technology is presented. The interest for biogas as a resource and for the anaerobic process as a means for improving the resource management in rural areas is still strong[95].

China is the country with most installed units. More than 7 million units has been reported installed over the years with the peak in 1978 (Qui *et al.* 1990). However the results from the Chinese efforts seems uncertain but it is quite clear that the performance of the installed units has not been that good (Kristoferson *et al.* 1986b; Smil 1986). Among other things gas leakage has lead to low availability of biogas in as many as 30-50% of the units (Stuckey 1986). However the most of the units were constructed in the 70's and the momentum in the construction efforts have diminished to a great extent today.

In Africa efforts have been made in different countries, such as Tanzania and Egypt. It seems that there is actually not very much happening on the scene of further dissemination at the moment. The main thrust to diffuse biogas technology in Africa was from the late 70's and to mid and late 80's.

In South East Asian countries, such as Vietnam, Thailand, and Indonesia, there has been different programmes running, aiming at diffusion of biogas technology to rural areas. It seems that the bag digesters and alternative building material to concrete and bricks had gained some popularity among the people involved in the development of biogas in these countries. Different bag designs and PVC-tube designs have been installed (Rodíguez *et al.* 1998). The fixed dome design has been the main conventional model implemented however.

Nepal has since the early 1970's put efforts to diffuse the technology. There have been a national programme running and there seems to have been some good achievements. In the beginning the floating drum type of plants were advocated but this was later changed to the fixed dome type. In Nepal there has been a one-design approach while several organisations and enterprises have done diffusion and installation (Gautam 1996).

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[95] Anaerobic process is receiving growing attention in Europe and USA as a means for managing municipal solid wastes. The processes and equipment used within this field could with some adjustments be used in for example India. Sewage treatment works and growing difficulties to take care of solid wastes are problems faced globally. This type of technology is quite different from the household type that is discussed in this text. For an introduction to municipal solid waste treatment plants see for example Lusk . *et al.* (1996) or IEA Bioenergy (1998).

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