"Energy enterprises for development in rural areas: the case of clean cooking fuel"

Final Report

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Executive Summary

This report describes the project "***Energy enterprises for development in rural areas: the case of clean cooking fuel***", designed and implemented by the Asian Regional Energy Initiative[1] of the International Energy Initiative (IEI). The project is a demonstration, in an Indian village, of a *sustainable clean energy - rural development* model that integrates improved household energy-services with income generation. Demonstrating the feasibility of this project is expected to expand opportunities for replication. This demonstration was financially sponsored mainly by the Wuppertal Institute for Climate, Environment, and Energy, Science Centre, North Rhine-Westphalia, Germany, through the 3rd Round of their Sustainable Energy Project Support.

Developing countries like India have millions of rural families who lack basic amenities including clean and efficient cooking fuel (***Section 1.1***). Several barriers to improved energy services exist, important among which is the families' inability to afford the increased costs of and therefore access to improved energy services, particularly in the case of domestic cooking that does not yield financial returns.

To surmount this and other barriers, an energy-development approach has been adopted, in which clean/efficient energy service(s) are generated within an economic enterprise that provides income and employment (***Section 1.2***). For this particular demonstration, a dairy-biogas option of the model was selected. An economic cost-benefit analysis was carried out, at the prevailing market prices. The dairy would employ local people, with its waste fuelling biogas generation, that in turn would deliver fertilizer, and its milk sales would financially support the operation. Biogas would be supplied to all homes in the village, replacing the existing (traditional) biomass-stoves and thereby avoiding fuel-gathering, indoor pollution, and carbon emissions. All the required activities – from interacting with the local people for the selection of a village and formation of the enterprise, to the establishment of the dairy, biogas delivery and operating systems have been executed by IEI, Bangalore (***Section 1.3***).

While selecting a village for the demonstration of the clean energy – rural development model, the focus was on economically disadvantaged areas, as indicated by the type of housing and possessions, and the dependence on daily wage labour. In addition, for the dairy-biogas option of the model, factors such as (surface or underground) water supply had to be included (***Section 2.1***). This information was obtained through informal interaction with local organisations and a survey of ten villages in a neighbouring district. On the basis of these data, the village of *Chikkana Devara Hatti* in the state of Karnataka was selected. It is inhabited by people of the "*Kadu Golla*", a traditional shepherd tribe, who are in need of socio-economic assistance. The village had a population of 238 at the time of the survey (***Section 2.2***). To ensure democratic involvement of all the families in the beneficiary community, a *grama vikas sabha* (GVS) or village development assembly (represented by one member of every household) was formed, with the guidance of IEI. This was followed by a formal agreement between the GVS and IEI, the implementing organisation (***Section 2.3***).

The establishment of the dairy involved three main components -- construction of the dairy buildings, selection and purchase of cows, and arrangements for daily operations. The

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dairy construction (***Section 3.1***) consisted of four cattle sheds that can house a total of 112 cows, the water facility, and a small office. Care was taken, based on advice from agricultural scientists, to provide enough space for each animal, with the appropriate feed and water troughs, and suitable flooring and drainage. For adequate water supply, the dairy has been provided with an independent well and storage tanks, and to facilitate water collection, pipelines have been drawn to faucets in each of the cattle sheds.

On completion of the construction, cattle were purchased from farms in areas specializing in dairying (***Section 3.2***). Veterinary certification and insurance were obtained for these animals. To ensure a steady milk supply, cows of different ages and lactation cycles have been purchased.

The dairy is being operated in a labour-intensive (rather than mechanised) manner (***Section 3.3***), in order to provide employment and income to the unemployed village folk. These had to be trained for the required tasks. These include feeding and caring for the animals (cows and the calves born to them), milking the lactating cows, cleaning the sheds, and carting the collected dung to fill the biogas plants. All the required accessories have been provided. As dairy activities have to be carried out continuously without a weekly holiday, duties are scheduled among the regular employees. To ensure responsibility, each employee has been assigned a specific set of tasks that are recorded. A competent supervisor has been appointed (from a neighbouring village) to oversee these activities and keep records and accounts. Fodder consists of packaged feed preparations as well as plants and crop residues from the region. The milk from the village enterprise is collected twice a day by a regional processing/distributing agency. The quantity and density of milk are measured and recorded at the village-dairy, so as to verify the agency's records, on the basis of which payment is received by the village-enterprise. Regular veterinary care has also been arranged.

For computing the total biogas generating capacity to be constructed (***Section 4.1***), the biogas requirement per family was estimated on the basis of the present biomass use, adjusted for the higher calorific value and efficiency of biogas. The estimated family requirement of 0.75 m^3 (or 750 litres) was deliberately doubled, to provide for increases in residents and/or cooking time. To meet the needs of all the village families, the total biogas requirement was divided between several shared biogas digesters. This was estimated to be the most effective method of gas delivery, considering both construction costs and operational efficiency. Based on the pattern in which houses have been situated in the village, the location of eight biogas plants, six of $8m^3$ capacity and two of $10m^3$ capacity, was planned (***Section 4.2***). The cylindrical pit - floating-drum biogas digester model was chosen, as these plants are proven to be durable, with minimal maintenance. The construction of each biogas plant (***Section 4.3***) involved earth excavation for the cylindrical digester pit, masonry lining for the digester wall, fabrication and installation of the guide frame and gas holder (drum), construction of the (slurry-mixing) inlet-tank and effluent-outlet tank adjacent to each digester pit, and the piping connections for retrieval of the gas. The labour for the "unskilled" construction tasks was obtained from the village itself, with skilled labour from elsewhere. IEI project staff provided the design of the gas-holders and supervised their fabrication. The guide frames and the gas-holders for all the digesters were fabricated outside the village and transported to the site for installation. The gas-holders were treated with primer and then painted to prevent corrosion.

As a benefit of the integrated system, the biogas plants are directly fuelled from the dairy (***Section 5.1***). Dung from the cattle sheds is collected regularly during the day and stored in large covered bins, to minimise emissions. After the cattle have been fed and milked in the morning, the bins are moved in wheelbarrows to the biogas digesters along with similar containers of water, and the inputs stirred into the (slurry mixing) tank of each biogas digester. Daily fuelling consists of 150 kg each of dung and water for the six $8m^3$ digesters, and 200 kg each of dung and water for the two $10m^3$ digesters.

To deliver biogas to every household, a mini-grid piping system has been created between each digester and the group of households it serves (***Section 5.2***). The main pipe connected to the outlet of each gasholder leads to a stop-valve used to regulate the flow of gas. A moisture trap has also been provided. The household delivery pipes (of braided PVC material) are connected using nozzles attached to the valve. Each kitchen is provided with a double-burner stainless steel stove, with control knobs. Based on suggestions from the users regarding their cooking timings, gas availability to the homes was initially restricted to three hours every morning and one and a half hours every evening. Later, it was made available continuously, eliminating the need for any alternative fuel. The users are very satisfied with this service.

The accounting system (***Section 6.1***) consists of daily recording of inflows and outflows by the supervisor at the village enterprise office and weekly verification and electronic recording of the relevant details by IEI. In addition, daily communication between the supervisor and IEI ensures that any problem is dealt with as soon as possible. The records maintained (***Section 6.2***) include that of the employee-roster, and accounts of the daily milk collection and payments due, and for purchase, inventory and consumption of fodder and medicines.

The concluding Section lists what was learnt from the experience of this village-demonstration, the possibilities for replication, and the benefits of the model. The factors relevant for the successful operation of such a rural enterprise and the lessons learnt from this project are explained; these include both technical and socio-economic issues, as well as factors affecting construction and financial and operational management (***Section 7.1***). Plans for extensions at this enterprise and for new village-enterprises have also been briefly explained (***Section 7.2***). The environmental benefits, in terms of avoided CO_2 and CH_4 emissions, have been projected, based on accepted emission factors of pollutant mass per unit of energy delivered (***Section 7.3***). If replication of such village enterprises occurred to the extent of 10% of the existing village dairy co-operatives in India, there could be a reduction of 11.3 million tonnes of CO_2 and 27.5 thousand tonnes of CH_4.

The implementation of the dairy-biogas option of the clean energy – rural development model leads therefore to the following benefits (***Section 7.4***), namely:

- replacement of collection and direct burning of biomass with a clean stove-fuel alternative (thereby avoiding tedious fuel-collection and reducing air pollution and the related health impacts);
- renewable generation of fuel from a waste resource (instead of competing with food crops or forests for land);
- development of an economically viable system for use of this alternative resource through income and employment generation;
- avoidance of the use of petroleum-based "clean" fuels (-- kerosene oil and LPG) to which households shift while ascending the energy-ladder;
- availability of improved natural manure, reducing the need for chemical fertilizers;

- the use of well-known technology and procedures that can be easily adopted and do not require sophisticated installation/maintenance;
- reduction of environmental impacts through lower stove emissions that could help in the battle against climate change, and if large enough, also derive carbon credits for reduction of CO_2 and CH_4 emissions.

Acknowledgement

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1. Background

1.1 Problems being addressed

Nearly three quarters of the people in south-Asia live in villages and most depend for their cooking needs on traditional biomass fuels. In Indian rural areas, about 90% of rural homes still depend on biomass for cooking fuel: 64.1% on fuel wood, 13.1% on crop residues, and 12.8% on cattle-dung (Census of India, 2001). Those who have the task of cooking - usually women and girls -- and babies (held by them), because of their proximity to the stove and inadequate household ventilation, are exposed to inhalation of smoke and particles of incomplete combustion. These can contribute to serious respiratory ailments[2] (WHO, 2002). Lighting and tending traditional biomass stoves are tedious, even where such biomass is easily available and far more burdensome if collection and preparation of biomass for stove-fuel are required. The burden of these tasks usually falls unevenly on women and girls, a factor increasing gender inequity.

There can also be negative impacts on the community, through the ambient pollution from simultaneous cook-fires and land degradation in cases where fuel-wood is gathered in an unsustainable manner.

Alternatives to the present biomass fuel-stove combinations are available, for example, LPG. These superior options are being increasingly adopted wherever they can be paid for (D'Sa and Narasimha Murthy, 2004). However, the low income of a major proportion of the population precludes them from paying for better fuel when there are more urgent needs (-- inadequate water, food, sanitation, and housing) that they struggle to satisfy. Although cooking accounts for the greatest quantity of energy used in homes in rural areas (where 55% of homes are not yet electrified), it is usually treated along with fuel collection as just another domestic chore. While the reduction in energy use and shifts to less-polluting energy carriers are being considered worldwide, the needs of the rural poor have yet to be met in India[3] and other highly populated developing countries. Hence, even where better fuels are "available", they are not affordable and therefore not "accessible".

There have also been facilitating programmes aimed at providing models of improved/efficient stoves and/or fuels. However, thus far, these have either targeted "niche markets" of those who can get finance for their purchase (e.g. loans to cattle-owners for household-sized biogas plants) or else have been one-time donations (-- higher-efficiency biomass-based stoves, LPG connections, and other schemes for the rural poor) that fail when re-fuelling or replacements are needed, unless continuing state subsidies are obtained.

Hence, the problems we are addressing are:

- ***the energy poverty of the rural poor in India***, involving inefficiency of fuel-stove combinations and in-affordability and/or inaccessibility of better options, manifest in:

[2] WHO estimates that indoor air pollution contributes to serious respiratory ailments and even ischaemic heart disease, accounting for 3.7% of disability-adjusted life years (DALYs) in the high-mortality south-east Asian region.
[3] Studies show that there are more malnourished children in India than in Sub-Saharan Africa, but the successes of the country in other fields tend to obliterate these from the public view.

- indoor air pollution (IAP) and the consequent health impacts to those exposed, resulting from incomplete combustion in traditional stoves and inadequate ventilation in small huts,
- laborious collection of biomass-based fuels, resulting in poorer quality of life (QOL), usually for women, thereby worsening gender inequity, and
- the possibility of local environmental degradation in sparsely vegetated areas, and the contribution of stove-emissions from fuel wood to global warming,

- ***the financial barriers to change*** including the one-time problem of securing initial capital, and the perennial running problem because the absence of gainful returns from household cooking inhibits payment for better fuel, thereby making better fuel delivery unsustainable.

1.2 Our energy-development enterprise approach

This project has been designed and implemented by the Asian Regional Energy Initiative (www.iei-asia.org) of the International Energy Initiative (IEI), located in Bangalore (India). The main objective has been to demonstrate a village-based multi-functional enterprise that combines improved energy services with income generation and employment opportunities as well as efficient and sustainable resource use. Such a synergistic approach is vital to effectively bringing about rural development.

Specifically, the project establishes (Diagram 1) an "integrated clean energy – rural development enterprise" in a selected village. The enterprise (Diagram 2) consists of a dairy and associated household biogas supply systems. The establishment of the dairy comprises the construction of the civil structure, purchase of cattle and thereafter daily operation (cattle-care, milking and accounting) systems (Diagram 3). The biogas supply system consists of biogas-digesters linked to every household. The digesters are fuelled with the cattle dung from the dairy and the biogas (CH_4 and CO_2, approximately in the ratio 3:2) so generated is supplied to the biogas-stoves that are provided to all the village households (Diagram 4). Apart from providing employment to the village folk and a renewable source of fuel, the revenue from the dairy financially supports the system.

The energy-enterprise project is demonstrating that:

- every family, even the poorest, can obtain a better energy-service, thereby helping the people, particularly the women through --
  - reduced cook-stove emissions -- reduced IAP and adverse health impacts),
  - improved heating efficiency -- conserving energy and reducing cooking time,
  - more convenience, through the reduced tedium of collecting biomass and tending traditional stoves,
- a clean efficient fuel based on local resources rather than petroleum products can be obtained,
- this source of energy is sustainable, as it is derived from waste (avoiding competition with food for land),
- this improved energy-service delivery can be financially sustainable through the associated income generation, and
- improved livelihood is possible within the village.

It is also intended that:

- self-reliance of the people can be improved, with the enterprise in their village not being dependent on further grants/subsidies,
- further village development can be fostered through –
    - nutritional benefits (through the availability of milk),
    - improved agricultural productivity (through fertilizer from the digested slurry),
    - investment of the revenues of the enterprise (earned in the longer term) in other development projects.

1.3 Project activities

Apart from designing the project, major activities of IEI's project team included:

1. interacting with regional organisations for local information, drawing up village selection criteria, and conducting a survey of villages,

2. based on the data collected, selecting the village for the energy enterprise, establishing the *grama vikas sabha* (village development assembly) in the selected village, signing an agreement for the establishment of the energy enterprise, and acquiring land for it,

3. establishing the dairy system (including design and construction of the dairy buildings, purchase of cattle and arrangements for the collection and sale of milk),

4. estimating the biogas requirement for household cooking and planning the location and design of, and constructing the required biogas plants,

5. establishing the gas-distribution system (including fuelling the biogas plants, constructing the mini-grid-pipelines and providing all homes with biogas), and

6. establishing the management and accounting systems and monitoring them (to be continued even after the project completion).

Diagram 1: Schematic representation of the project

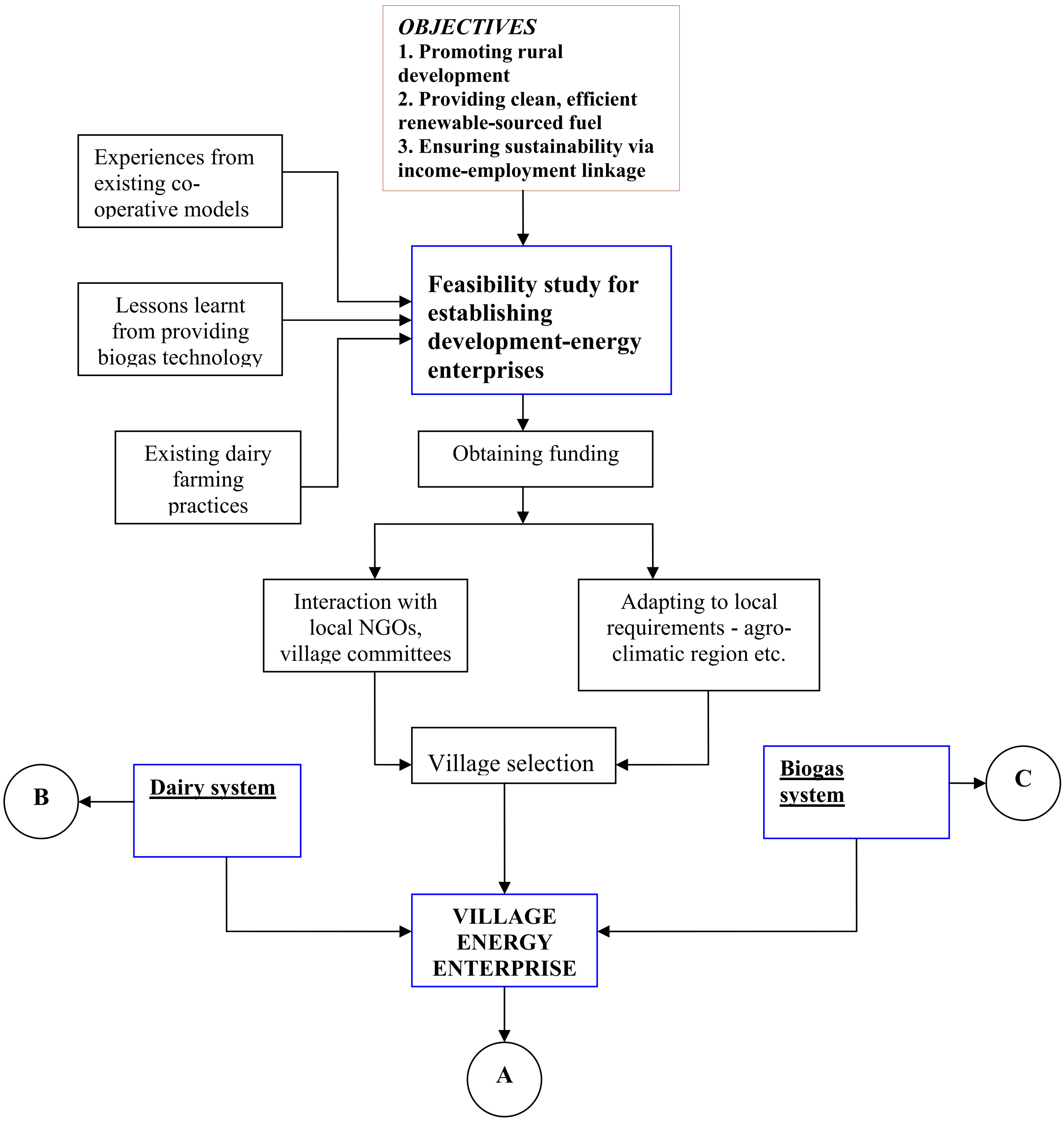


Diagram 2: Village energy enterprise system (A)

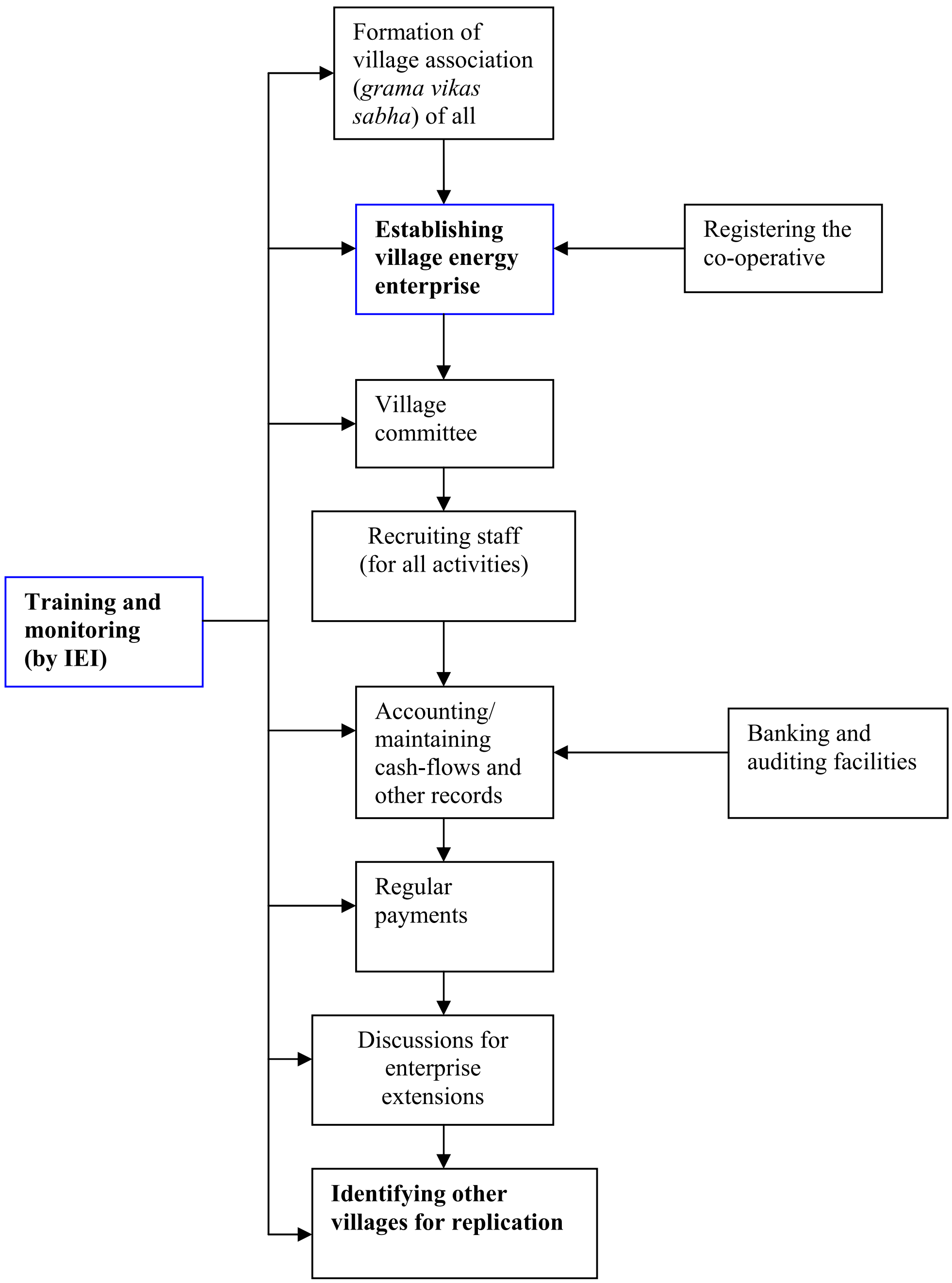


Diagram 3: Dairy system (B)

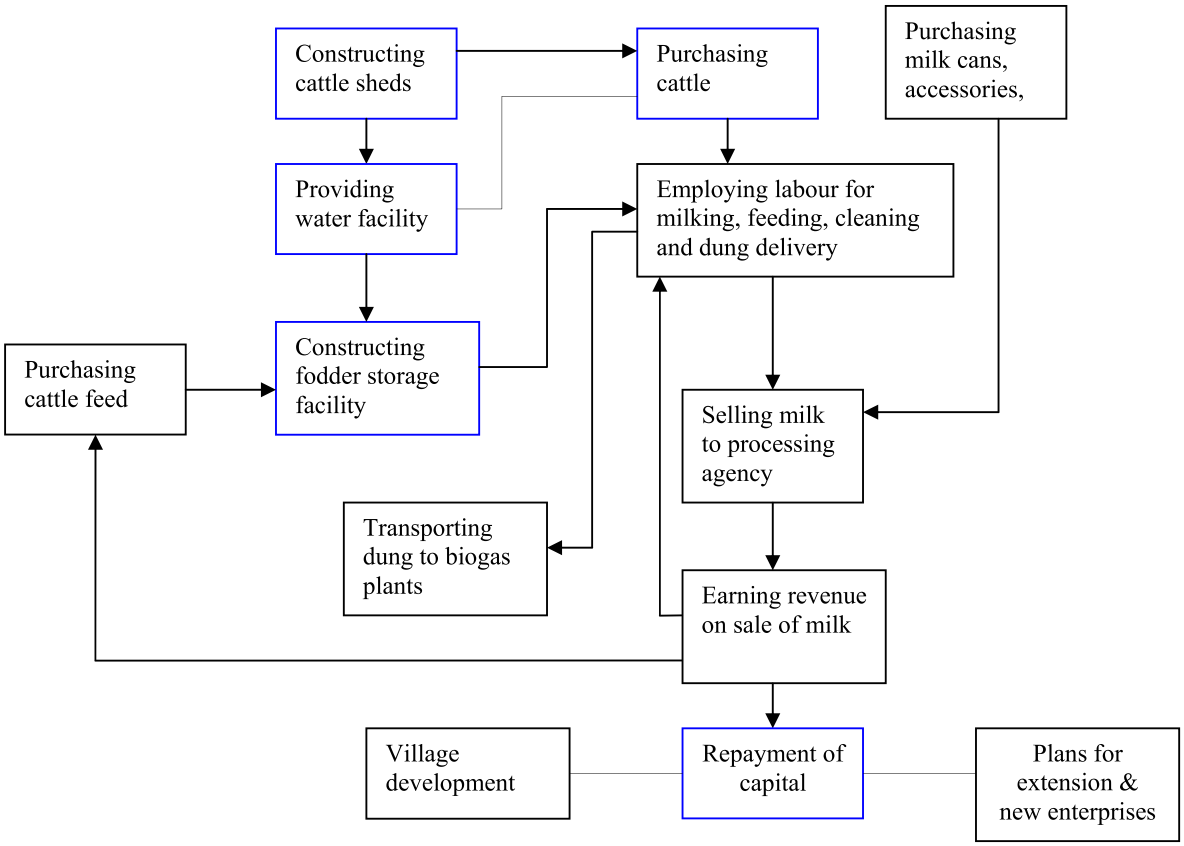
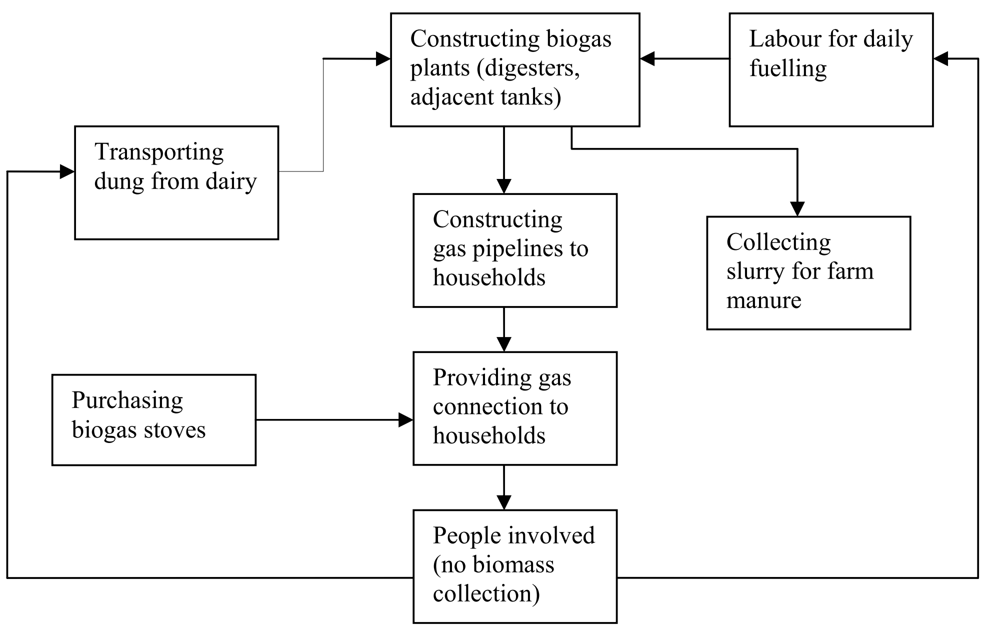


Diagram 4: Biogas system (C)



2. Village selection and enterprise foundation

2.1 Data collection

As it was intended that the enterprise be established in a village in need of socio-economic development, information on economic levels and social matters had to be obtained. Such information is not easily available. Information on rural income levels is not available (as agricultural incomes are not taxed) and even the National Sample Survey (NSS) uses reported monthly expenditure as a proxy for income levels. In addition, state-approved classifications are not always accurate, for example, some homes classified as "below the poverty line" (BPL)[4] are not necessarily in that category while others deserving such benefits have not yet been included. Regarding social matters, the existence of communal problems in village communities could adversely affect co-operative enterprise, but such difficulties would not be immediately apparent to visitors.

To overcome these problems, two approaches were adopted. Economic status was assessed through household surveys that recorded landholdings and visible possessions. A survey of ten villages in the neighbouring districts was conducted and relevant details elicited[5]. For socio-communal issues, local knowledge from people working in the field was used to identify problems.

Based on the information gathered, a set of criteria were drawn up for the selection of appropriate villages for the demonstration of the clean energy – rural development model. The focus was on economically disadvantaged areas, as indicated by the level of possessions and the dependence on daily wage labour. In addition, for the dairy-biogas option of the model, factors such as (surface or underground) water supply had to be included (Annexe 1).

2.2 Selected village

On the basis of the information collected during the village surveys and the selection criteria drawn up during the initial period of the project, the village chosen for demonstrating a sustainable energy enterprise is *Chikkana Devara*[6] *Hatti* (earlier known as *Gollara Hatti*) in Tumkur *taluk*,[7] of Tumkur district in the state of Karnataka. It has 47 families, with a population of 238 people, at the time of the survey. (Annexe 2 indicates the location of the village and Annexe 3, the demographic details).

Reasons for selection: The people of *Chikkana Devara Hatti* belong to the "*Kadu Golla*" community, a traditional shepherd tribe, rearing sheep and goats. Their small flocks are kept in pens adjacent to their homes (Figures 1-3). Most appear to be in need of economic assistance. They do not own land and even the few plots of land are too small to be remunerative. Only one family had an LPG connection but even they did not use it regularly

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[4] The "poverty line" is linked to the average calorific requirement and the monetary expenditure required for obtaining that food, taken as a proxy of living standards; as such, it varies with the estimated cost of living.

[5] The details were provided in the 1st Progress Report on the Project, March 2007.

[6] This is the name of the local deity.

[7] A *taluk* is an administrative unit of a district, which is in turn a unit of a state. It comprises about 100 contiguous villages and about 1,000 km^2.

because of the higher cost of fuelling. Hence, all families are dependent on collected biomass – twigs, dry leaves, etc. -- for stove-fuel, and this is burnt in traditional, inefficient "*ole*" [8] (Figure 4). Unlike in other villages, easily-available biomass (for example, crop residue is available to only a few families), so that fuel collection from the forest is necessitated. Most of the families (i.e. 38 of the total 47) depend on daily wage labour for their sustenance. There is little scope for improvement in their prospects as most are uneducated. In addition, as they have not been classified as needing assistance in the national Scheduled Caste/Scheduled Tribe categorisation, they have not been receiving much state assistance. An energy-enterprise such as we are establishing there would be impossible for the people without the assistance of this project: very few can afford cows, free fodder is inadequate (so that dairy possibilities very limited) and the people would not be considered credit-worthy for loans from financial institutions. In view of project implementation, the village is also suitable because of the availability of unused land and relatively better water supply[9].

In contrast, most of the other villages in the region did not seem as much in need of economic/financial assistance (in terms of their occupation, landholdings and other possessions) or clean fuel (as more families per village already used LPG or biogas). However, it is important to note that most villages have some proportion of very poor people and when extending the enterprise model on a large scale, many other villages would qualify for inclusion.

2.3 Foundation of the enterprise

Meetings were held with groups of people in the village to ensure that the purposes and planned activities of the enterprise were understood by and acceptable to all the people. Queries regarding costs and responsibilities were answered. Benefits, as perceived by the people, were chiefly employment and easy-to-obtain/use cooking fuel.

A *grama vikas sabha* (GVS) or village development assembly (represented by one member of every household) was formed, with the guidance of IEI. This ensured a democratic involvement of all the families. A formal agreement regarding the proposed energy enterprise was drawn up between the GVS of the beneficiary community -- the people of the village of *Chikkanna Devara Hatti*, Tumkur *taluk*, Karnataka state, and the implementing organisation -- the regional branch, in Bangalore, of the International Energy Initiative (IEI). (Annexe 4)

[8] This is the generic term (in the local language *Kannada*) for a biomass stove.
[9] A water-supply unit that is shared by four adjacent villages has been provided by the State government, although the supply is not continuous. The State has also provided grants for improvement of dwellings owned by families below the poverty line.

Figure 1:

Figure 2:

Figure 3:

Figure 4:

3 Establishment of the dairy

Establishment of a dairy consists of three main components -- construction of the dairy buildings, selection and purchase of cows, and arrangements for daily operations. Before commencing these activities, information was collected from the Dairy section of the University of Agricultural Sciences (UAS) of Karnataka state (located in Hebbal, Bangalore district). Apart from visits to the UAS dairy unit, visits were made to two dairy units in operation within the state of Karnataka (Sringeri in Chikkamagalur district, and Kappatguda in Chitradurga).

3.1 Construction

The dairy civil structure comprises four cattle sheds, the water facility (underground and overhead tanks, piping and faucets) and a small office.

The cattle-sheds can house a total of 112 cows, with each shed, measuring 20 x 11 m^2, suitable for 28 cows. This includes the space required for the cows and also for fodder storage and feed/water troughs. These dimensions meet the requirements of the Animal Husbandry Department of the University of Agricultural Sciences, Karnataka.

The structure of each shed consists of steel columns and trusses, covered with corrugated sheets. (Annexe 5 has the details and photographs during construction). Each shed has two rows of cattle-stalls, with corresponding feed and water troughs along one length and a clearing drain on the opposite side. The flooring of each shed consists of chiselled stone slabs, fixed with cement mortar and sloping slightly towards the drain; this is appropriate for cattle as it prevents slipping and can be easily cleaned. The drains are connected to a larger trough at the end of each shed, to facilitate immediate removal of waste for fuelling the biogas plants. Electricity is currently being purchased from the state electricity grid to meet the lighting requirements. The construction was undertaken by a civil contractor.

An underground water tank of 10,000 litres capacity was constructed for storing water from the village supply for use at the dairy. However, the supply was found to be inadequate, hence a new well with a depth of 140m has also been dug. This was fitted with a pump to obtain adequate water, as required, for both the dairy and biogas operations. In addition, an overhead tank of 5,000 litres capacity has been constructed for supplying water directly to the cattle sheds. Pipelines from the water tank have been drawn to the supply faucets in each shed to provide water for drinking and cleaning.

A two-roomed building was constructed adjacent to the dairy. It is used an office for the supervisor, for maintaining accounts and records and for discussion. If required, the supervisor can also stay there temporarily. Electric lighting has been provided and can be extended for computing facilities.

To help with the security of the dairy, the entire plot of 36.5 x 76 m has been fenced in and a single gate provided.

3.2 Cattle purchase

As advised by the dairy experts at the University of Agricultural Sciences (UAS) of Karnataka state, cattle purchases were made in the Doddaballapur-Chikkaballapur-Shiddlaghatta region of Bangalore rural district as this region has several farms where cattle are reared for sale. Cows of hybrid breeds (local cross-bred with Holstein, Friesen and Jersey varieties) have been selected. In order to provide for a fairly steady supply of milk at the dairy, cows at different stages of the lactation cycle were purchased in small groups of the same age (Figures 5 -10).

Before the actual purchase, each animal was certified by a veterinary surgeon (from Tumkur, a town near the village). This veterinary certification was also required for insurance (both life insurance[10] and transit insurance) for each cow. Groups of cows, as purchased from a location, were transported by cattle-vans to the energy-enterprise in the village (*Chikkanna Devara Hatti*).

Female calves born to the cows continue to be kept at the village-dairy, in a separate enclosure, where they are being cared for (Figures 11 – 12). Later, they can replace older cows that are past lactation, so that a steady population can be retained without incurring further purchase costs.

The total number of animals at the dairy is now 68. As there is room for expansion, more cows will be purchased during the next sale period, i.e. during the rainy season (June-September). Increases in the number of cattle would also facilitate more biogas production that could be used for other energy services, as discussed in Section 7.3.

3.3 Operation

For the operation of the dairy, a labour-intensive rather than mechanised approach has been chosen, in order to provide employment and income to the unemployed village folk. For example, milking is being done by hand rather than with milking machines. This coincides with agricultural operations in many parts of the country, where human and animal labour continues to be used. All the accessories for the dairy operations have been purchased for the village enterprise. This includes feeding buckets/bowls for the cows and calves, milk-buckets for milk-collection and milk-cans for delivery to the collecting centre, cleaning supplies, weighing balance and lactometer, troughs and covered cans for immediate collection of dung and wheelbarrows for transporting it to the biogas-digesters, and sickles for cutting the green fodder.

Unlike other productive enterprises, the dairy activities have to be carried out continuously. Hence, the twelve people employed for these regular tasks take their weekly holiday on different days of the week. The daily tasks include feeding and caring for the animals (cows and calves born to them), milking the lactating cows, cleaning the sheds, and carting (in wheelbarrows) the collected dung to fill the biogas plants. The employees had to

[10] One of the cows purchased in December died soon after arrival at the dairy, as a result of an illness contracted earlier. On certification from the veterinary surgeon, the dairy's insurance claim was honoured, and another cow has been purchased.

be trained for the tasks as they had no prior experience. To ensure responsibility, each employee has been assigned a specific set of tasks (Figure 13).

A retired teacher (from a neighbouring village) who has been involved with dairying, has been appointed as the supervisor (Figure 14). His tasks include supervision of the tasks for which the dairy employees are responsible, according to the roster, and maintaining records[11]. The records include that of the employee-roster, accounting for the purchase, inventory and consumption of fodder and medicines, and accounting for the daily milk collection and payments due[12]. Records of each cow and calf are also maintained, on the basis of their tag-numbers (used for insurance). An assistant supervisor from the village is also currently employed because of the present work load.

Fodder of several types is being provided, both packaged preparations and plants grown in the region. The packaged category includes bypass protein feeds, wheat and rice bran, corn powder and mineral mixtures (as prescribed by veterinary supervisors). When possible, these feeds are purchased and transported to the village in bulk to reduce the unit costs. The green fodder includes corn stalks and leaves (after the cobs have been harvested), sugarcane stalks, leguminous plants, dried *ragi* (millet) and paddy stalks (in the form of hay), and specially-grown grasses (such as Napier grass).

The animals (both cows and calves) are fed twice a day with the packaged fodder preparations, and thrice a day with grown fodder (green and dried) obtained nearby. The village-enterprise employees are also involved in cutting and collecting the green fodder. On an average, each cow is fed 8 kg of packaged feeds and 8 kg of green fodder/hay every day. Each cow is also provided with (60 – 70 litres) of water daily. This is easily available from the faucets at each cow-shed, as water-pipelines have been drawn from the tank constructed.

Arrangements have been made with a large milk processing and distribution agency (*Arogya* Dairy) operating in the state, to collect milk from the village enterprise after each milking. The cows are milked twice a day and the milk kept in 40-litre cans for collection by the agency, at about 9am and 9pm. The quantity and density of milk are measured and recorded at the village-dairy, so as to verify the agency's records, on the basis of which payment is received by the village-enterprise.

The veterinary surgeon operating in an adjacent town has been employed for periodic visits to the dairy, and also for additional visits to tend to any health problems that occur among the animals. The supervisor keeps records of the requirement of medicines. Arrangements have been made for the purchase of medicines at a wholesale rate from the pharmacy in a nearby town.

It may be noted from the description above that arrangements have been made for every requirement of the entire dairy establishment (Figure 15).

[11] Many of the village residents, including two employed at this enterprise, are illiterate, hence the supervisor has to shoulder the burden of keeping written records.
[12] These will be dealt with further in Section 7.

Figure 5:

Figure 6:

Figure 7:

Figure 8:

Figure 9

Figure 10

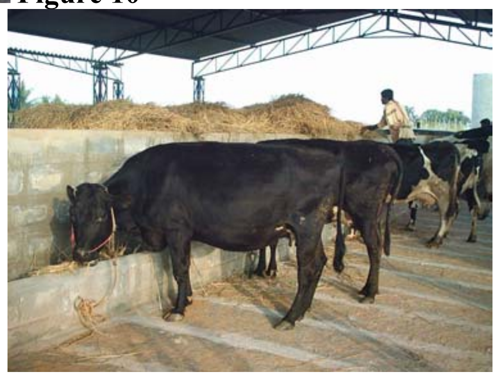

Figure 11

Figure 12

Figure 13:

Figure 14:

Figure 15:

4. Biogas plants

4.1 Biogas requirement

A civil engineering survey was conducted, citing the location of each house (some housing more than one family). Simultaneously, the household survey elicited information on the number of people residing in each cluster of homes, as well as the types of food consumed and cooking periods.

The amount of biomass (consisting of twigs, crop residues, etc.) used for cooking has been estimated to be about 1,400 kg/family per year or 250 kg/capita per year (for an average[13] family size of 5.6). This biomass use for cooking was adjusted for the higher calorific content of biogas and efficiency of biomass-stoves, thus:

$(15 \text{ MJ/kg x efficiency of } 15\% \text{ x } 250\text{kg/year x } 5.6)_{\text{traditional biomass}}$ /

$(23 \text{ MJ/m}^3 \text{ x efficiency of } 50\%)_{\text{biogas}}$

$= (274 \text{ m}^3\text{/year})_{\text{biogas}}$

Hence, a family requirement of 274 m^3 of biogas per year of biogas was estimated. This corresponds to a daily requirement of 0.75 m^3 (or 750 litres) of biogas per family, which is pertinent for the capacity of a biogas digester. When designing the biogas plants, the estimated requirement was doubled, i.e. a daily availability of 1.5 m^3 (or 1,500 litres) of biogas per household was considered, so as to provide for longer cooking time (if more people were to join the household, if food intake increased, and if additional services such as water-heating were required).

The construction of collective plants (serving a number of families) works out more economical than that of family-sized plants. It was also estimated that several plants of 8-10 m^3 capacity would be preferable to one/two large plants. There are advantages of this decentralised option. Firstly, the required pipelines are shorter and the pressure of the gas supply easier to maintain. Secondly, the involvement of a small group of households ensures closer ownership, so that problems, if any, are dealt with quickly.

4.2 Design and construction

IEI's past experience with biogas technology at rural centres as well as reports of other experiences of biogas generation have led to the selection of the cylindrical pit - floating-drum biogas digester model. These plants are durable, being estimated to last at least 25 years with minimal maintenance.

Each biogas plant consists of a (slurry-mixing) inlet tank, the digester with its gas outlet, and the effluent-outlet tank (Figure 16). Construction activities involved earth excavation for the cylindrical digester pit, masonry lining for the digester wall, fabrication and installation of the gas holder (drum) and its guide frame and, and construction of the inlet-tank and outlet tank, adjacent to each digester pit, and the piping for retrieval of the gas. (Annexe 6 has the engineering drawings of a standardised floating-drum biogas plant as well as the details and pictures of some of the plants while under construction).

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[13] This was the average at the decennial Census of India, 2001.

The labour for the digging of the eight digester-pits and the other unskilled construction tasks was obtained from the village itself, under supervision. Skilled labour was obtained from outside for tasks like masonry.

The gas-holders and guide frames of all the digesters are of mild steel and were fabricated outside the village and transported to the sites for installation. IEI project staff provided the design of the gas-holders and supervised their fabrication. The gas-holder of each $8m^3$ plant had dimensions of 1.5m height and 1.9 m diameter, while that of each 10 m^3 capacity plants had dimensions of 1.5m height and 2.1 m diameter. The gas-holders were treated with epoxy-etch primer and then painted with epoxy-coal tar to increase durability.

4.3 Location of the plants

A biogas digester of 8 m^3 (or 8,000 litres) capacity was planned for each cluster of four to eight families, depending on their size. However, as some of the related families reside together, there were fewer independent houses. Larger plants of 10 m^3 were provided for two clusters (with larger families). Based on the pattern in which houses have been situated in the village, we identified the location of eight biogas plants, six of $8m^3$ capacity and two of $10m^3$ capacity. In order to avoid obstruction of regular activities, each biogas plant has been located on the periphery of the cluster of houses it serves.

To simplify the explanation of the location of each plant in the village, the eight plants have been listed from A to H, and the homes of the families have been shown from 1 to 47 in Diagram 5. The numbers served by each plant are listed in Table 1.

Table 1:

Plant	Number of families* (as numbered)	Number of people (including children)	Plant size (m^3)
A	1-6	36	8
B	7-13	30	10
C	14-19	26	8
D	20-25	22	8
E	26-31	35	8
F	32-37	30	8
G	38-42	29	8
H	43-47	30	10

* Some related families reside in the same house.

The eight plants in the schematic representation can be viewed in Figures 17 – 24, respectively.

Diagram 5: Location of the eight shared biogas plants and the adjacent families being provided with biogas

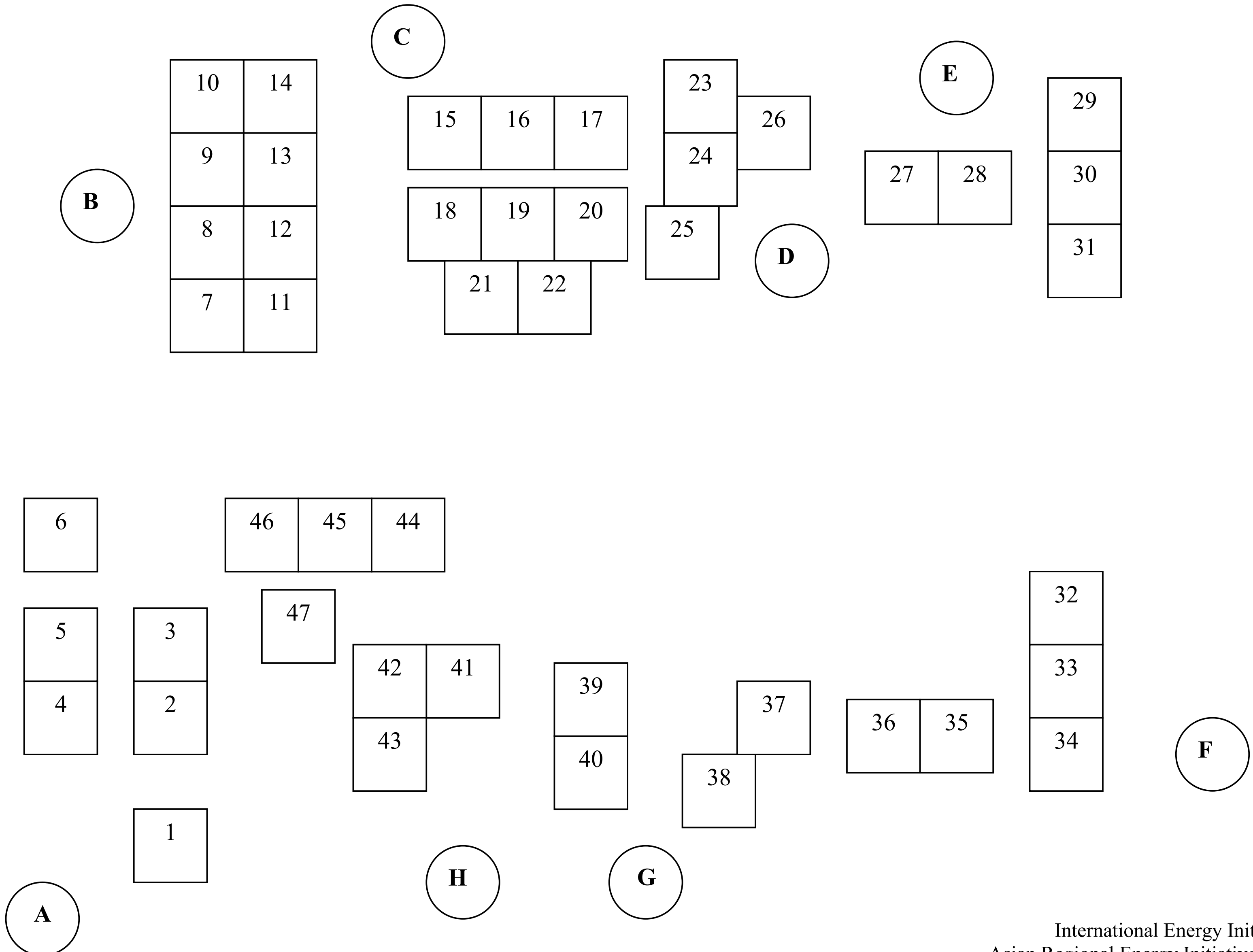

Figure 16:

Figure 17:

Figure 18:

Figure 19:

Figure 20:

Figure 21:

Figure 22:

Figure 23:

Figure 24:

5. Fuel delivery system

5.1 Fuelling and maintenance

Fuelling of the digesters is a part of the employees' daily set of tasks and to ensure responsibility, the filling of each biogas-digester has been assigned to specified employees. Dung from the cattle sheds is collected regularly during the day and stored in large covered containers or bins (Figure 25). After the cattle have been fed and milked in the morning, the bins are moved to the biogas digesters along with containers of an equal quantity, by weight, of water[14]. Wheelbarrows have been procured to facilitate their movement from the dairy (Figure 26). The slurry of dung and water is stirred in the input tank of each biogas digester (Figure 27).

The initial "charging" of each digester required a total of about 2 tonnes each of dung and water. This charging had to be undertaken one digester at a time, as the fuel supply was not adequate for all the digesters. However, for daily fuelling of plants in use, the required inputs are taken by the employees who have been assigned the responsibility. Daily fuelling consists of 150 kg each of dung and water for the six digesters of $8m^3$, and 200 kg each of dung and water in the two digesters of $10m^3$.

For anaerobic digestion to take place, the pH value of the input mixture should not fall below 6, as methanogenic bacteria are sensitive to acidic environments and fermentation could stop if the pH value fell too low[15]. The optimal temperature range for gas production is 25 - 30°C. Approximately 45 days elapsed between the first filling of each digester and capacity accumulation of biogas in the gasholder of each digester.

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[14] To simplify the filling procedure, the containers have been marked with the required level, corresponding to the appropriate weight as earlier measured on the weighing balance at the site.

[15] In the initial period of fermentation, acid-forming bacteria produce organic acids that result in the pH value falling within the digester. However, as time passes, the digestion of nitrogen increases the pH value. Biogas generation is optimal when the pH value in the digester is between 7.6 and 7.8. When the CH_4 production is stabilized, the pH value within the digester is between 7.2 and 8.2.

Figure 25:

Figure 26:

Figure 27:

Figure 28:

5.2 Connections and gas delivery

To deliver biogas to every household, a mini-grid system has been created between each digester and the group of households it serves. A 38mm diameter pipe of neoprene (synthetic chloroprene rubber) has been connected to the outlet of the each gas-holder (Figures 28 - 29). This main pipe leads to a stop-valve (ball-valve) of gun-metal, used to regulate the flow of gas. To prevent the blocking of gas flow in the outlet gas pipeline due to water accumulation (as a result of condensation of moisture), a moisture trap (i.e. an attached U-shaped pipe) has also been provided.

After each gasholder was filled, it was connected (linked with pipelines) to the designated households for gas delivery. The household delivery pipes are of braided PVC material (Figure 30). They are connected using nozzles attached to the valve. Each has an internal diameter of 10mm. The number of delivery pipelines connected from each digester depends on the households connected, and the length on the location of the houses (as shown in Diagram 4).

The household end of each gas delivery pipe is fixed to a double-burner biogas stove[16]. The stoves are of stainless steel structure, with two brass burners each and corresponding control-knobs (Figures 31 - 32).

Based on suggestions from the users regarding their cooking timings, gas is being provided for three hours every morning and one and a half hours every evening. The users are pleased with this service (Figures 33 - 36). Apart from the improvement in appearance, as compared with the earlier-used biomass stove, there is no longer the need to collect stove-fuel, and they now enjoy the advantages of easy lighting and cleaner cooking-pots and kitchen walls. Furthermore, despite being a shared service, the number of users of each digester is small enough to make adjustments for convenience, such as altering the timing of supply.

As discussed in Section 4.1, the capacity of the eight biogas plants has been over-designed so that there will not be a problem of supply-shortage in the near future. The gasholder domes are usually seen standing above the level of the surrounding wall; despite the outflow valve being opened for 4.5 hours a day, the daily addition of dung and water ensures that biogas availability continues. New houses may be constructed in the village (as the State is providing loans to economically-disadvantaged families), but these will have to be constructed beyond the existing clusters, so that there will be space for more digesters adjacent to them.

[16] The stoves have the Indian Standards Institute (ISI) approval mark IS 8749.

Figure 29:

Figure 30:

Figure 31:

Figure 32:

Figure 33:

Figure 34:

Figure 35:

Figure 36:

6. Establishment of the management and accounting system

6.1 The system outline

The accounting system worked out by IEI (jointly with the supervisor) consists of daily (hand-written) recording of inflows and outflows by the supervisor at the village enterprise. (It is intended that a computer be purchased later). This is verified by weekly monitoring by IEI at the village and electronic recording of the relevant details at the IEI office. In addition, daily communication between the supervisor and IEI ensures that any problem is dealt with as soon as possible. However, since most receipts and payments at the enterprise occur monthly, this facilitates the monitoring of accounts at IEI.

The office adjacent to the dairy is being used for the initial recording of all inflows and outflows, in particular, of daily milk collection, fodder inventory and use and the duty roster of the employees, as elaborated below. This office is also used for discussions, whenever required, and for storing bags of processed feed and medicine, pending use at the dairy.

IEI is currently involved in directly overseeing the project. This is intended to continue for 5 years. After a period of five years from the date of beginning of operations at the energy enterprise, the entire enterprise (including buildings, cattle and the remaining bank balance) will be handed over by IEI to the GVS for future management.

6.2 Accounting and records

Accounts of all operations at the dairy and for the biogas plants, discussed in Sections 3.3 and 5.1 respectively, are being recorded, so that checks and balances can be maintained. These are being briefly listed below.

The supervisor of the enterprise (dairy and biogas plants) is not a member of the GVS, and reports only to IEI. He is assisted (for implementation, but not recording) by an assistant supervisor, a member of the village who is available on the supervisor's days off.

Both dairy and biogas tasks have been assigned to the employees who are residents of the village[17]. The employees' regular tasks consist of filling the feeding troughs (of the cows and calves) thrice a day with the specified amounts of (packaged and green) fodder, cleaning these animals, milking the lactating cows, shifting the dung regularly from the sheds to the closed bins, cleaning the sheds, and once a day wheeling the dung and water containers to fuel the biogas digesters. To ensure that tasks are accomplished efficiently, responsibility for specific animals and digesters has been assigned to each employee. The supervisor maintains a roster for the employees' tasks and records their performance. When there are additional tasks such as cutting grass and crop residues (such as corn stalks) on specific days, these are also undertaken. Records of regular and special duties are maintained at the site office.

[17] The head of each household has been named the member of the *grama vikas sabha*, but the people working at the enterprise are members of their families.

Every employee gets one weekly holiday, but these vacation days are rotated between the members of the group over the days of the week, to ensure staffing on every day. Exchange of vacation-days is permitted, and the total number employed is deliberately higher than required, so that absentees do not adversely affect the required tasks. The daily wages have been set above the market rate for unskilled work. Monthly payments are computed on the basis of daily wages including the allowable holidays and a bonus at the festival times.

The quantity of milk collected from each cow is recorded, as are dosages of any medicine or additional feed, as prescribed by the veterinary surgeon. The total milk accumulated in the cans to be collected by the procuring agency is also recorded at the enterprise office. The required density is also checked and recorded, as the price varies with the quality and monthly payment is computed on the basis of the daily quantity and quality collected. The office of the procuring agency is located only 3 km away, enabling the supervisor to verify the readings and monthly computation.

Sale of milk (on a daily basis and on specific occasions) to people of the village is allowed at a lower-than-retail rate, i.e. at the same rate as to the collecting agency. Accounts of these dues are also maintained.

Packaged fodder is usually procured in large quantities (e.g. 10 tonnes of by-pass protein cattle feed) to obtain the bulk- rates. This necessitates keeping the inventory of the types of fodder purchased, the daily consumption of each (to prevent pilferage), and also changes for specific situations, and replenishment due. Medicines are also purchased and stored in the office and records of stocks are maintained.

Thus far, the effluent-slurry that emerges from the digesters has not been sold, despite its considerable value as fertilizer. This is another potential source of revenue and would be accounted for in the same way.

7. Conclusions

Our intention has been to promote "integrated clean energy - rural development" enterprises that will address, in a sustainable manner, the dual need for cleaner/more efficient energy services and economic support through employment/income, in the villages of India (and of similar developing countries). The construction and operation of the enterprise in *Chikkana Devara Hatti* was meant to demonstrate the development and running of such an enterprise and to use this experience for further work in the field. The sections above have described the enterprise in detail. We now consider the relevance of the factors that we had believed to be essential and the lessons learnt from this experience, the projected impacts of large-scale replication of such enterprises, and the benefits that would be derived from each village-enterprise.

7.1 Confirmation of the clean energy – rural development model and lessons learnt

For the purpose of replication, it is important to consider the factors that have been proved essential to the successful operation of the clean energy-rural development enterprise model, as well as any “lessons” learnt and alterations/innovations introduced to overcome problems. These have been grouped as socio-economic and technical issues, and matters concerning project implementation, and financial and operational management:

Socio-economic issues:

- *Income generation for economic sustainability and replication*: Some economic return has to be derived from or linked to the enterprise, so that it is not dependent on grants or subsidies for its continuance. (Other rural energy schemes have been discontinued when financial support was stopped). Further, with income generation integral to the enterprise, there can be extension of energy services and other development measures. From the entrepreneurial view, there can be return of the capital (after an initial moratorium), thereby providing for reinvestment and replication of the model.
- *Economic opportunity for traditional communities*: People in traditional communities (e.g. the shepherd community in Chikkana Devara Hatti) have few opportunities for advancement when they are struggling to eke out an existence and have little education or finance for investment in improvement. Hence, an enterprise providing steady employment (in place of uncertain daily wages) affords a rare opportunity to improve livelihood.
- *Fulfilment of basic needs*: Since incomes are low in this village, the living standards are correspondingly low; for example, people eat only twice a day and these meals consist chiefly of grains. Household water-supply and sanitation facilities are non-existent, and people have to travel long distances for healthcare and schooling. As this is the situation in other villages too[18], better fuel alone might not be adequate and needs to be associated with the fulfilment of other basic needs, directly or through better livelihood.

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[18] The proportion of all rural families with access to drinking water within a distance of 500 meters from their homes has increased from 26.3% in 1981, to 55.9% in 1991, and 80.5% in 2001 (Census of India, 1981, 1991, 2001) but only 28.7% experience the convenience of a source of water at their houses.

- *Co-operative operating structure*: The collective involvement in the dairy and the biogas enterprise – particularly that *all* families benefit from the fuel supply (regardless of income or social strata) – has contributed to successful operation. Observation of other projects have indicated failure of public participation because of perceived inequalities (e.g. only those owning cattle had to supply dung), or restricted to private endeavour (e.g. those households who could afford the costs had their own plants).
- *Other economic linkages*: Indirect earning opportunities also help the region. For example, this enterprise pays for fodder-supply -- both from the cultivation of fodder-crops and from the residues of other crops, so that people with small plots of land can get additional income.

Technical issues:

- *Benefits of clean and convenient stove-fuel*: The supply of biogas and new stoves are appreciated because the chore of collecting fuel is avoided, the stoves are much easier to light than the earlier *ole*, and the cooking pots and kitchen walls remain cleaner than before. (The benefits to health that could result from clean fuel have as yet not been felt).
- *Adequate water supply*: The enterprise had been informed that the village water supply could be used, so that only in a tank was needed to provide for regular use. However, this supply was found to be inadequate. To solve the problem, an independent supply was found: a deep well was dug specifically for the enterprise and a pump purchased in order to provide water whenever needed. Hence, this particular (dairy-biogas) option of the clean energy-rural development model is restricted to regions with adequate (surface and underground) sources of water.
- *Appropriate stoves*: The biogas stoves available in the market and purchased for the village households are not suitable for larger-scale cooking in some cases. For example, in "joint-family" households, cooking large amounts of cereals (like *ragi*, a kind of millet commonly used in this region) is not convenient on the small gas-burners[19]. More appropriate biogas stoves, similar in structure to the currently-used biomass-based *ole* would need to be designed.
- *Other clean cooking alternatives*: Apart from the complete replacement of the existing cooking fuel/devices by biogas, other clean-cooking alternatives can be considered, if they can be linked with income/employment. In areas where biomass is "freely" available, either from crop residues or from proximate public forest land, improved (i.e. more efficient) biomass stoves could be an alternative to a completely new fuel scheme, at least in the near future. In dry regions where vegetation (and consequently biomass) is inadequate for fuel supply, the option of solar cookers could be considered.

Project implementation issues:

- *Phased biogas digester construction*: Sequential completion of each biogas plant and associated mini-distribution system would have been more efficient in terms of the total implementation time required, than the completion of all construction work followed by all the pipeline links. But this project was forced by rising prices of construction materials, to complete the construction activities of all eight plants (to avoid further cost escalation) and only then move to the delivery system. Future projects will follow the sequential (phased) implementation pattern.

[19] At times, the vessel has to be removed for vigorous stirring and re-set on the stove.

- *Outdoor construction:* Unforeseen problems cause delays that are worsened when construction activities planned for an earlier season have to be completed in unsuitable weather, for example, during the rains[20]. Despite these problems, all the eight plants were completed in the locations planned.
- *Total construction time:* The total time taken from the initial village surveys till this final report has been 17 months. As a generalization, for replication of the model, an implementation period of 15 – 18 months is suggested (Annexe 7).
- *Cost increases beyond the control of implementers*: The increase in the prices of several essential requirements for construction (cement, steel and bricks) in India, during the past year, raised costs above that estimated. The materials were purchased according to the plans, but these exceeded the budget.

Financial management issues:

- *Steep rise in fodder prices*: During the past year, the revenue accruing to dairy operations in India has fallen considerably, because the price increases (local and worldwide) of grains, and therefore of fodder, have not resulted in a corresponding rise in the selling price of milk (that is controlled by the State). Due to this, the dairy is currently struggling to break even financially.
- *Appropriate cost-effective mix of fodder sources*: To offset the high prices of prepared feed, less expensive green fodder is being purchased from the village and its surroundings, by leasing plots for growing perennial grasses and also purchasing the remnant stalks of crops grown. A judicious mix of these is not only nutritious for the animals and supportive of small farmers, but also reduces operating expenses for the enterprise. When the model is replicated, it is recommended that land (purchased/leased) for growing fodder is also integrated into the enterprise; this will ensure that green fodder is available to the enterprise at the time of cattle-purchase itself and thereby protect it from spurts in the market prices of grain.

Operational management issues:

- *Management of payments*: Accounting practices have to be strictly maintained to prevent scope for pilferage and/or perceived unfairness in the operations. For example, payments have to be received even when the GVS members (i.e. people from the village) take milk from the enterprise. Hence, while the operational tasks are assigned to people from the village, some supervision should preferably be in the hands of an independent authority.
- *Regulation of biogas fuelling operation*: Seemingly small cases of incorrect handling lead to problems that adversely affect the running of the operations. There has to be regulation over the operating systems and prevention of misuse of the facilities.
- *Regulation of dairy activities*: It has taken longer than expected to get the employees trained in the daily routine required to be accomplished at the dairy, particularly as they did not have regular employment before the enterprise was established. This is a characteristic of the partially-employed and has to be provided for.

[20] Due to the need for manual digging for the biogas plants, the terrain should have been checked. Hard underground rock made the digging much more difficult. As a result of this delay, rains occurred during the period when the pits for the biogas plants were being dug; this necessitated the accumulated water having to be pumped out.

7.2 Plans for replication

Extension of the existing system:

With additional biogas generation potential, there is scope for extending energy services, for example, generating electricity. Another biogas plant can be constructed, and the biogas so generated can be used in a dual-fuel engine to generate electricity for the dairy. The present electricity services at the dairy can then be extended, for example, to a refrigeration unit. This will be worthwhile both to avoid the increasing costs of electricity purchased for the dairy and to make the enterprise self-sufficient. More importantly, electricity can also be generated for supply to the households (to replace the existing grid supply), and for other energy services in the village. This will require the addition of a dual-fuel (diesel-biogas) generator.

The digested manure effluent (from the biogas plants) that is in excess of that required by the GVS members will be sold as fertilizer, outside the village.

Replication in other places:

We intend replicating this village project (or modified versions of it) in other villages. For this, there will be further surveys of villages to select activities suited to the needs of the people and the agro-geographic characteristics.

To increase interest in the energy-development model, we intend spreading information about this project (beyond the local region in which people are already aware) through (reports in newspapers (in the local languages), and local television programmes. For propagation at the national and international levels, we intend using our web site reports, and later, presentation at workshops and publication of articles in journals. More importantly, the observable benefits obtained through the demonstration are already being noted and interest in replication is being expressed.

7.3 Environmental impacts of large-scale replication

The environmental benefits of this project and others like it can be translated to financial value through carbon credits, if the scale of replication is large enough. Biogas has been proved to be much preferable to traditional biomass stoves/fuel not only for its fuel-efficiency, but due to much lower emissions of GHGs (CO_2, CO, CH_4, non-methane hydrocarbons and N_2O) and particulates of incomplete combustion that have an even higher climate impact (Smith, *et al*., 2000). Financial support through the CDM mechanism could therefore bring about larger-scale replication of the biogas option of the rural energy-development model.

While our project is a demonstration intended for replication, the total emissions reduction effected will depend on the number of homes that get involved in such energy-development enterprises. There are around 101 million dairy-animals (cows and buffaloes) spread over 0.5 million villages among 70 million farmers, of whom about 11 million farmers are linked with about 100,000 village milk co-operatives. In view of the livestock holding and the co-operative structures, we are considering *adoption of the energy-enterprise by 10% of those in co-operatives*, that is, 1.1 million rural households (with about 5.36 per family).

Then the current cooking-fuel requirement of 1.474 million tonnes of biomass (estimated at 250 kg/capita) would be replaced by 0.337 million tonnes of biogas. This would reduce CO_2 emissions by 11.293 million tonnes. The corresponding CH_4 reduction would be 27.54 thousand tonnes (as computed in Annexe 9).

There is also the reduction of CH_4 emissions through immediate diversion of cattle dung (usually left in the open) to biogas digesters. However, the value of this has not yet been computed.

If the usual clean alternative of LPG (commonly used in urban areas and among the affluent in villages) were to be provided for the same number of people, instead of biogas, it would necessitate additional LPG requirements of 121 tonnes per year (at an average use of 110kg of LPG/household/year). This use should be avoided not only because of the rising costs of petroleum-based products (and India's import-dependence), but in the environmental context, because of the infrastructure required and the energy use and emissions that would result from transporting LPG around the country.

7.4 Summary of benefits

In conclusion, the benefits of such a clean energy – rural development model are:

- replacement of collection and direct burning of biomass with a clean stove-fuel alternative (thereby avoiding tedious fuel-collection and reducing air pollution and the related health impacts);
- renewable generation of energy from a waste resource (instead of competing with food crops or forests for land);
- development of an economically viable system for use of this alternative resource through income and employment generation;
- avoidance of the use of petroleum-based fuels (-- kerosene oil and LPG) that are the usual "clean fuels" to which households shift while ascending the energy-ladder;
- the use of well-known technology[21] and procedures that can be easily adopted and do not require sophisticated maintenance[22];
- availability of improved natural manure (from the digested slurry[23]), reducing the need for chemical fertilizers, that is particularly relevant in view of soil preservation needs and the shortages of manufactured fertilizers;

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[21] The biogas technology has been in use in India for decades (IARI, 1980), and has been promoted in a concerted manner since the All India Co-ordinated Project in Biogas Technology and Utilisation of the Department of Science and Technology (Government of India) was launched in the 1970s' (DST, 1979). *Fateh Singh ka Purva* (a hamlet in the Etawah district of the north Indian state of Uttar Pradesh) had the first community-based plant constructed in 1979 (Bahadur and Agarwal, 1980).

[22] While there have been some problems with the long-term use of such plants, these have been non-technical, specifically the lack of revenue to meet increasing costs, when only household utilities are satisfied (IEI, 2003).

[23] The nitrogenous content of the effluent obtained through anaerobic fermentation is higher than that obtained in open-air compost heaps because with composting, much of the original nitrogen content is lost to the air in the form of ammonia or dissolved in surface run-off in the form of nitrates, whereas in anaerobic decomposition, nitrogen is converted to ammonium ions that are easily affixed to soil particles and is thereby available to plants.

- reduction of environmental impacts through lower stove emissions could help in the battle against climate change, and, if large enough, derive carbon credits for reduction of CO_2 and CH_4 emissions that could finance further replication;
- economic linkages (such as payment for crop residues).

References

- Bahadur, S. and Agarwal, S.C., 1980. *Community Biogas Plant at Fateh Singh ka Purwa – An Evaluation*, Planning Research and Action Division, State Planning Institute, Lucknow (Uttar Pradesh, India).
- Census of India, 2001. *Houses, household amenities and assets: India, States and Union Territories – 2001 Census*, Office of the Registrar General, Census of India, Government of India, available at www.censusindia.net
- D'Sa, Antonette and Narasimha Murthy, K.V., 2004. "LPG as a cooking fuel option for India", *Energy for Sustainable Development*, Vol. VIII, No.3, September, pp.91-106.
- DST (Department of Science and Technology, Government of India), 1979. *All-India Co-ordinated Project on Biogas Technology and Utilisation – Progress Report*, Department of Science and Technology, Government of India.
- IARI (Indian Agricultural Research Institute), 1980. *Biogas Research at IARI: Status Report*, compiled by T.D. Biswas and P.K. Chhonkar, Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, New Delhi, September.
- IEI, 2003. *Report on IEI's village-based water-supply project*, International Energy Initiative, Bangalore, available at www.iei-asia.org
- Khadi and Village Industris Commission (KVIC). "Non conventional energy programme under KVIC" available at http://update.kvic.org.in/activities_biotechnology.htm
- Smith, K.R., Uma, R., Kishore, V.V.N., Lata, K., Joshi, V., Zhang, J., Khalil, M.A.K., 2000. "Greenhouse implications of household stoves: an analysis for India", *Annual Review of Energy and Environment*, 25, pp.741-763.
- WHO, 2002. *The World Health Report 2002: Reducing Risks, Promoting Healthy Life*, World Health Organisation, Geneva.

Annexe 1: Criteria for selection of village(s) for the energy-development enterprise

Based on experience with rural energy programmes and the feedback from interviews and reports, IEI's Asian Regional Energy Initiative has drawn up a list of criteria for selection of a village for establishing an energy-enterprise. These include general criteria and those pertinent to a biogas-dairy system.

General criteria for co-operative enterprises:

- Current use of clean fuels – There should not be many households with access to better fuels (even partially)[24] so that the village as a whole can be involved in, and derive benefits from, the project. (Those already using clean fuel are likely to be more affluent and therefore not in need of employment at the enterprise).

- Estimates of income levels – In the absence of income data, the size of landholdings can be taken as an indicator of income, while the proportion of landowners is an indicator of income distribution in the village. Hence, a low proportion of landowners, or conversely, a high proportion of landless (who usually have to subsist on daily-wages for unskilled labour in their own or other villages) would indicate that most homes are in need of economic assistance and would benefit from a development enterprise. While there are often a few relatively wealthy families in every village, similarity between most of the people in terms of economic status makes it conducive to co-operative enterprise.

Criteria pertinent to a dairy-biogas model[25]*:*

- Location of homes – The position of houses in the village should be conducive to extending the micro-grids for gas delivery to every home. Homes clustered around the village centre would be most effective. In contrast, at some villages, many families stay on their farms that are interspersed over extensive or undulating area, making the biogas pipeline grid connection difficult.

- Land availability - The availability of uncultivated land that could be used for the dairy and space between houses/huts for the biogas plants are important; there should not be congestion in the village as a result of the project.

- Suitability for dairy/biogas systems – The likelihood of access to water supply in the region (including the depth to which wells have to be sunk) is also important. (This criterion is critical to a dairy-biogas system, but would be less important in other models of energy enterprises).

- Amenities available – Access of homes to amenities like electricity are indicators of the standard of living. Even if homes are not yet electrified, electricity supply to the village would be useful because of the need for lighting at the dairy and water for both the dairy and the biogas plants. (However, with an adequate amount of biogas, electricity can be generated at the village enterprise using a dual-fuel (diesel-biogas) generator, hence this is not a limiting factor).

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[24] The average use of clean fuels in Indian rural homes was found in 2001 to be 7.8% -- 5.67% with LPG, 1.6% with kerosene, and 0.5% with biogas.

[25] We intend demonstrating other models appropriate to different village conditions.

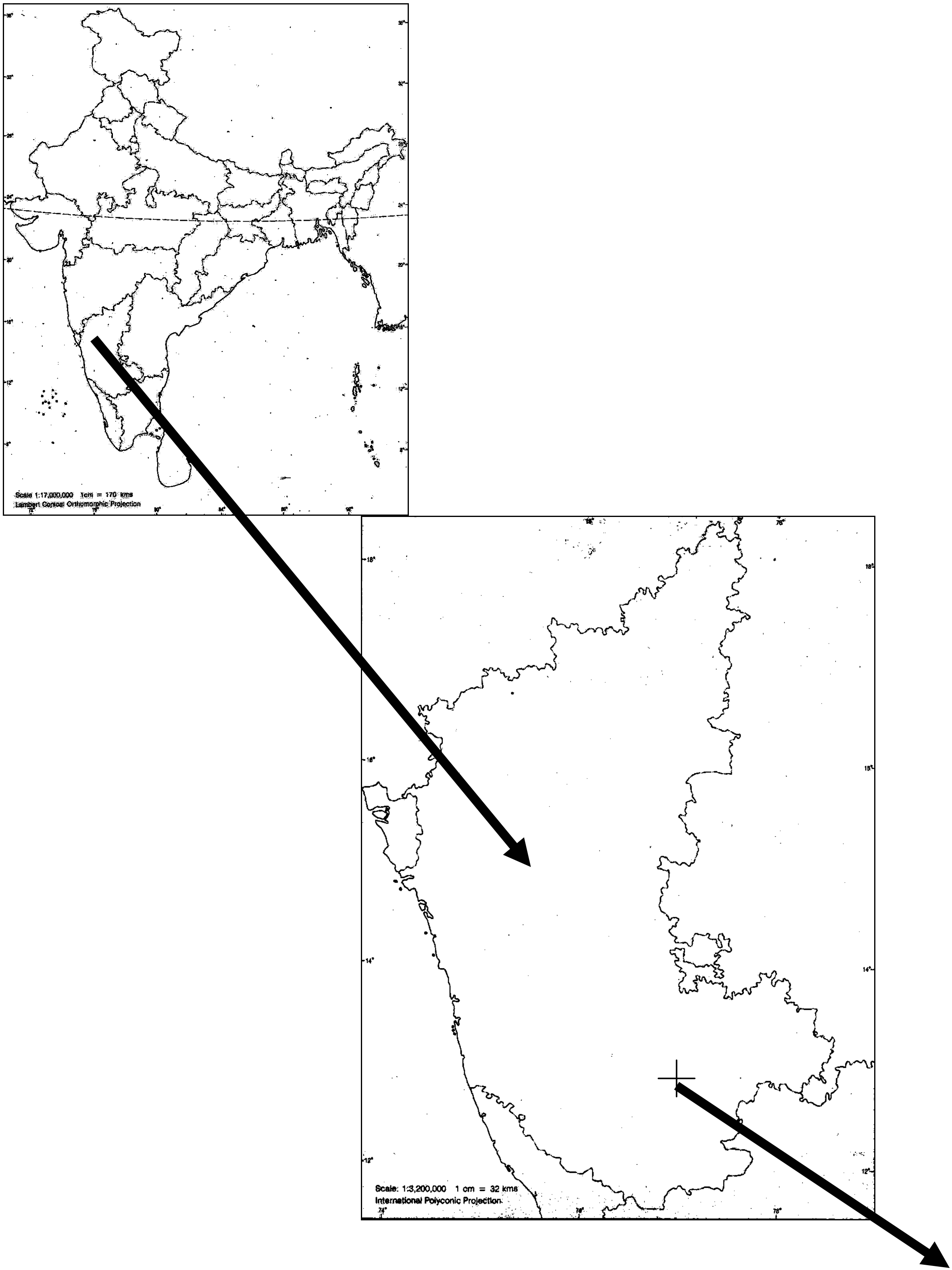
- Connectivity – In recent years, most villages in India have telephone connections. Other factors determining connectivity include the distance from and traversable roads to towns, and bus-services for transport to such towns. These in turn enable access to facilities that are not available in villages, such as branches of nationalized banks, medical and veterinary facilities, etc.

- Existing co-operatives - The operation of one or more "Self-Help-Groups" (SHGs)[26] in the village would indicate understanding of the co-operative system. It is not essential that SHGs are in operation, but it would then be easier for people to participate in another co-operative enterprise.

- Other factors - Further parameters for final selection include less tangible factors such as the people's views on the project and their expressed support.

[26] SHGs are voluntary associations of under 20 people (usually women) who pool their small savings towards a common fund; this in turn is saved in a bank and used for a co-operative purpose.

Annexe 2: Location of the selected village *Chikkanna Devara Hatti, (77° 2' E longitude, 13° 7' N latitude), Tumkur taluk, Karnataka state*




Hebbūr
Veterinary dispensary
Market
Overhead tank
PS
Rāyavāra
Baichanahalli
Narasāpura
809
Doddaguni
Siddanāyakanapālya
Timmanāyakanapālya
Siddanāyakana
Rāmenahalli
Siddalingeshwaraswāmi Math
Boulders
Sangalāpura
821
Power line
Power & telephone lines
Kalkere
Shantapura
838
Boulders
Gollarahatti
839
Bannikuppe
Kallupālya
Narjanakuppe
Rocky knob
Chikka Malalavādi
814
Malalavādi
Gollarahatti
Kareshānayyanapālya
Koppalbāre
Hālganahalli
Rocky knobs
Boulders
Taredakuppe

Annexe 3: Details of the selected village

Name: *Chikkanna Devara Hatti*
Location: Tumkur *taluk*
Village headman (*panchayat* representative): Rajanna
Total number of families: 47
Total number of people: 238
Community: *Kadu Golla* (shepherds who rear sheep and goats)
Number of families depending on wage-labour ("*coolie*") activities for sustenance: 38 (who have to go to other villages in search of employment)
Number of families registered in the "below the poverty line" (BPL) category: 38
Chief cooking fuel: twigs/dried leaves etc. (collected from the forest, about 3 km away)
Fuel collection: about 6 hours/week (chiefly by women)
Number of families with clean cooking fuel: Only one family has an LPG connection (but this is not used regularly because of the re-fuelling cost).
Electrification: 16 families do not have electricity at all and 27 are connected through the (lifeline) *Bhagya jyothi* scheme[27]
General topography: There is a well-known temple (*Virannanagudi)* around which the village has grown, with all the houses clustered. The village has no main road. Only one house has a concrete roof and the rest do not appear to be well built.
Land availability: Public land is available for the project use.
Cattle availability: Very few can afford to rear cattle; only sheep and goats are being reared.
Water supply: This village has state-sponsored water supply (when electricity is available) and an overhead water tank that caters to three villages. The depth of the ground-water table is about 400 feet.
Connectivity: There is a traversable approach road from the highway, with the village located 5 km from a small town (Hebbur) and 11 km from a larger town (Kunigal). There is one telephone in the village (in the home of the largest family).
SHG activity: Three *Sthree Shakti* SHGs (women's co-operatives) are in operation
Schooling: There is one *anganwadi* school for primary education, located in this village and shared between this one and the neighbouring villages. Those who study further have to go to the middle school in the next village or the high school in *Hebbur* (about 3 km away).

[27] Electricity supply is usually intermittent in the rural areas; on an average, a village receives six hours of supply per day.

Annexe 4: Grama vikas sabha (GVS) agreement
(signed on the 8th March 2007 between a representative of each household and IEI)[28]

1. All the households in the village have formally associated to form a *grama vikas sabha* (GVS) with the signature of a representative of every household. All the members of the GVS will have equal rights. The GVS will later elect office bearers (President, Secretary, and others) to interact with IEI on its behalf.

2. The village will allocate unused land of at least 15,000 feet^2 belonging to the village/people of the village, for the dairy (cattle-shed and office).

3. For the construction of shared household biogas plants, small plots of land near/between the households will be identified. The biogas plants will be constructed on these selected plots and operated by the energy enterprise.

4. The village will allow the energy enterprise to use the water required for construction and operation of the dairy and biogas plants, from the existing village overhead tank. The energy enterprise will pay the costs of water and additional electricity supply for pumping.

5. For operation of the energy enterprise, the following terms are agreed upon:
   a) The GVS will allow IEI to establish the village energy enterprise (construction of dairy, purchase of cattle, and biogas plants). IEI will pay for all the costs incurred.
   b) The GVS will allow IEI to supervise the operation of the dairy and the biogas plants until they are handed over to the GVS.
   c) The land allocated by the village (in 2) is to be used for construction of the dairy (including fodder storage and office space).
   d) The construction activities will have to be contracted to a civil contractor and the selection of the contractor will be made by IEI.
   e) IEI will procure the cattle required for fuelling the biogas plants. If required, assistance from the village people will be taken.
   f) IEI will construct appropriately-sized biogas plants for clusters of households, after analyzing the cooking-gas requirement. Supply of biogas to each household will be free of cost until the system is fully operational, and later, at a mutually-agreed price.
   g) The village energy enterprise, with the supervision of IEI, will employ people for the operational tasks required. These people will be selected from within the village, as far as skills are available.
   h) The milk obtained from the dairy will be sold to procurement agencies, or to individuals, on a daily basis.
   i) The slurry (digested biomass) from the biogas plants will be sold as fertilizer.
   j) The village energy enterprise will open a bank account at a branch of a nationalised bank.
   k) All financial transactions of the village energy enterprise will be channelled through this bank account, to the extent possible.
   l) Written accounts of all transactions will be maintained at the energy enterprise office.
   m) IEI will employ and train the people employed for the energy enterprise activities.

[28] This is a translation of the original signed agreement that was drawn up in the local language (Kannada), so that it could be read and understood by all the families. In cases where the family head is illiterate, the contents of the document were explained verbally and the left thumb impression of the individual stamped in place of a signature. (This is the accepted practice in India for the illiterate).

n) Once the GVS is able to run the enterprise independently if IEI's assistance, (say, after a period of five-seven years from the date of beginning of operations), the entire enterprise (including dairy and biogas generation and delivery structures) will be handed over by IEI to the GVS for future management.

Annexe 5: Dairy - construction details

Each shed, measuring 20 x 11 m^2, can house 28 cows. The height of the shed is 4.6 m in the centre, sloping to 2.4 m at each side. This includes the space required for the animals and also for fodder storage and feed/water troughs.

The structure of each of the four sheds consists of steel columns and trusses (Figures A1 and A2). Every shed has 10 columns, with each column consisting of with 50x50x6 cm sections, totalling 25x25 cm^2. (As a precaution against weathering, the steel columns were treated with primer and painted before installation). The columns are embedded in the ground with base plates and foundation bolts. (This foundation structure was adopted as it is more cost-efficient than a stone/concrete masonry foundation). The trusses consist of angles of 75x75x6 cm, with the end purlin (horizontal beam along the length of the roof) of 50x25x25 cm. The roofing consists of corrugated sheets.

Each shed is bounded on three sides by walls. It has two rows of cattle-stalls, separated by two walls within which fodder can be stored (Figures A3 and A4). Each row of stalls has its corresponding feed and water troughs. The flooring of each shed consists of chiselled stone slabs, fixed with cement mortar. These are suitable for keeping animals, as they prevent slipping and can also be easily cleaned. A slight slope towards the adjacent drain has been provided (Figure A5). The walls consist of un-plastered 23 cm solid concrete blocks, to a height of 1.5 m each, built on rubble-masonry (Figure A6). Again, the un-plastered concrete blocks are more economical than the alternative of moulded bricks.

Each row of feeding troughs is 0.5 m deep, sloping towards one end to facilitate cleaning and loading. Rings for tethering the cows have been provided at the side of the trough walls. A drain has been constructed along the side of each row of stalls, opposite the feeding trough. It slopes towards one end, so that the waste can be easily accumulated. The drains are connected to a larger trough at the end of each shed, to facilitate removal of waste for the biogas plants.

The central aisle between cattle stalls has been designed for storing fodder. This fodder storing area, between two rows of cattle-stalls, extends along the length of the shed, and is 1.5 m high and 1.5 m wide (Figure A7). Location of the fodder storage near the feeding troughs facilitates the daily feeding task.

A sump (underground water tank) of 10,000 litres capacity has been constructed for storing water. In addition, an overhead tank of 5,000 litres capacity has been constructed for supplying water directly (by gravity) to the cattle sheds (Figure A8). The pipeline from the water tank has been drawn to the supply points in each shed.

Each shed has been provided with six fluorescent tube lights within and two at the entrances. Later, this supply will be extended to a refrigeration unit and water pump (if the water flow is inadequate).

Figure A1:

Figure A2:

Figure A3:

Figure A4:

Figure A5:

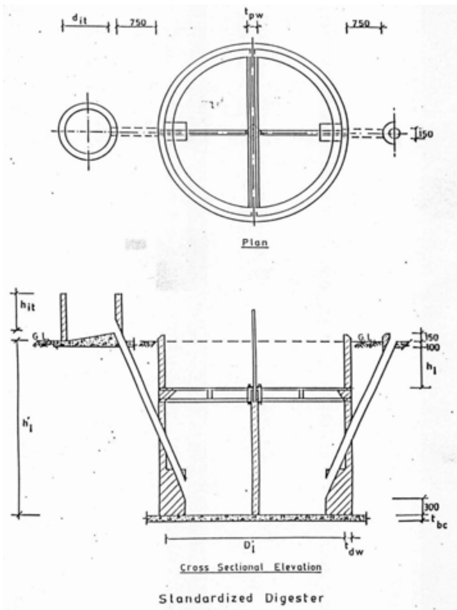
Figure A6:

Figure A7:

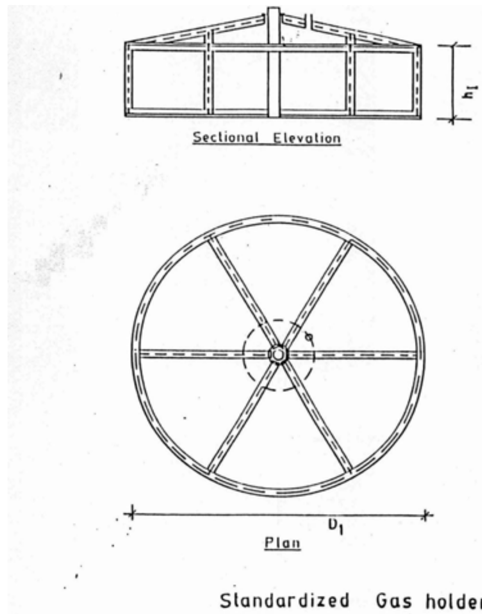
Figure A8:

Annexe 6: Biogas plants – construction details

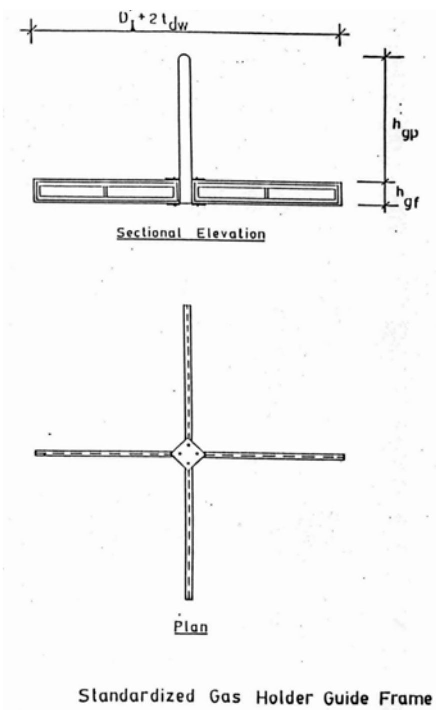
Engineering drawings of a standardised floating-drum biogas plant



Standardized Digester



Standardized Gas holder



Standardized Gas Holder Guide Frame

Construction

As explained in Section 5.2, the eight digesters consist of 6 plants of $8m^3$ each and 2 of 10 m^3 capacity. For each $8m^3$ biogas digester, excavation had to be carried out till a depth of 4.1m and a diameter of 2.1m, whereas for the 10 m^3 plant, the corresponding dimensions were 4.4m and 2.3m. Local people were employed for the digging and other unskilled tasks (Figure A9). The region was found to contain rocky strata. Digging therefore required more effort and time than originally expected.

Construction-quality bricks were used for the nine-inch brick-lining of the digester walls, following which the internal wall of each digester was plastered with cement mortar (Figure A10). A partition-wall has been constructed across the diameter of every digester, to balance the pressure generated by the dung-water slurry on each side. The construction standards were monitored by a civil engineer at every stage.

The guide frame of every biogas plant consists of bracing of mild steel angles (each of 40mm x 40 mm x 4 mm) with a pipe of 100 mm diameter in the centre (Figure A11). The purpose of this guide frame is to support the gas-holder when it rises and falls, depending on the amount of gas accumulated. The guide frames of all the biogas plants were fabricated outside and brought to the village for assembly and installation. In each digester pit, the guide frame has been grouted (with concrete) at a depth of 2.66m. At this level, a ledge of treated iron rods (of 0.15m) was provided, to ensure that the weight of the gas-holder is distributed evenly. Care had to be taken (with guidance from IEI project staff) to ensure the correct alignment of the guide frames, in order that the gas-holders were properly positioned. (Figures A12 and A13 show some of the biogas plants at this stage).

As in the case of the guide frames, the gas-holders of each biogas digester were fabricated outside the village and transported to the site for installation. Each gas-holder has been made of mild steel of 3mm thickness. The gas-holder of the $8m^3$ plants had dimensions of 1.5m height and 1.9 m diameter, while that of the 10 m^3 capacity plants had dimensions of 1.5m height and 2.1 m diameter. The gas-holders were treated with epoxy-etch primer and then painted with epoxy-coal tar to ensure its durability.

Each digester is connected to an inlet and an outlet tank with PVC piping (of 20 cm diameter). The inlet tank has dimensions of 1.2m x 1.2m x 0.9m, with a slope towards the digester. The outlet tank has dimensions of 1.2m x 1.2m x 0.15m, and is constructed at a lower level (1m) than the inlet. Care has been taken to ensure that the inlet pipe is inserted at a higher level than the outlet pipe. (The inlet pipe was inserted at 0.7 m from the bottom of the digester, while the outlet pipe, at the opposite end, was inserted at 0.4m).

Figure A9:

Figure A10:

Figure A11

Figure A12:

Figure A13:

Annexe 7: Actual implementation time-schedule

	months (for the entire WISIONS-sponsored project period)																
Activities:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Interaction with regional organisations	■	■	■														
Selection of village	■	■	■	■													
Formation of GVS & the energy enterprise				■													
Staff recruitment		*		■													
Establishment of the dairy					■	■	■	■	■	■	■	■	■				
- Construction of the dairy					■	■	■	■	■	■	■	■					
- Purchase of cows										■	■	■					
- Operation of the dairy										■	■	■	■				
Location & Construction of the biogas plants									■	■	■ *	■	■				
Initial charging of the biogas plants											■	■	■	■	■		
Connections and gas delivery															■	■	■
Establishment of management accounting system													■	■	■	■	■ *

The asterisks * indicate the Progress Reports.

Annexe 8: Estimation of the emissions reduction through large-scale replication

Estimation of the emissions reduction, if the dairy-biogas enterprise model were adopted by 10% of those currently belonging to milk co-operatives:
The comparison of the expected project outcomes with the baseline is with respect to the cooking (heating) fuel use and the resulting GHG emissions. The appropriate emission factors for heating have been adopted from an in-depth study of greenhouse implications of household stoves, based on ultimate emission factors of pollutant mass per unit of energy delivered to the cooking-pot (Smith, *et al*., 2000, Table 4, pp.752).

Definition of baseline energy requirement:
1.1 million households are equivalent to about 5.896 million people.
Considering that the current cooking fuel used is biomass (of fuel wood, twigs, leaves, crop residues, etc.),
the *baseline* cooking fuel required (@ stove-fuel efficiency of 15% and fuel energy content of 15.10 MJ/kg) = 250 kg/capita x 5.896 million = 1.474 million tonnes

Estimation of CO_2 emissions reduction:
Baseline CO_2 emissions = 0.550 kg/MJ x (1.474 million tonnes x 15.1 MJ/kg) = 12.241 million tonnes
Biogas cooking fuel requirement (@ stove-fuel efficiency of 50% and fuel energy content of 17.71 MJ/kg) = 63.95 kg/capita x 5.896 million = 0.377 million tonnes
Calculation of resulting CO_2 emissions with biogas use = 0.142 kg/MJ x (0.377 million tonnes x 17.71 MJ/kg) = 0.948 million tonnes
=> Reduction of CO_2 emissions = (12.241 – 0.948) million tonnes = 11.293 million tonnes

Estimation of CH_4 emissions reduction:
Baseline (biomass-based) CH_4 emissions = 1.267 grams/MJ x (1.474 million tonnes x 15.1 MJ/kg) = 28.2 thousand tonnes
Calculation of CH_4 emissions with biogas use = 0.0989 grams/MJ x (0.377 million tonnes x 17.71 MJ/kg) = 0.66 thousand tonnes
=> Reduction of CH_4 emissions = (28.2 – 0.66) thousand tonnes = 27.54 thousand tonnes