OUTLINE

REPLICATION OF RURAL ENERGY & WATER SUPPLY
UTILITIES (REWSUs)
AN IMPLEMENTATION PACKAGE

Executive Summary: Generation of electricity from biogas is a clean source of renewable and decentralised power. From the experience gained in Pura village near Bangalore it is clear that similar Rural Energy and Water Supply System can be replicated in about 100 villages, to start with. The REWSU can supplement the State Electricity Board's supply for lighting, drinking water supply, small rural industries such as flour mill and towards the demand from irrigation pumpsets. The fixed cost of the system with about 250 cattle in a village supplying 1000 kilogram of dung to the community biogas plant will cost about Rs.300,000 at 1992 prices and the recurring cost can be met from the sale of electricity supplied. In about three years time 100 such systems can be built. The proposed financing is by GTZ. The State Council for Science and Technology has to take a leading role in training persons and organisations to construct and maintain the system in the initial years. The other organisations closely involved are the Electricity Board, the Khadi and Village Industries Board, voluntary organisations, the Corporate sector companies, the Zilla Parishads and Mandal Panchayats, besides the Government. The International Energy Initiative will play the coordination role and facilitate financing by GTZ. In the background of scarcity of funds, mounting foreign debt, inability to use fully the sanctioned foreign aid for power projects and pollution-related problems in executing fossil-fuel based power projects, the decentralised and renewable source of power supply in rural areas offers a significant solution.

1 Introduction

1.1 One of the basic requirements in rural areas is safe and adequate drinking water and reliable lighting in the evening say from 1900 to 2200 hours. Small industries such as village flour mills, which grind cereals and pulses into flour to meet the cooking needs of villagers also use electricity if available. While statistically speaking 83% of India's villages and 9 million pumpsets and tubewells have been electrified from the centralised power system,[1] the dependability and quality of such electrification leaves much to be desired. While power cuts, load shedding and blackouts are very common in towns and cities, they are much worse in Indian villages.

1.2 Biogas from bovine dung (cattle and buffaloes) can be a significant source of renewable energy in India where, unlike in China, human waste is not traditionally used due to social taboos. For over three decades the Government has been trying to promote biogas energy in India. The Ministry of Non-conventional Energy Sources (MNES) in Delhi is at present the central agency to promote bio-gas energy. While 1.5 million rural families are said to be benefitting from 1.4 million biogas plants constructed as on March 1991[2], almost all these plants are individually owned. However, since only comparatively rich farmers have adequate number of cattle, most small farmers and landless labour and artisans in the villages cannot have biogas plants.[3] The common needs of the villagers such as lighting and water supply cannot be met from individual plants. Privately owned bio-gas plants are used mostly for cooking and the sludge for fertilising the fields. There are very few successful community biogas plants (CBG) in India or abroad. After the launching of the national programme for biogas development in 1981-82, till 1991 a total of 1.4 m family biogas plants have been built but only 494 community biogas plants, most of which are institutional biogas plants constructed by organisations such as the Khadi & Village Industries Commission and Boards etc.[4]

1.3 There are many constraints to the expansion of CBP programme which are briefly shown below:

ECONOMIC - High capital and interest cost of CBP compared to the smaller family biogas plant; high repair and maintenance cost;

SOCIAL - Women gather fuelwood for cooking while the decision making for CBP is with menfolk; lack of awareness;

TECHNICAL - Inadequate dung availability; initial gestation period of about two months of feeding; scarcity of water; non-availability of space; maintenance problems; high rate of plant failures;

INSTITUTIONAL - Complex procedures to obtain loan, subsidy and repair charges; inadequacy of funding and lack of masons and skilled labour.

2 Objective

2.1 The objective of this paper is to provide a complete implementation package for the replication of REWSUs based on the experience gained from the Pura village biogas-based system for electricity generation and water supply. It will demonstrate the feasibility and desirability of establishing, to start with, about 100 Rural Energy and Water Supply Utilities in the three southern states of Karnataka, Andhra Pradesh and Tamilnadu. The paper discusses the advantages of this decentralised and renewable source of power and the economics of the system. The role of various voluntary and Governmental agencies to ensure the success of REWSU is also discussed. The implementation package will include all the components related to the system hardware and to the software such as financing, management, institutions/organisations, poolicies, training, manpower, standards and quality control, technical support etc. required to operate the hardware of the plants.

3 Current Rural Energy and Water Supply and Consumption Patterns

3.1 A field study[5] of six villages including Pura shows that Commercial Energy (conventionally referred to electricity, kerosene, coal and diesel) forms a neglible part in rural energy consumption. According to this study, the pattern of village energy supply and consumption in 1980 was as follows:

Source-wise contributions		**Sector-wise consumption**	
Source	%	*Activity*	%
Human	7.7	Agriculture	4.3
Men	(3.1)	Domestic	88.3
Women	(3.8)	Lighting	2.2
Children	(0.8)	Transport	0.5
Animal	2.7	Industry	4.7

Firewood 81.6	
Kerosene 2.1	
Electricity 0.6	
Other 5.3	

3.2 Electricity consumption in 1980 in the surveyed villages was thus neglible and it was used mainly for pumping water from irrigation wells and to some extent domestic lighting. 13 Irrigation Pumpsets in these villages used 42,108 kWh during the year which gives an average of 3,239 kWh consumption per pumpset. Five of the six villages covered by this study were having electricity. One fifth of the households of these five villages used electricity for lighting. However, fetching water for domestic use was entirely by human labour. Each household spent 1.53 hours every day in fetching water mainly from public wells (62%), ponds and tanks (18.4%), hand pumps (8.4%), canals and rivers (6.1%) and private wells (5.1%).

3.3 Rural electrification has made progress since then. The villages electrified and pumpsets energised during the decade 1980-90 are as folows:

	Villages Electrified	Pumpsets Energised	Installed Capacity	Total Energy Consumed*
1980-81	16,793	308,763	1,470 MW	6,988 MU
1990-91	26,483	744,045	2,760 MW	15,129 MU

*After adjusting auxiliary consumption, import and export of power.

(Source : Power Supply in Karnataka - Statistical Profile 1969-86 and Annual Administration Report 1990-91 of Karnataka Electricity Board)

3.4 Since 1980 a large number of drinking water wells, most of them borewells, have been provided in rural areas. The submersible pumps installed in the higher capacity borewells and the large number of Irrigation Pumpsets place a heavy demand on the Electricity Board. Added to this, there is no incentive to conserve energy as IP sets are non-metered. It is also likely that pumpsets officially not yet energised tap power without sanction.

4 **Community Biogas Electricity System in PURA village[6]**

4.1 It is against this background that the community biogas plant in Pura village, about 120 km from Bangalore, in Tumkur district of Karnataka State, established in September 1987 and working successfully ever since, assumes importance for replication. Briefly, Pura is a village away from the district town which had in April 1991 87 households and a population of 463 and 248 heads of cattle. Two digesters of 4.1 m diameter and 4.2 m depth were constructed with mild steel "floating drum" design. The maximum design input to the plants is 1.25 tonne of cattle dung mixed with 1.25 m^3 water per day. At this maximum loading, the influent slurry mixture contains 212 kg of dry matter (8.5%) having a volatile matter content of 177 kg (7%). The carbon content of this mixture is 57 kg (27% of the dry matter), the nitrogen content is about 3.6 kg (1.7%) and the carbon-nitrogen ratio is 16. The plants can produce, at an average ambient temperature of 25-26^oC, a maximum of 42.5 m^3 biogas per day (approximately 60% CH_4 and 40% CO_2). In addition to the gas, the charging of the dung plus water slurry would displace about 2.45 m^3 per day of digested slurry, which yields after removal of the water by filtration about 1.2 tonne per day of sludge. This slurry contains 164 kg (6.67%) dry matter and 109 kg (4.45%) of volatile matter, 39 kg (24% of the dry matter) of carbon, and 3.6 kg (2.2%) of nitrogen - the same amount of nitrogen as in the input. The output carbon-nitrogen ratio is 11.

4.2 A 7 horsepower (5.2 kW) water-cooled biogas-diesel (dual-fuel) engine has been installed in an engine room (5.05 m * 3.5 m) located at the edge of the village next to the fields. The engine has been mounted on anti-vibration footings and bolted firmly to the ground with foundation bolts. The exhaust pipe, attached to a silencer, has been extended through the engine room wall to the open air in a direction toward the fields and away from the village. The biogas from the biogas plant passes through a condensation trap and then enters the engine where it is mixed with diesel to provide the fuel. The engine is coupled to a 5 kVA 440 volt three-phase generator to enable the operation of a three-phase submersible pump.

4.3 The **lighting system** was energised in October 1988. It consists of 103 20-watt fluorescent tube lights - 97 in homes, two at a public temple, and four in the biogas plant complex. 47 houses elected to have one tube light and 25 have two. The life of the tube lights was found to be between 1580 and 1957 hours on the basis of the empirical experience of replacing 58 tube lights from August to December 1990.

4.4 The water **water supply** system which has been in operation since September 1987 consists of a three-phase, 3 horsepower (2.24 kW), 6.75 m^3 per hour submersible pump fitted into a bore well. This pump lifts water from a 50 m depth to an overhead tank. The water is then distributed by gravity through nine street taps in the village. One of the taps is for livestock and one tap is in the biogas plant compound. In addition, there are 29 private taps inside the households. From September 1987 to April 1991 (44 months), the engine ran for 4521 hours - for supplying water 2211 hrs and providing lighting for 2310 hrs. The average daily operation time has been 4 hr 9 min - 1 hr 40 min for water and 2 hr 29 min for lighting.

4.5 The present operation of the Pura system for about 4.15 hours per day corresponds to a dung input of 291 kgs per day. But the plant is designed to take an input of about 1250 kgs of dung per day to sustain an operation of about 18 engine hours per day. A daily dung input of 1250 kgs would correspond to the output of the present cattle population of 250 each yielding 5 kgs of dung per day. The village flour- mill owner has requested for power connection from the biogas plant and the new housing colony built for poorer people by Govt also requires lighting and water supply. Thus the present low load factor of 17% of the biogas plant can in theory increase to over 65% in the near future.

5 Potential Contribution of Rural Energy & Water Supply Utilities

5.1 The Pura example is given in some detail to show the potential it holds for rural energy and water supply. The essentialdvantage of this system is that it is based on a renewable energy source that is reliable because it is from within the village. The bovine dung which is now used directly as farmyard manure or as fuel in households without access to fuelwood can be better used in the form of slurry because it is a better fertiliser after going through the digester. In Pura the slurry displaced from the digester is filtered through a sandbed and returned to the original dung suppliers at the rate of 750 grams per kilogram of dung received. Due to anaerobic digestion, it contains double the nitrogen content of farmyard manure, 1.9% as compared to 0.9% in FMY. Environmentally, biogas-sludge fertilizer is superior as it does not smell, does not attract flies and is less conducive to weed growth. Biogas is an ideal fuel to run an engine as a prime mover to convert biogas into shaft power that could then drive a generator and generate electricity[4]. Diesel engines are suitable for this purpose because

- the low flame velocity of biogas is best suited to low-speed diesel engines,
- they have a high thermal efficiency compared to other types of engine,
- they are more extensively used in rural areas than other types of engines,
- the normal working life of a diesel engine (4-8 years) is more than that of other types of engines,
- they are reliable and simple to maintain,
- they can be easily converted to the dual-fuel (biogas-diesel) mode which is the most practical and efficient method of using biogas,
- in case of a shortfall in biogas supply during an important operation, an engine can switch over smoothly without interruption to conventional diesel operation.

5.2 The use of biogas in biogas-diesel engines is ideal for electricity generation in rural areas because

a) it is a clean fuel for combustion in engines, with little or no pollution, unlike diesel
b) it is a locally available and renewable source of energy
c) it can be produced cheaply with indigenous technology
d) it can provide employment to local people
e) it makes rural electricity systems self-reliant
f) centrally supplied electricity has become scarce and expensive
g) rural areas have been neglected in conventional electricity planning except for energising irrigation pumpsets
h) centralised system of distribution involves a transmission and distribution (T & D) loss of 22.9%[7] in India
i) electricity has become extremely unreliable in rural areas both with regard to duration and voltage

5.3 Apart from biogas, the rural energy centres can also generate energy from wood-gasifier systems from energy plantatations, low-head micro hydels across irrigation canals and photovoltaic systems. Near Pura village a wood gasifier based power generation system is functioning in Hosahalli village since December 1988[8]. This is a village about 110 km from Bangalore with a population of 250 living in 43 households.

From an energy plantation of two hectares yielding 6.96 tonnes of wood per hectare per annum, a gasifier-engine-alternator system has been installed with a generator of 3.5 kVA capacity. It provides lighting to the houses and eight street lights besides providing drinking water supply and will shortly run a flour mill.

5.4 Renewable energy sources are in the short run a valuable supplement to the existing centralised electricity supply system of the State Electricity Boards (SEBs). From the performance of Pura system over five years by 1992, it is clear that even at a conservative estimate of about 1000 kg of cattle dung available daily from 248 cattle, about 22,000 kWH of energy can be generated in a year.[9] In Pura village, there are 26 irrigation wells with electric pumpsets. The KEB has arrived at an average consumption of 5,880 kWh per IP set for the year 1991-92 on the basis of a sample of 277 transformers in the rural areas in the state. Applying this state average the 26 IP sets in Pura village would theoretically consume 152,880 kWh in one year. According to the Central Electricity Authority, the electricity consumption per pumpset in India in the year 1988-89 was 4,972 kWh. However, this consumption figure is on the basis of the existing non-metered pumpsets with no incentive for energy saving and also, possibly, including illegal connections. A study shows that as much as 50% of the energy consumed by the pumpsets in India can be saved by investing in improvements the technology and equipments for which is wholly indegenously available.[10] These improvements are replacements of faulty foot valve, GI suction pipe and delivery pipe with RPVC pipe, and faulty motor and pumps with efficient monoblock.

5.5 In a more detailed experiment in 1987, the KEB with the assistance of Rural Electrification Corporation of India retrofitted in 5,000 pumpsets in geographically disperse selected taluks of Karnataka, frictionless foot valves, HDVP/RPVC pipes etc., at a cost of Rs.5 million. At the end of the experiment it was found that the energy saved was 38%.

5.6 In most of the villages the main consumption of electricity is by the irrigation pumpsets. The energy generated from the biogas system can thus be sizeable. The auxiliary power consumption in a centralised system, especially in thermal power stations is about 8% and the Transmission and Distribution losses of SEBs in India was 23% in 1989-90.[11]

5.7 In addition to being a supplement to SEB's supply, the quality of the power supply from a decentralised source is important. It is much more reliable for continuity and availability, voltage fluctuations are absent and is managed at the village level. In Karnataka, over 70% of electricity generation is from hydroelectric projects that are dependent upon the South West Monsoon in the crucial months of June and July. If this monsoon fails (the average cycle is two years good monsoon, two years average and one year less than average), there will be formal power-cuts up to 60% and informal load sheddings three to four hours a day. There was one year when there was a 100% power-cut (for industries) in Karnataka! Though it was justified by storage levels in the reservoirs, it was withdrawn in a few days time because of its political implications to the party in power! In the case of coal-based thermal stations, frequent shut-downs are common due to non-availability of coal. For instance, in Karnataka State, there is no coal mine and the three units each of
210 MW of the Raichur thermal Station of the State-owned Karnataka Power Corporation has to receive coal daily from the coal mines of neighbouring Andhra Pradesh, about 300 miles away. The coal requirement of one 210 MW unit is 3,500 tonnes per day (the ash content is about 40-45% besides mud and stones). For three units 10,000 tonnes of coal is required per day and the thermal station leads a wagon-to-boiler existence. Till November 1992, for three months, only one unit out of the three was functioning due to non-availability of coal.

5.8 There are many organisational problems in generating electricity from coal-based thermal power stations. Firstly, due to the Mafia-like militantly organised labour unions, often the coal is not mined beyond certain agreed levels of production a day; the mined coal often is not lifted out of the mines; railway wagons are not available in required number to transport the coal to thermal stations; pilferage of upto 5% takes place from open wagons. Recently the Railway Ministry announced an "Own your wagon" scheme for industries using coal in large quantities. Even when they are available, the railway lines are clogged because of increasing demand of passenger traffice. Secondly, the State Electricity Boards are in financial straits and they cannot fulfill Coal India's condition of "cash and carry". There are therefore innumerable organisational and financial problems facing the State Electricity Boards. Also, the cost of generating one kilowatt hour of electricity exceeds Rs (to be filled up) in new coal based thermal power stations, and about Rs. in hydro-electric stations. Apart from the cost aspect, it is the unreliability and voltage fluctuations damaging installations and devices which is the main problem in centralised supply systems. It is in this respect the village-based decentralised system becomes important to rural areas.

6 Benefits accruing to SEBs from REWSUs

6.1 Village water supply is a most sensitive issue in rural areas. Over a period of about two decades a large number of 6" diameter high speed rigs have been employed to drill deep borewells in villages. About 20% of these borewells are failures if a failed well is taken to be as one with a capacity of less than 200 gallons per hour. Successful wells are provided with handpumps. In a few cases, a water supply system is sanctioned in which case a submersible pump that can be operated with power is installed. Even in these systems only public taps at central locations are provided. Quite often, however, due to the unreliability of the electric supply the water supply system suffers as the water cannot be pumped. Street lighting is also another sensitive issue in the villages, though to a lesser extent. Due to voltage fluctuations the bulbs burn out and the village panchayat does not have funds to replace the bulbs and tubelights frequently. The main reason why even in an electrified village not all the households take individual connections and those who have taken do not get the full benefit, is the general malady of voltage fluctuations and unreliability. Hence, for lighting most villagers have to rely upon old fashioned hurricane lamps using kerosene. It is in this context that the REWSU can come to the aid of Electricity Boards. In all states the generation and distribution of electricity is with the State Electricity Boards (SEBs). In some states there are a few private sector companies generating power such as the Tata Electric Co in Bombay city. In Karnataka State, the generation of electricity, hydel and thermal, is by the state-owned Karnataka Power Corporation while the distribution is by the Karnataka Electricity Board. The KPC sells power wholesale (except the auxiliary power) to the KEB on a cost plus basis and therefore is not in the red. But the KEB, according to its annual report for 1990-91, loses about 19.5% of the power bought from KPC in transmission and distribution. The supply to the rural areas, mainly for pumpsets, is on a highly subsidised basis. It is supposed to recover the loss by charging a higher rate from the Industries. The share of consumption sector-wise in India and Karnataka in 1990-91 is a
as follows:

SECTOR	KARNATAKA	INDIA

Domestic	14.8 %	16.5 %
Industry	44.6	44.9
Agriculture	36.8	26.0
Others	3.8	12.6
Total	100.0	100.0

By encouraging REWSUs, the KEB will benefit in two ways. Firstly, the energy supplied by REWSUs is a net addition that need not be supplied by KEB to the villages. It will therefore be available for other uses, e.g., energising more pumpsets or reducing power cuts to industries. Secondly, the KEB can increase the supply to irrigation pumpsets which will earn the goodwill of farmers.

6.2 KPC is in an unenviable position. While the objective of establishing KPC was to specialise in the construction and maintenance of power generation installations and leave KEB to look after only transmission and distribution, KPC has recently run into problems. Karnataka has no coal and its only thermal plant at Raichur, 350 miles north of Bangalore on the Andhra Pradesh border, gets coal from outside the state by rail. There is not much scope for expansion of coal-based thermal plants or gas based plants. While the hydro-thermal mix in India is about 30%-70%, in Karnataka it is the other way round. However, all the sources of hydro power are in the Western Ghats, a 1,000 metre steep range of rocky hills running north to south parallel to the Arabian sea for about 1,000 miles which gives the orographic lift cooling the moisture-laden monsoon clouds which precipitate immediately giving rainfalls upto 10 metres per annum in certain places. These are the only locations for dense forests in this state, but most of these forests have already been lost by farming, mining, rehabilitating land-losers of projects and refugees from Tibet, Srilanka and Burma, submersion of lands under irrigation and power projects etc.[12] While the KPC has installed about 1800 MW of hydro power and the potential is a total of about 7000 MW, new hydro projects have increasingly run into opposition from the environment-conscious public of the Western Ghat districts and other organisations. Many projects initiated by KPC have landed in the Courts and protracted litigation is going on. Under these circumstances, the highly competent engineers of KPC can only turn to projects of other less resistance-prone projects. The KPC has a division headed by a Chief Engineer for Renewable Energy Sources of (other than hydro) Wind, Solar, Biogas, tidal, etc. By intensifying its efforts on a purposeful, rural-oriented sector as electricity from biogas, the KPC will immensely benefit from the goodwill of the rural population apart from keeping its competent staff fully engaged. In fact, the public contact that REWSU will earn for KPC can even help it in enlisting the support of rural population in Western Ghat area to take up bigger hydro projects by certain amount of give and take such as locating the project at a site with a lower head that will reduce the generation of power but will also reduce submersion of forests.

6.3 The benefits to the village community and to the state are obvious. The villagers can get assured water supply and lighting which they do not have now most of the time. Small service industries like flour mills can get reliable power. If there is power to be spared after all these demands, the requirement for irrigation wells can be addressed. The villagers will also be motivated to improve their economic position as is happening in Pura village. The dung availability at present in Pura being 5 kg per head of cattle per day, the villagers have realised that by forming a Dairy Cooperative Society which will enable them to get hybrid cattle, both dung availability and milk production will go up. Pura villagers are already in the process of forming such a society. Apart from this, the health of the villagers will also improve because of uncontaminated groundwater as will education because of better light to read in the evenings.

7 **Economics of REWSUs**

7.1 Once the fixed cost is borne by an agency, which was the Karnataka State Council for Science & Technology (KSCST) in the case of Pura, most of the variable expenditure can be met by the funds generated within the project. The details of the recurring and non-recurring cost and the economics of the biogas electricity generation is given in Appendix 1. Taking into consideration the T and D losses of 19.5% (1990-91) and the cost of drawing power from generation point to the village, the huge establishment cost of the SEBs and the indirect benefits of biogas based electricity generation such as better quality of fertiliser, self-reliance of the villagers, etc. the REWSU scores on every point, apart from being a net addition to energy from renewable source. The economics of biogas electricity will further improve if more sophisticated methods of shadow prices providing for pollution abatement are used and economic returns (aside from financial returns) to the society is taken into consideration. The cost per kilowatt hour of biogas electricity decreases with increasing load factor. Demand from small village industries and especially from irrigation pumpsets will increase the load factor.

8 **Replication of REWSUs**

8.1 The KSCST has not been readily acceding to the demand of the neighbouring villages to replicate the Pura system. Only recently, after Pura has been operating for about 5 years, the KSCST has come forward to replicate the system in four other villages nearby with the financial assistance of KPC restricted towards the fixed cost. It can be seen that the Pura REWSU is a success by any count. Juxtaposed to the deteriorating power supply system in India, replication of Pura system needs urgent attention. The supply side power scenario in India is quite alarming. The installed capacity of electricity in India at the end of March 1992 was 69,874 MW and the Central Electricity Authority (CEA) has estimated[13] an **additional** capacity creation of 141,429 MW by the year March 2007 (i.e. in 15 years) assuming an annual compound growth rate of 7.1% as shown below:

	March 1992	**March 2007**
Hydro	19,508 MW 27.9%	51,637 MW 37%
Thermal	48,331 MW 69.2%	81,647 MW 58%
Nuclear	2,035 MW 2.9%	8,145 MW 5%
Total	**69,874 Mw 100**	**141,429 MW 100**

8.2 The 141,429 MW projected is the *additional* capacity projected from the existing capacity, taking into account the retirement of 7,500 MW existing installed capacity. The fund requirement is estimated at Rs.5,000 billion (US$ 166.7 b @ 1 US$=Rs 30) of which 50% is foreseen to be available. The World Bank has estimated that hardly 40% of the project estimated cost of India can be met by aid agencies[14]. Due to the high debt-servicing ratio of upto 30% and the balance of payments problems, India will not be able to borrow much above the current levels externally.

8.3 Due to paucity of funds, the Government of India has scaled down its proposed investment in the electricity sector in the Eighth Five Year Plan (1992-1997) to instal 24,480 MW from the originally proposed 36,645 MW and expects private foreign and domestic investment to fill the gap of about 12,000 MW. A high-power official delegation headed by the Cabinet Secretary had been to USA, Europe and Japan in May-June 1992, to invite private foreign investment. However, if the Government cannot guarantee payment for energy generated and sold to SEBs, the private investment in electricity sector is not likely to materialise in a significant way. The problem is still worse. It is not just that funds are not available. In fact the loans sanctioned by the aid agencies for power projects are not being absorbed by the SEBs and Central power corporations because of implementation problems and commitment charges are being paid on the instalments due for release but not drawn.

8.4 It is against this background that decentralised, renewable sources of energy which can satisfy the needs of rural people assume great importance. It takes about 6 months to construct a Pura-type system with two 42.5 m^3 floating drums with an engine and genset and other necessary small appurtunances. It is reasonable to assume that it will take one year to construct a full system and put it in good working order. It will take one more year for the villagers to be convinced that they can themselves manage the day to day functioning of the REWSU. In 1992 prices, it takes about Rs 300,000 to establish one REWSU and about Rs.35,000 annually to operate. It is therefore feasible to plan for about 100 REWSUs within a radius of about 200 kms from Bangalore in a period of three years, at the rate of 20, 40 and 40 respectively. Bangalore is almost at the tri-junction of the states of Karnataka, Tamilnadu and Andhra Pradesh and is transport-wise easily accessible. The cost of establishing 100 REWSUs will be about US$ 1 million and the annual maintenance cost US$ 117,000 at the present exchange rate of US$ 1 = Rs 30 (US$ 1m = DM 1.6m).

8.5 The organisations required to be involved to implement this in Karnataka state for instance will include the following:

a. KSCST
b. KPC and KEB
c. Rural Development Department
d. Zilla Parishad and the Deputy Commissioner at the district level
e. Village Development Committee at the village level
f. Voluntary Organisations (NGOs) at the state or district level and Khadi & Village Industries Board (KVIB)
g. Private Sector Companies working in the area

The role of KSCST is crucial because of the technical expertise that it has gained so far. Training supervisors to construct and maintain the biogas plants is of vital importance. Indeed the success of the scheme will depend upon the perfection with which the plant is constructed and maintained. The Khadi and Village Industries Board has a vast network of organisation in rural areas. The KSCST can therefore train the KVIB personnel and the Zilla Parishad staff in construction and maintenance of the system, apart from the voluntary organisations and corporate sector companie who may also come forward to participate in the programme.

8.6 Institutional support has to come from essentially KEB and to a lesser extent from KPC. As a significant supplement to rural energy, the KEB has to treat the REWSU electricity generation as its own and the existing KEB poles for distribution have to be used to avoid duplication of investment. Apart from this, there are many other areas of close coordination between REWSU and KEB such as formal permissions, surveys, etc.

8.7 At the state level, the support and direction of the Rural Development Department is essential. At the district level the Zilla Parishad (the elected body for District Development) and the Deputy Commissioner, have to co-ordinate and assist the project. The Zilla Parishad and the Mandal Panchayt are elected bodies. Local administration in rural area vests with these institutions. Hence their active involvement is essential for the execution of the project.
The REWSU at the village should be managed by a Village Development Committee as in Pura.

8.8 Besides the Governmental and Panchayati Raj institutions, it is necessary to involve other organisations for technical help and supervision. This is because the KSCST cannot reach a large number of villages and its role should be confined to training other institutions who in turn will have to construct and help to maintain the system. Apart from the ZP and KVIB, there are many voluntary organisations and Corporate sector companies working in the rural areas. They have to be identified and wherever it is feasible for them, they should adopt certain REWSUs in their jurisdiction to construct, maintain and supervise the systems.

8.9 In the first year it is necessary not to spread the sites in different districts. One district in each of the three states may be selected and not exceeding seven villages in each district may be taken. The counterpart of KSCST in the other two states will have to be closely involved, besides the State Electricity Boards. The IEI, Bangalore has to play a crucial role in co-ordinating with the donor agency and the government.

8.10 Appendix 2 to this paper shows a chart enumerating various agencies involved, tasks and functions to be performed by each of them.

9 Donor Agency and Financing Pattern

9.1 It is proposed that GTZ be approached for the financing of the project for the equivalent of about DM 1.6 m equivalent to about US$ 1m. To cut the red tape, it is possible for the funds to be routed through the IEI which in turn can make available to the implementing agency at the district level in quarterly instalments according to progress. The GTZ can also route funds through the GOI as in all the bilateral aid programmes, but in this case the amount is small and the red tape involved is too long that it will take years to take off. The quicker and feasible alternative is to choose the IEI which can receive funds from foreign donors for such a purpose as REWSU. There is some red tape involved in the implementing agency receiving the fund from IEI but this is manageable. The project has to be fully supported for the first three years on each site after which it has to be handed over for financing and management entirely to the State, district and village level organisations jointly.

FUNDING PATTERN (IN '000 US$)

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Total**
CBPs	20	40	40				100
F/Cost$	200	400	400				1,000
R/Cost$		23.3	70	116.7	93.3	46.7	350
Total $	**200**	**423.3**	**470**	**116.7**	**93.3**	**46.7**	**1,350**

9.2 The flow of funds is suggested as follows:

[KSCST (for training)

[ZPs (for Build & Operate of CBGPs)

GTZ--> IEI--> [NGOs (do)

[CORPNS (do)

[KVIB (do)

9.3 The GTZ has a rich experience of over 15 years in biogas. It is therefore advisable that, apart from financing REWSU, GTZ is also involved in the technical planning and supervision stages. A technical person of GTZ who has experience in biogas can be stationed in KSCST for about two years to assist the programme exclusively.

9.4 It is likely that there will be some funding by the Government for certain expenditure not covered by GTZ. Such funds need not be routed through IEI and can be directly remitted to the agency concerned.

10 **Policy issues, Manpower and Training**

10.1 There is no major policy change required for implementing REWSU as establishment of community biogas plants is a programme of the Government for the past at least three decades. Nevertheless, the experience of Pura shows that, if not policy changes, certainly cooperation of state level agencies, especially the Electricity Board and the District administration is required for its implementation. Fundamentally, the approval under the Electricity Act for generation of electricity is legally required, however small the generation by each REWSU is going to be. The SEB has to approve the same and there is no real problem in giving such approval. Secondly, to avoid duplication of expenditure, the SEB has to permit use of its cement-concrete poles erected in the villages electrified by the REWSU to take the latter's electricity to the houses and streets and water supply source. This has been allowed in Pura. It has to be done in all the cases wherever the SEB poles are usable. Thirdly, more than passive permissions, the SEB has to realise that the REWSU is just a supplement to its own efforts and therefore its staff at the district and village level have to help solve many small management problems that arise in practice. The REWSU is not a rival to SEB in any sense. The more successful the REWSU the more can the SEB release its own electricity for other purposes. Such an attitudinal change has to be created at the state level by the Govt making it clear that all assistance needed by REWSU has to be given by the Electricity Board and indeed by other agencies. This can be helped by the issue of a formal order by the Govt while starting the project.

10.2 The **Manpower** needed for the establishment and maintenance of the project has to be identified. Since there are not many construction activities going on in the villages, skilled labour like masons, carpenters, electricians, etc., are not available in rural area as most of them have flocked to urban areas or given up their traditional work. Availability of manpower with even elementary skills cannot be assumed away at the village level. It has to be planned at least at the district level. Appendix 3 shows the manpower requirements to implement the Project.

10.3 Since this is a new type of work in the rural area, **Training** has to be planned and provided for the different levels of persons who are going to implement the REWSUs. With the expertise gained by it, the KSCST has to take up the training programme of prior to the commencement of the project. The cost of such training should become an integral part of the Project cost.

APPENDIX 1

ECONOMICS OF REWSU

1 CAPITAL COST:

A biogas plant of 60 m^3 digester volume capacity is nearing completion at Suggenahalli village near Pura. Hence the current capital cost of construction is available from this plant. Only, the Suggenahally digester is of 60 m^3 capacity while the REWSU is of 42.5 m3 capacity. However, basing on the cost of 60 m^3 capcity, adjustment can be made to arrive at the cost of the 42.5 m^3 digester.

The cost of Suggenahalli plant at 1992 price is as shown below:

BIOGAS PLANT + GENSET	(Rupees)
Biogas plant, Piping etc	116,799
Sand filters	6,105
Diesel Engine and Genset	48,365
Engine Room	51,936
	223,205
WATER SUPPLY SYSTEM	
Pump	25,506
Accessories	19,752
Overhead tank	15,596
Piping	46,246
	107,100
ELECTRICAL DISTRIBUTION	
Street Wiring	62,000
	62,000
	392.305

The fixed cost of Rs.392,305 is for a 60 m^3 plant. For a 442.5 m^3 plant the cost will proportionately be Rs.276,921. Allowing for some cost rise since 1992, the fixed cost can be taken to be Rs.300,000.

2 FIXED COST DURING 25 YEARS:

While the life of the biogas reactor, generator and all other items except the engine are 25 years, the life of the biogasdriven engine is only 5,000 hours after which its life can be extended by 15,000 hours with overhauling. Each overhauling extends the life of the engine by 5,000 hours and a maximum of three overhaulings are possible. Thus the life of an engine with overhauling will be 20,000 hours.

The number of replacement engines (including overhaulings) required to keep the system going for 25 years depends upon the average number of hours the system works each day. If the system works for 14.28 hours per day (corresponding to a dung delivery of 1,000 kg per day and engine capacity of 59.5%), the life of an engine (with overhauling) would be 3.837151 years (3 years and 306 days), and there must be seven engines (with overhaulings) that is, at 0 years, 3.837151 years, 7.674302 years, 11.511453 years, 15.34-8604 years, 19.185755 years and 23.022906 years to run the system for 25 years.

The engine cost (1992) is about Rs.17,000 and the cost of each overhauling is about Rs.5,000. The cost of an engine plus its three overhaulings is Rs.29,116 after discounting at 12% to the date of purchase of the engine. The present value of the 6 replacement engines (with 18 overhaulings) works out to be Rs. 49,515.75. The cost of overhaulings of the first engine is Rs.12,116.36 and the total cost is Rs.61,632.11. Since it takes 6 months to commission the engine, the PV of replacing and overhaulings at the commencement date is Rs.58,236.87 for 5 kW and therefore Rs.11,647.37 per kW.

3 RECURRING COST:

Dung: At Rs.0.02/kg, the cost of 1,000 kg dung per day for 365 days will be - Rs.0.02*1,000 kg*365 days = Rs. 7,300.

Diesel: At 0.280 litres of diesel peer engine hour and a price of Rs.7.12 per litre, the diesel cost for 14.28 hours a day for 365 days will be - Rs.7.12*0.280 litres*14.28 hours*365 days = Rs.10,391.04. The cost of engine oil is estimated at Rs.575 on the basis of Rs.115 during the period April 1991 to March 1992 for only about 4.15 hours per day. Five times of Rs.115 is provided taking into account price increase and higher consumption due to longer hours of working.

Labour: At present two daily workers are employed at Pura. For handling more than three times of dung and the plant working longer hours, four daily workers are provided at a daily wage of Rs.11 per day. The labour cost will therefore be Rs.11*4*365 = Rs.16,060.

Repairs: The repairs cost at Pura for one year is Rs.733 at present for a daily engine working hours of 4.15. For 14.28 hours per day this will be Rs.733*14.28/4.15 = Rs.2,522.

Transport: This cost is at present Rs.151 for one year at 4.15 hours of daily working. For 14.28 hours the cost is proportionately taken as R.520.

The recurring cost of all items including physical contingencies will thus be as follows:

Dung	Rs. 7,300	
Diesel	10,391	
Oil	575	
Labour	16.060	
Repairs	2,522	
Transport	520	
		37,368
	+ 5% Contingency	1,868
		Rs. 39,236

The PV of the annual payment of Rs.39,236 for 25 years which is the life of the system is Rs.307,733. The PV discounted to the commencement date (by six months) is Rs.290,781.

The total discounted capital cost to the date of commencement and recuring cost is therefore as shown below:

	For 5 kW	For 1 kW
Initial capital cost (para 1.3)	Rs.300,000	Rs.60,000
Working capital (5%) of Rs.30,000	15,000	3,000
Cost of 6 replacement engine and overhaulings (para 2.3)	58,237	11,647
Total Capital Cost	Rs.373,237	Rs.74,647
Recurring cost	290,781	58,156
Total Life-cycle Cost	Rs.664,017	132,803

To be more precise, the cost will have to be increased by the interest factor for 6 months since the plant starts operating only after six months. Taking into account the six months required for commissioning, the Life-cycle cost will therefore Rs.702,730 for the 5 kW system and Rs.140,546 for one kW.

4 UNIT COST OF ENERGY

The life-cycle cost per kW should be annuitised over the 25-year life-time of the system and should be divided by the net kilowatt-hours generated during the year, to arrive at the cost per kWh. The annuity for a PV of Rs.1140,546 at 12% for 25 years is Rs.17,919.61/kW. The gross energy generated in kWh per kW corresponding to 14.28 engine hours per day with a 4.23 kW load is 5,212.2 kWh and since there will be almost no transmission and distribution losses, a 1% auxiliary loss is assumed which gives a net energy generated of 5,160.08 kWh/kW. For a annuitised total cost of Rs.17,919.61/kW, this will give a cost of Rs.3.47 per kWh.

If we take only the recurring cost of Rs.58,156/kW (para 3.8) the annuitised cost per kWh is Rs.1.52.

APPENDIX 2

SINGLE REWSU

Function	Agency	Task
FUNDS	KSCST/VOLUNTARY ORGANISATION/KVIB/ZP/ CORPNS (Depending upon who takes the responsibility for the REWSUs)	
CONSTRUCTION	SAME AS ABOVE	
SKILLED PERSONNEL	KSCST/ZP/POLYTECHNIC/ITI/KVIB/CORPNS	
VILLAGE SUPPORT BUILD TRAIN	VILLAGE DEVELOPMENT COMMITTEE/ZP/ MANDAL PANCHAYAT/VILLAGE YOUTH CLUBS	&
GOVERNMENT SUPPORT	DEVELOPMENT COMMISSIONER/SECRETARIES OF RDP, ENERGY AND ANIMAL HUSBANDRY DEPARTMENTS/KPC/KEB	
TECHNOLOGY	KSCST	
ELECTRICITY PERMISSION	KEB	

OTHER PERMISSIONS — ZP/MANDAL PANCHAYATS/DEPUTY COMMISSIONER

FUNDS — VILLAGE DEVELOPMENT COMMITTEE AND KSCST/VOLUNTARY ORGANISATION/KVIB/ZP/ CORPNS (Depending upon who takes the responsibility for the single REWSU)

OPERATOR — SAME AS ABOVE

SKILLED PERSONNEL — KSCST/ZP/POLYTECHNIC/ITI/KVIB/CORPNS

VILLAGE MANAGEMENT — VILLAGE DEVELOPMENT COMMITTEE/ZP/ MANDAL PANCHAYAT/DEPUTY COMMISSIONER OPERATE

GOVERNMENT SUPPORT — DEVELOPMENT COMMISSIONER/SECRETARIES OF RDP, ENERGY AND ANIMAL HUSBANDRY DEPARTMENTS/KPC/KEB

TECHNOLOGY — KSCST

FUNDS — VILLAGE DEVELOPMENT COMMITTEE AND KSCST/VOLUNTARY ORGANISATION/KVIB/ZP/ CORPNS (Depending upon who takes the responsibility for the single REWSU)

OPERATOR — VILLAGE DEVELOPMENT COMMITTEE/ ENTREPRENEUR

MAINTENANCE	SAME AS ABOVE	TRANSFER
MANAGEMENT	SAME AS ABOVE	
GOVERNMENT SUPPORT	DEVELOPMENT COMMISSIONER/RDP/ DEPUTY COMMISSIONER	
MONITORING	KSCST/RDP/DEPUTY COMMISSIONER	

100 REWSUs

FUNDS	GTZ, IEI, GOVERNMENT	
TRAINING	KSCST, POLYTECHNIC	BUILD +
CONSTRUCTION	KSCST/VOLUNTARY ORGANISATION/KVIB/ZP/ CORPNS (Depending upon who takes the responsibility for the REWSUs)	TRAIN + OPERATE +
VILLAGE SUPPORT	VILLAGE DEVELOPMENT COMMITTEE/ZP/ MANDAL PANCHAYAT/VILLAGE YOUTH CLUBS	TRANSFER

R E F E R E N C E

[1]

[2] *Biogas-A Rural Energy Source,* Dept. of Non-Conventional Energy Sources, New Delhi, March 1992

[3] Prasad et al EPW 1973. Lichtman (give full reference)

[4] *Biogas Options for India - Constraints and Strategies* by N.H.Ravindranath et at, Paper presented to UNDP workshop at Bangalore in November 1992.

[5] *Rural Energy Consumption Patterns - A Field Study,* 1981, by ASTRA, Principal Investigator Amulya Kumar N.Reddy.

[6] All the details of Pura village Biogas Electricity system are from *Biogas Electricity-The Pura Village Case Study* by P.Rajabapaiah, S.Jayakumar and Amulya K.N.Reddy.

[7] *Current Energy Scene in India, May 1992,* Centre for Monitoring Indian Economy, Bombay.

[8] The information is from *A Gasifier Based Rural Power Generation System: Performance and Problems* by S.N.Srinivas, N.H.Ravindranath, S.Dasappa, U.Shrinivasa, and H.S.Mukunda of ASTRA, Indian Institute of Science, Bangalore.

[9] The collectable wet dung from the local cattle is a minimum of 4 kgs a day and for 248 cattle the dung collected is 992 kg or a rounded 1000 kg daily. 70 kg of dung is required for running the engine for one hour. With 1000 kg the engine will run for 14.28 hours daily. Assuming the maximum load of the 7 hp engine at 4.23 kW, the electricity generated per day is 14.28 engine hours * 4.23 kW = 60.40 44 kWh/day and for the year 60.4044 * 365 = 22,047 kWh or a round 22,000 kWh.

[10] *Improving Efficiency of Agricultural Pumping Systems for Energy Conservation,* by Operations Research Group, Baroda, 1992 (p 34)

[11] Teri Energy Data Directory & Yearbook 1990 -91, p 107.

[12] In 1986-87 the forest area in Karnataka was 3,864,564 ha against the geographical area of 19,049,436 ha (20.29%) and the forest area lost from 1956 to 1986 -87 for various reasons and purpusses was 209,913 ha (5.15% of 1956 forest area) as shown below;

1	Hydro-electric purpose	22,194 ha	10.88 %
2	Electricity lines	1,688	0.83
3	Roads	330	0.16
4	Irrigation tanks	35,840	17.58
5	Townships	1,791	0.88
6	Mining	42,676	20.93
7	Agriculture	67,217	32.96
8	Rehabilitation	25,820	12.66
9	Other purposes	6,357	3.12
		203,913	100

Source: Statistical Brochure, 1987, Karnataka Forest Department.

[13] *Report on Perspective of National Power Development upto the end of 10th Plan (2006-07),* Central Electricity Authority, October 1991.

[14] *Far Eastern Economic Review,* 1 August 1991, p 50