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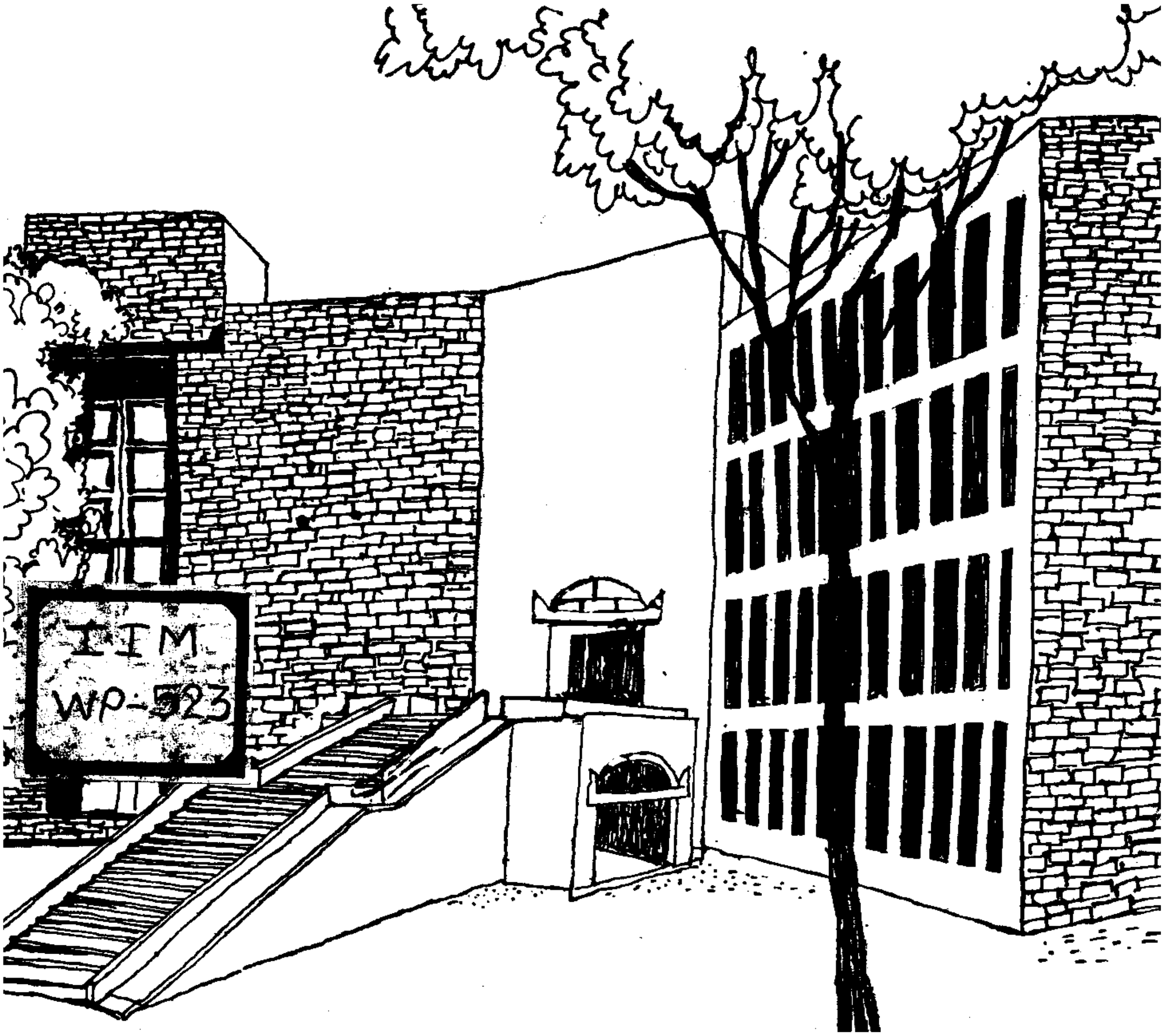

INTEGRATED ENERGY SYSTEM : SOME CASE STUDIES ON FOOD ENERGY NEXUS IN INDIA

By

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Introduction

Directly or indirectly, the whole process of food production, processing, and ultimate consumption is positively related to energy input. In fact, the most critical element in the whole food production chain has been the energy flow from the sun through a most enduring and ubiquitous energy factory - photosynthesis. The use of modern energy inputs in the food production system in the form of fertilizer, pesticides, irrigation and fuels for farm machineries are simply to increase the storage of solar energy through photosynthesis.

The staggering potentiality of biomass as energy sources, can be understood from an account given by Russell Peterson (1978):

> "In a single day the sun sends more energy to earth than the world consumes in an entire year. Although plants capture only 1 per cent or less of that energy, they store some 20 times as much energy in a year as the world uses. It has been estimated that, used efficiently, 10 per cent of the world's current yearly production of biomass could readily meet the entire projected year 2000 requirements for food and energy. Biomass remains the main source of fuel for half the world's people".

Important as it is, however, the energy input into food production system in terms of sources, intensity and efficiency very between countries and communities depending on cultural traditions, industrialization/modernization, available resource endowment. In USA, for example, "biomass accounts for about 2 per cent of the total annual energy consumption, which is equivalent to all the hydroelectric power delivered annually by that vast network of reservoirs, dams and hydroelectric plants, all across the country. It is equivalent to about 7 per cent of imported oil and about 65 per cent of the heat released by nuclear fission to generate electricity in the country" (Peterson 1978).

Similarly, the intensive use of organic manure in agriculture in China through recovery and re-use of biomass residue, is well known. Elsewhere it was observed by the present author (Moulik:1982) that the average input of biomass manure per hectare of cultivated land in 50 odd communes spread over 6 provinces in China was 13 times more than the amount applied by the progressive Ludhiana farmers of Punjab. It was estimated that through organized collection and scientific conservation China used 22.9 MT of organic fertilizers in 1980-81, which was over 4 times of India's total fertilizer consumption in the same year. The massive use of organic fertilizers derived from biomass by the Chinese farmers has its impact on food production. Agricultural productivity per hectare of cultivable land in China is almost 3 times more than in India. In 1980-81, for example, China produced about 300 million tonnes of food-grains from 100 million hectares of cultivable land as against India's 131.5 million tonnes of food-grains out of 145 million hectares.

The point I am driving at is not merely to show the relationship between energy input and food production which is a common knowledge, what needs to be emphasized is the potentiality of biomass energy and its varying levels of underutilization or misutilization in different communities or countries. As Shacklady (1978) reported, "the greatest degree of hunger and the greatest accumulation of organic residues both occur in the developing countries". At global level it was estimated that 40 per cent of roots and tubers, 60 per cent of grain crop, 85 per cent of oilseed crop and 90 per cent of sugar crop could be regarded as residues. In addition, there is the enormous quantity of manure from the world's 9500 million heads of domesticated livestock of all types.

As mentioned above, the levels of under- or mis-utilization of this enormous biomass energy sources for the food production system vary between countries depending or influenced by various endo- or exogenous factors. India, for example, utilizes merely 15-20 per cent of 260 MT cattle dung manure for necessary energy input into agriculture and the rest is either wasted or burnt as energy-inefficient fuel. What is, however, important to note here is the fact that while earlier it had been possible to strike an equilibrium in terms of food production and energy input nexus by a community or a country within a particular geographical area limit, eventhough at a low-productivity and often at a serious environmental cost, it is not possible any more.

The equilibrium which every community in a geographical area has been striving to achieve or has already been achieved within the technological and available resource constraints, is now seriously disturbed by a host of internal and external factors. The factors responsible for such disturbances are: increase in population resulting unfavourable land-man ratio; overuse of natural resources, such as, land and forest without replenishment; complete monetisation of economy and increased poverty with concommitant decrease in purchasing power etc. The disturbance has been further aggravated by the modernist onslaught of industrialization and technological progress based on cheap fossil fuel as energy sources. This process essentially replaced or modified the bioresources with manufactured and synthetic non-renewables and made people increasingly dependent on non-renewable external energy sources for the food production. In India, for example, there has been progressive declining trend in biomass energy use over the decades - from 67 per cent in 1953-54 to 40 per cent in 1980 - with increasing dependence on external energy source from costly fossil fuel. Ultimately, the energy crisis of 70's made the balance in the process of equilibrium in food-energy nexus totally unmanageable and hazardous, particularly for the resource poor developing countries in the Third World.

The result of this disequilibrium is not only a severe deterioration of the natural environment, but also hunger and poverty, dependence and other socio-political imbalances, such as, concentration of wealth. It is in this context of despair and imbalance that the role of bioenergy in restoring the balance of food-energy nexus in India needs to be examined.

India's Food Energy Nexus: Alternative Scenario

The increasing population pressure on land has made it an immediate necessity for India to modernize agriculture in order to increase productivity per unit of land. This is required not only to increase the per capita level of food consumption but also to even maintain the present level of consumption. Our national average of 14 qtl/ha grain production is one of the lowest in the world, way below the world average of 20 qtl/ha. The increased level agricultural productivity can be achieved by adopting improved package of practices for crop production involving HYV seeds, increased fertilizer application along with plant protection measures, providing irrigation and using efficient agronomic practices and farm machineries.

Modern agriculture is becoming increasingly energy-intensive. FAO (1981), for example, reports that each 1 per cent growth in output requires 2.4 per cent growth in energy use. Recent studies by the Indian Agricultural Research Institute, Delhi indicated that wheat production in an area with modern intensive agricultural practices was about 3960 kg/ha with straw yield of 2700 kgs/ha as compared to 1200 kgs/ha and 2000 kgs/ha respectively under non-intensive traditional agricultural system. The corresponding energy inputs in high intensive agriculture was 23,353.70 MJ/ha, while for non-intensive agriculture it was only 6338 MJ/ha. It was also shown that the energy input-output ratio was relatively more favourable in the case of non-energy intensive agriculture. But the fact remains that the input of energy is the key factor in increasing productivity.

The nature and extent of energy input required for increasing India's agricultural productivity can be understood if we examine the future demand of foodgrains. Assuming the total demand for foodgrains in India in 2000 AD as 220-225 million tonnes, as projected by the National Commission on Agriculture, it is possible to achieve this target by raising the total consumption of chemical fertilizers to 10 mt., gross cropped area to 150 m. ha; gross area under HYV to 90 m. ha. and gross irrigated area to 66 m. ha. For meeting this target, the total input requirements would mean an investment of the order of about Rs 4068 crores at 1979-80 prices as annual working capital and an annual investment of about Rs 9,489 crores on irrigation development, soil and water conservation, tractorization etc. This is a financial investment not within each reach for a country like India.

Let us take a different scenario of India's food production. Sinha and Swaminathan (1979) has worked out the absolute potential of Indian agriculture to 4572 mt of grain equivalent - 35 times the present production. This latent capability was calculated on the basis of "photosynthetically Active Radiation" available per day and the yields of 40.4 tonnes/ha in just one season only. Only 40 per cent of the total biomass as the edible grains was assumed in the calculations. In order to reach this potentiality, the cropping intensity should be raised to 400 per cent from the present 120 per cent. Assuming that only 10 per cent of 4572 m.t. is achievable feasibility in 2000 AD., the total energy requirement for irrigation, manufacturing agricultural machinery and fertilizer would be around 68 m.t. of fossil fuel. This is again a colossal amount of energy input.

Meeting these energy needs for higher food production from fossil fuel source would not only be difficult for India, but also unbearably costly. In fact, it has been estimated that the crude bill of Rs 5500 crores in 1980-81 may shoot upto Rs 50,000 crores by 2000 AD. if the present trend of fuel use and crude price increase continue. With every single dollar increase in the price of the crude, India has to pay an extra Rs 100 crores.

The dependence on fossil fuel as necessary energy input sources is not only unbearably costly for India, but also it prevents spread of modernization amongst all classes and regions. For, of 81 million holdings in the country, as many as 60 million are small and marginal holdings with a per capita income of Rs 2 per day. Since over 70 per cent of their budget is expended on just foodgrains, they have hardly any purchasing power left to buy necessary energy inputs and more so due to ever-rising high costs of energy. To this vast majority, energy means freely-gathered wood, farm and animal wastes. But now even these poor man's fuels are increasingly becoming scarce and commercial, not to speak of grave ecological damage. The Fuelwood Study Committee of the Planning Commission (1982), for example, had projected the firewood shortages of 100 million tonnes by the year 2000 AD. The scarcity of fuelwood forces them to resort to burning of cattledung and crop-wastes, which are not only energy-inefficient uses but also deprives the soil of its natural organic food. Consequently, the whole food production system for this large majority is characterized by low-productivity and low-energy input syndrome.

The foregoing analysis clearly indicates that unless the food-energy chain is harnessed and strengthened by some alternative sources of energy input other than fossil fuel, it would be difficult, if not impossible, for India to get out of the low productivity syndrome. The alternatives which are being seriously discussed and promoted is a <u>decentralized energy system</u> based primarily on biomass energy sources. Essentially this means harnessing of local resources of renewable energy such as biomass, solar energy, wind energy, small hydro-energy etc., which are indigenously available, easily affordable and environmentally sound energy sources. Such decentralized energy system is not only an additional source of energy, but also promote a largely self-reliant and self-sustaining development with greater local control and participation.

There are several possibilities and potentialities claimed by various authors about an alternative energy scenario based on bioenergy exploitation. Dayal (1980), for example, claimed that almost 100 per cent of the commercial energy (fossil fuel) consumption in rural India could be replaced by bioenergy sources. Dayal (1984) also elaborated these possibilities subsequently in which it was shown that 1000 hectares of energy plantation with fast-growing varieties of trees having a rotation cycle of 4 years could easily support 3 MW of power apart from providing the fuel wood or charcoal needs of population of 125 or 150 families. He also indicated that if only 1/5th of India's million hectares of barren or waste lands could be covered by the combined energy plantation and gasifier power project, it could support a generation capacity of 48,000 MW from dispersed decentralized sources to meet local power and fuelwood requirements. This capacity is considerably more than the entire installed power capacity in the whole country in 1983-84.

But a still more interesting bioenergy based scenario is formulated by Paul (1981). Taking fertilizer and irrigation as the major energy inputs for modernization of India's agriculture, he worked out an energy balance-sheet for 2000 AD exclusively with bioenergy sources. Given the total energy demand projected for 2000 AD and the available internal capacity for the supply of fossil fuel based energy, he worked out a plan for 37.80 million tonnes of fossil fuel equivalent of bioenergy input as alternate fuels (See Table 1).

Table 1: Energy Balance Sheet for 37.80 mt of Bioenergy Based Alternate Fuel for Modernization of India's Agriculture in 2000 AD

Items	Resource	Energy Input (in mt)
1 <u>Fertilizer</u>		
(i) Biogas Plants Slurry (composting)	At 75% collection basis, 250 million cattle population would yield 260 mt manure (slurry) with N content of 3.9 mt, when processed through 1 million biogas plants. By composting this biogas slurry, the biogas manure would yield 1 tonne of extra nitrogenous fertilizer.	4.9
(ii) Additional Nitrogen from organic wastes, sewage sludge and Bio-dung etc.	500 mt of organic and cellulosic residues available in the country in 1980 would yield 2.0 mt nitrogen biofertilizers. This is apart from cattle urine of 658.90 mt yielding 1.22 mt of P_2O_5 and 2.06 mt of potash.	2.0
(iii) Through Nitrogen fixation and green manuring	About 20 million hectares of waste land planted with suitable trees and crops (Subabul etc.) would yield 1 mt of nitrogenous biofertilizers.	1.0

(Table contd...)

Table (contd.)

Items	Resource	Energy Input(in mt)
(iv) Algae Sources	Blue Green Algae and Azolla for 40 million hectares of paddy cultivation would yield 1.4 mt. nitrogen biofertilizers.	1.4
(v) Water Hyacinth	Composting of 0.5 million hectares of water hyacinth yielding 4 mt biofertilizers (nitrogenous)	4.0
	SUB TOTAL	13.3
2 Irrigation		
(i) Biogas Fuel for Dual-Fuel engines	0.5 million large size community biogas plants would yield 25,550 m^3 gas, equivalent to 12.689 mt of diesel per annum. (If added organic wastes and night soil, gas production would be substantially higher)	12.68 (+ 6 to 8 if organic waste used)
(ii) Power Alcohols		
a) Ethanol	3 million hectares of waste land under tapioca	5.00
b) Methanol/ Producer Gas	10 million hectares of energy forest yielding 150-200 mt. of wood per annum.	3.00 (+5.0 if high density plantation)
	SUB TOTAL	20.68(+8-10)
	TOTAL (1+2)	33.98(+8-10)

The alternative scenario as outlined above is not a mere wishful thinking but a possible action programme in reality. In fact Paul claimed that with suitable and necessary modifications, this bioenergy based alternative plan could effectively stem the existing negative synergism of food-energy nexus within a decade or two.

The enthusiasm about the potentiality of harnessing bioenergy in the food-energy nexus is increasingly shared by many. Fired with enthusiasm and also by virtue of necessity, many developing countries including India have launched major programmes in this direction. Some renewable energy technologies like biogas and windmill are becoming popular and widespread in several countries.

There is, however, a wide difference between the potentialities and actual exploitation. There are uncertainties in technologies and imponderables in terms of organizational and other socio-economic factors. What follows next in the paper is a number of detailed case studies in which bioenergy has played its role successfully in augmenting the food-energy nexus at micro level in India.

Case Studies

A A BIOENERGY INTERVENTION THROUGH WASTE RECYCLING

A successful experiment with waste recycling in the National Dairy Research Institute (NDRI), Aarey Colony, Bombay, has been an eye-opener for many in India. It started as early as in 1967, seven years before the energy crisis. The successful intervention in the food-energy nexus in the NDRI farm has become a very well-known fact not only in India but internationally as well.

What the experiment at NDRI had done was not establishing a new scientific knowledge, - the use of waste recycling process in the food-energy nexus being a known process at the time, - but a practical demonstration of its multiplier effects in a sufficiently large field operations. It was in many ways a new activity in India with far reaching implications.

The fact that NDRI farm in Bombay was an organized institutional system perhaps made it easier to conduct the experiment. But this should not take away the credit from Mr Paul, the newly appointed Head of the Institute in 1967. For, like NDRI, Bombay, there were many such organized Institutes spread all over the country. Neither, was the process of waste recycling and its use in food-energy pivot unknown. Thus, the whole credit for the experiment in NDRI, Bombay, must be given to Mr. Paul, who seized the opportunity and implemented the programme.

When Mr Paul joined NDRI in 1967, there were 75 cows including young calves. Immediately on joining, Mr Paul made two critical observations: <u>first</u>, all the solid wastes of the attached farm were being dumped and liquid wastes were drained away to the adjoining hilly jungle; second, inspite of the small number of the herd and sufficient land available, the Institute had been buying fodder from outside to meet the requirements.

Accordingly, Mr Paul took two immediate actions towards waste management. A compost pit was dug where all the cowdung and other solid wastes were filled in daily. Secondly, one hectare of hilly land lying on both sides of the cowshed was planned to be developed for fodder cultivation by utilizing urine and waste water from the cowshed.

But these were neither adequate nor permanent measures for total waste management for the Institute. One compost pit was not enough for the daily output of the solid waste. Given the retention time for composting, very soon the daily waste output had to be stored somewhere before the pit was empty to take fresh input. On the other hand, development of the hilly land would require regular irrigation and sufficient manure input for growing fodder. Fortunately for Mr Paul, before he faced the inadequacy of the measures, the Khadi and Village Industries Commission (KVIC) contacted him for setting up a demonstration biogas (cowdung gas) plant at NDRI.

KVIC was then the sole implementing agency of biogas programme in India. It had a scheme to set up large size institutional plant on 50 per cent grant and 50 per cent loan basis. Mr Paul could immediately see the usefulness of the biogas system in his scheme of waste management. Having perceived the economic benefits, he was ready to bear 50 per cent of set-up cost of the biogas plant from the Institute account itself instead of taking loan. However, Mr Paul was not very sure himself about the rate of gas production, particularly, during the heavy monsoon period of June-August. He was perhaps somewhat skeptical about gas production in view of the conspicuous failure of a big biogas plant built in the same area by the Central Government with Hungarian technical collaboration. He was, therefore, more keen to ensure continuous working of the biogas plant as a compost plant even if it failed in gas generation. Accordingly, he made some changes in the design, which was accepted by the KVIC. It took about 4-5 months to set up the biogas plant which was commissioned by April 1968.

By the time the biogas plant started operating, it soon became necessary to dig two more compost pits to ensure full utilization of the waste. All the fodder waste from the cowshed and slurry from the gas plant were put into the three compost pits in continuous operations.

Simultaneously, land development operations on 1 hectare hilly land were undertaken. The boulders and stones from the hilly land were used for terracing the slopes, building 3 sedimentation tanks, one water-reservoir, permanent water-channels connecting the land with the cowshed, and compound walls, pump house and toilets in the NDRI premises.

Having completed the waste water collection system, a sprinkler irrigation system operated mainly by the dual-fuel biogas engine was installed. Apart from water, the liquid slurry from the compost pits were used in the sprinkler irrigation system, which was operated for 6-8 hours per day for six days in a week. Gas generated from the biogas plant was also used for lighting the cowsheds, heating the laboratory and canteen uses.

Thus, the biogas plant completed the process of waste recycling in NDRI by not only providing energy for running the irrigation pump but also by producing enriched organic fertilizers. Compost was liberally applied to the terraced plots of the newly developed land. Hybrid Napier and Guinea grasses were planted. The first harvest of grass after 50-60 days was poor, which improved substantially with subsequent cuttings. In fact, the yield of fodder grasses had been continued to be remarkably high since the waste recycling process started.

The yield of hybrid Napier grass, for example, was between 179.3 and 272.7 tonnes per acre per annum, while the comparable yield of Guinea grass was between 126.5 and 201.8 tonnes. However, due to better palatability and nutritive values of Guinea grass, it was planted in alternate rows, along with Napier grass. Even in this mixed system, the per acre yield was about 148-150 tonnes in 12 cuttings in a year. This was reported to be much higher average yield under Indian conditions. In fact, it was earlier estimated that under liberal manuring, irrigation and better soil condition, as much as 100 tonnes per acre yield could be obtained. The fact that NDRI soil condition was relatively poorer than the average grass land, the yield of 148-150 tonnes per acre was a spectacular achievement, indicating the potential of organic recycling in food production system. Not only was it possible to increase the asset base of fodder land by land development of hilly plots, but also it made NDRI more than self-sufficient in fodder requirements for its cattle herd of 100.

What was still more interesting was the extension of the use of biomass energy utilization through the waste processing system beyond fodder production. For the first time, NDRI started raising various fruit trees, fuel-wood trees and flower in its farm. This was possible due to irrigation facilities and available compost manure. NDRI even started feeding the old chicks and month-old male calves with dry compost, which saved the feeding cost considerably. However, since these feeding practices were not authorized on Government farms, the results could not be propagated.

Apart from the food production system, the whole waste recycling process in NDRI had a conspicuous impact on the immediate environment. Since all the wastes were fully utilized through a digestion process in biogas system, the place became almost free from the menace of flies and mosquitoes.

It was interesting to note that the whole developmental process stimulated by the waste recycling by biogas system continued uninterrupted for 10 years without any problem. After about 10 years, the gasholder developed leakages due to corrosion, which reduced the gas collection rate. But the amount of gas generated was still enough for laboratory demonstration and canteen use. The waste recycling system, however, remained undamaged and operational.

Meanwhile, Mr Paul left and joined the National Institute of Waste Recycling Technology, Bombay, - a befitting reward for his dynamism and initiative. The potentiality of harnessing a self-reliant food-energy nexus through locally available biomass energy system had been aptly demonstrated in NDRI not only for increasing food productivity but also for stimulating a host of multiplier economic and environmental benefits. The scale of the experiment and its sustained operations for a long period was sufficient to generate ripple of demonstration effects.

That the system developed problems in terms of gas leakages after 10 long years of field operations was hardly a negative factor. For, if desired, the whole system could have been revived at a minimum cost and efforts at any point of time. What intrigues us most is the fact that inspite of such a positive demonstration at NDRI, no commensurating demonstration effects had followed even in organized institutional sectors. It took the 'energy crisis' of 1970's to recount the experience of NDRI and revive the interest. We, the human beings, tend to learn in hard way.

8 ENERGY FROM BIOMASS WASTE : A CASE FOR URBAN ECODEVELOPMENT

The problem of urban waste disposal, particularly, night soil has been one of the serious sanitation and health problems in Indian cities. It is equally, if not more, distressing to see the scavengers, carrying night soil on head or in trollies on the main roads of Indian cities, - the scavengers who are commonly known as 'Bhangi', one of the poorest and lowest untouchable castes in India.

A recent UNDP survey of 800,000 households in 110 towns in India indicated that only 23 per cent of the households had the facility of flush latrines, while 29 per cent used dry pits or bucket privies and 8 per cent defecate in the open. Even in the Delhi Metropolitan Area (DMA) - often claimed as the best cared for urban centre in India - about 1.5 million people were reported to be served by dry pit latrines and bucket privies, while half a million households i.e. 3 million people defecate in the open. This means that of the 7.1 million population of DMA, only a third had the sanitary latrine facilities, resulting serious unhygienic conditions for the whole population in the urban centre.

One of the conventional solutions for the immense problem as mentioned above is the well-known water-borne sewerage systems. Apart from the associated management problems, the sewerage system apparently requires enormous capital investment. To illustrate, to cover 77 per cent of the country's present urban population of 160 million with water-borne sewerage system would cost about Rs 20,000 crores.

In fact, it is this enormous cost of water-borne sewerage system which compelled the Indian government and various international agencies to look for an effective but less costly alternative. The alternative which has been recommended and is being implemented is a simpler water-sealed handflush privy. According to UNDP survey mentioned above, a hundred per cent coverage of the urban areas in India with handflush privy was estimated to cost only Rs 4315 crores. Not only the handflush privy system would be simpler and less costly, but would also save the 'Bhangis' from their sub-human and unhygienic occupation.

Realising the potentialities of the handflush privy system, the Government of India launched a programme of popularizing the handflush privy system integrated with the 'Bhangi Mukti' (Saving the Scavengers) programme. The case of Sulabh International of Patna, Bihar - a voluntary organization created by Mr. B. Pathak - as discussed below is an innovative and active response to the Government's Integrated 'Bhangi Mukti' programme.

Mr Pathak, a frustrated unemployed Sociology graduate joined the Gandhi Centenary Celebration Committee of Bihar as "Pracharak" (propagator) in 1967. He was assigned to the 'Bhangi Mukti Cell' of the Centenary Committee - the work dear to Gandhi's heart. However, he was not contented with simply preaching. He wanted the Cell to undertake the actual implementation of the programme by converting the existing practice to handflush privies. The 'Bhangi Mukti Cell' was not responsive to his ideas and enthusiasm. Mr. Pathak had to leave the Cell very soon.

In 1970, at the suggestion of a Bihar Minister, Mr Pathak set up a voluntary organization called the Sulabh Shauchalaya Sansthan, presently known as Sulabh International, in order to implement the government's scheme of 'Bhangi Mukti' programme. Meanwhile, Mr Pathak also designed a handflush latrine system popularly known as Sulabh Shauchalaya.

The Sulabh Shauchalaya as designed by Mr Pathak is nothing but a commonly known handflush waterseal pit privy. As Mr Pathak claims, it was not his invention. What he, however, did was changing the design suited to the habits of the people in the area. Basically, it is a pan on the waterseal connected to two storage tanks or pits. It is claimed that "each tank can serve a family of 5 for a period of 5 years. Two years after the closure of the first pit, the manure can be taken out preferably in summer season for reuse of the pit. In this way, the pits can remain in use by turn for a period of 100 years" (Pathak, 1981).

Sulabh International markets the above mentioned watersealed handflush privy and it has been doing it with spectacular success. Apart from the government encouragement and support, what has made this voluntary organization spectacularly successful is its decision to provide not only the hardware but also the software service facilities. The 5-year guarantee, prompt repair and maintenance facilities, assistance in processing bank loan applications of the private households, readiness to remove manure from the pits at a nominal service charge in case the households are unwilling to do it and most importantly, a close monitoring and review of the performances, are some of the innovative software marketing strategies which made a difference for Sulabh International. Its success appears still more glaring in contrast to the progress made by the regular government programme assisted by UNDP and the World Bank, which according to the official report has been facing serious problems.

Sulabh's success can be seen from the fact that in less than 10 years time it has built more than 300,000 privies in various urban centres in India. In Bihar, the place of its origin, it has largely eliminated scavenging and public defecation in 8 medium-sized towns. Propelled by its success, it has been expanding its area of operations in many more cities/towns in India including Calcutta and in other South East Asian countries. In money terms, from Rs 3 crore business in 1982, it did Rs 12 crore business in 1983. Sulabh has been earning by doing without imposing financial burden to the Government's exchequer.

But a more striking innovation of Sulabh in urban ecodevelopment has been in the installation and management of watersealed community latrines in a number of towns and cities in India. Almost all the cities and towns in India have some public latrine facilities built by the town authorities. Unfortunately, the way these public facilities are managed keeps the users away. The utter lack of cleanliness in most of these public facilities in Indian cities is proverbial. Sulabh International has shown a programme by which these facilities could not only be managed efficiently to attract users of all classes and caste/religious groups, but also the management could pay for itself.

Sulabh's experiment with community latrines in urban areas started in 1973, when the Bihar government asked it to build a set of public latrines at Gandhi maidan in Patna - one of the filthiest spots in one of the dirtiest urban centres in India - in order to prevent open defecation. Sulabh got it built in record time. But it soon realized that the problem of public latrines was not merely in creating facilities, but more important was its maintenance in order to make the users use the facilities. As innovative as it has been in marketing its handflush latrines to private household users, Sulabh started charging 10 paise per user (later increased to 20 paise) for the use of latrines. With this small levy, it not only could maintain manpower to manage the system properly by keeping it consistently clean, but could provide also soap, water and even water facilities for free bath to the users - a facility unheard of in India. The mere fact that the latrine system is kept consistently clean along with other hygienic facilities made even the poor people willing to pay the small levy ungrudgingly. Sulabh, however, graciously decided not to charge those who could not pay but needed urgently the facility. It also permitted the children and women to use the facilities free of charge.

The success of Sulabh's self-sustaining management of the community latrine system attracted Government's attention immediately. It has been offered to extend its activities to other community latrines not only in Patna but also in many other cities/towns in India. The impact of Sulabh's management of the public latrine system has been so conspicuous that the Patna city dwellers seem to have forgotten that a few years earlier they had to keep their nose closed while passing through Gandhi Maidan - a place notoriously used for open defecation.

But Sulabh could not remain contented with this spate of success. Neither was it full utilization of the potentialities of night soil recycling in urban centres. Sulabh's striking innovation in influencing urban ecosystem came through its experiment in integrating biogas technology with community latrines. The experiment with biogas system started in 1977 in one of its community latrines at Adalatganj, Patna city.

The community latrine system at Adalatganj, Patna city under Sulabh's management have 46 privies. In 1977, Mr. Pathak first got a floating dome biogas plant connected with the latrine system. The gas from this biogas plant were mainly used for cooking by the employees within the latrine complex and for lighting the complex. The slurry from the biogas plant was discharged to the pits to be removed after being dried as compost.

Subsequently, Sulabh got 2 more fixed dome biogas plants installed at Adalatganj community latrine complex at a cost of Rs 80-85,000. It was necessary to increase the capacity of the biogas system, firstly, due to some problems in the first floating dome plant and secondly, in order to digest the increasing night soil input from the latrines. By 1983, the daily number of users of the Adalatganj latrine complex rose to an average of 2500. At the rate of 100 gms of night soil per person, the total feedstock input in the biogas system was about 250 kgs. per day, which ultimately gave an output of about 8 tonnes of rich biomass manure.

At the time of this reporting, about two-third of 2500 daily users were reported to pay 20 paise levy, generating a daily income of Rs 350.

This was more than sufficient to meet the staff costs (9 people were employed) and other infrastructural costs like providing soaps, free bathing facilities etc.

Till 1982-83, Sulabh did not give any serious thought about proper utilization of the slurry manure and biogas as well. However, Mr.Pathak was reported to use the slurry manure in his 1.25 acres plot of land at the rate of 1 tonne per acre and had been producing a variety of vegetables with net income of Rs 2800 per acre per annum.

Since there was a general resistance for using the gas from night soil for cooking, 4800 cft. of gas generated was mostly used as demonstration for lighting the Adalatganj latrine complex and for preparing tea at the complex. It became necessary to find a more meaningful alternative use. Ultimately in 1983 with an investment of Rs 1 lakh, a dual-fuel generator was installed for electricity generation, which produced 280 units of power per night with 33 per cent conversion efficiency. The experiment was revolutionary in the sense that it was for the first time in India electricity has been generated from night soil through a community latrine system in such a scale.

Initially, the electricity so generated was used to light up the latrine complex. By December 1983, the electricity was used for street lighting on one of the main roads of Patna. There were 34 poles each with two mercury bulbs of 125 watts. The effect of street lighting by "Sulabh Urja" (Cheap energy) has been so conspicuous in Patna - a city with severe problems of power failures - that Sulabh International became a household name overnight.

Unlike NDRI, Bombay in the first case, Sulabh's experiment in Adalatganj, Patna, attracted immediate Government's attention at the highest level. Severe energy crisis and the meance of frequent power failures were perhaps the reasons for this new awakening and attention among the public and government policy makers. Be that as it may, Mr Pathak of Sulabh International has been asked to extend his programme to other community latrine systems not only in Patna city, but to other towns/cities in India also with government support.

While the demonstration effects of electricity generation from night soil have been conspicuous, the potentialities of biomanure in urban ecodevelopment has not yet been fully appreciated. Sulabh has started distributing its 8 tonnes of annual output of biomanure from its Adalatganj latrine complex to the city dwellers of Patna. Most of these biomanures are used in the vegetable and in some cases even for grain production in the household compounds. At the rate of 1 tonne per acre, as used by Mr. Pathak in his own garden, 8 tonnes of biomanure could make 8 acres of land generate a net income of Rs 22,400 per annum in terms of vegetable production. Many of the households using the biomanure have to become self-sufficient in their own vegetable requirements.

Adalatganj is a small experiment. It is not difficult to see the potentialities and social implications of the experiment when the same is extended to all the public latrine system in a city/town. Not only the electricity output would then be in a larger scale, but its impact on the food production chain within the urban centres could be enhanced menifold by using biomanure. Even the green belt of urban centres could be expanded and maintained with the use of biomanure. Apart from hygienic and social impact of 'Bhangi Mukti', the expanded version of Sulabh's experiment in Adalatganj could easily be integrated with various income and employment generating activities in a city/town.

Sulabh International has demonstrated in practice the wealth of urban waste, the human excreta. To the extent that Sulabh's experiment in Adalatganj, Patna has been paying for itself also indicates its economic viability in the sense that it reduces the burden of government's sanitation programme in urban centres with concomitant development of food-energy nexus in urban ecosystem.

C A WINDMILL THAT CHANGED THE LOT OF A SMALL FARMER

Bahri Yadav is a 45-year old farmer of Deokali village in Ghazipur district, UP. Bahri lives in a joint family with his adult brother and their mother. Besides two male and three female (wives and mother) adults in the family, the household have 5 school-going children.

Bahri Yadav's is a typical small farmer household of a backward district of UP owning 4 acres of land and 4 cattle (2 bullocks, 1 cow and a calf). There was no water source in their land which was, in fact, a dry land of poor soil quality. With this meagre resource base, Yadav family has been merely eking out their livelihood by cultivating their 4 acre land depending solely on the nature's grace. The main crops were paddy and bajra (sorghum) in Kharif (rainy season) with average yield of 2.5 qtls/acre of paddy and 2 qtls/acre of bajra. The yield was apparently extremely poor. In the rabi (winter season) Yadavs would grow wheat depending solely on rains. Wheat yield varied between 1.5 to 4 qtls/acre depending on rainfall. Once in every third year wheat crop failed completely. Without irrigation facilities, Yadavs could not cultivate any summer crop.

Farming being the only source of income, the dryland cultivation of Yadav family could hardly meet their subsistence needs. In fact, their economic situation had worsened so much that since 1975 there were serious attempts made by the family to migrate a part of the family in some urban centres. Yadavs had been searching for a job in the nearby towns without any success.

It was in this desperate situation, a bioenergy source of windmill had turned the fate of Yadav family drastically. A voluntary organisation named Labour Organization for Rural Poor (LORP) in Gazipur had started a windmill testing programme in collaboration with a Dutch agency (TOOL). It was a simple windmill of Dutch design costing about Rs 10,000. In 1981, the TOOL-LORP team selected Yadav's farm as one of the possible windmill testing sites.

It was interesting to note that Yadav's farm was selected in spite of the fact that there was no water source in the farm. However, Yadav fulfilled other criteria for selection, such as, absence of wind obstacles at the site, closeness to the road and Yadav's willingness to cooperate, in the experiment.

A 4-inch borewell was sunk in Yadav's farm in October 1981 on which the windmill was installed in November 1981. The LORP officials helped Yadav in getting 33 per cent subsidy for the whole project from the Small Farmers' Development Agency (SFDA). An earthen water storage tank of 0.1 hectare was constructed in February 1982.

Having installed the windmill Yadavs applied pyrite in the farm for soil improvement and changed the cropping pattern completely. Firstly, in the 2-acre paddy field Yadavs started cultivating improved high yielding varieties, which from second year onwards gave an average yield of 7 qtls/acre as compared to 2.5 qtls/acre earlier. This was more than sufficient for meeting the staple food need of the family. In fact, a small part of paddy output became even marketable surplus fetching some cash income to the family.

Since November-January are low-wind velocity months, Yadavs found the windmill energy not adequate for wheat cultivation. Instead, in 1983 he started experimenting with sugarcane cultivation in 0.63 acres, partly in response to the ready market in a nearby sugar factory. However, the yield of sugarcane obtained was not very good, although it fetched Rs 400 as cash income to the family in the first year.

But, what made Yadav augmenting the food-energy nexus in the farm was his decision to cultivate a variety of vegetables (chilli, potato, peas, onion and other mixed vegetables) all the year round. With 2.73 acres of land under vegetable cultivation, Yadav family started earning a net annual income of Rs 3049, apart from meeting their own family requirements of vegetables.

Besides agriculture, Yadavs had been keenly interested in rearing fish in the storage tank from the very beginning of the project. With the adoption of scientific method of fish rearing, 0.1 hectare of water area in the tank yielded a net annual income of Rs 436.

Thus, a simple bioenergy input in the form of windmill in Yadav's farm has augmented the food productivity and family income substantially. In money terms, the total net income (annual) of Yadav family has been raised to Rs 3885 as compared to less than subsistence income of Rs 1000 before the bioenergy intervention. It should be noted that the net annual income of Rs 3885 was excluding the family's subsistence need of staple food paddy, vegetables, fish and the cash income from the marketable surplus of paddy.

with the augmented food-energy pivot, the small farmer Yadav seemed to be fairly confident that there was no necessity to migrate to urban centres. At least, the family was no more threatened with the spectre of hunger and poverty.

D INTEGRATED BIOENERGY SYSTEM : THE ULTIMATE ALTERNATIVE

The three cases discussed above are some examples of successes in harnessing bioenergy resources. They only indicate the potentialities of bioenergy sources in augmenting food-energy nexus. Obviously, these are not the only examples. In a country as vast as India and with almost a decade of major efforts in promoting various renewable energy technologies in the country, it is not difficult to identify a good number of such success stories as described in the case studies. The case of biogas technology is a clear example. In a concerted effort and through a stepped-up national programme, about 0.2 million family size biogas plants have been set up in India in the last one decade. The benefits of the biogas technology are slowly but steadily being appreciated among the rural households (Moulik 1982). Similar examples, perhaps at a lesser scale than the biogas programme, can be cited in relation to other renewable bioenergy technologies, such as, wind, solar, other biomass conversion processes etc.

While empirical experiences about the promise of bioenergy are abound, it has yet to reach a critical mass as a real alternative. Firstly, for a country like India, the spread of bioenergy interventions seems to be too sporadic and isolated to create a macro-level impact. Secondly, apart from uncertainties in technologies and technology-specific resource constraints, there are problems of ecomomic viability, particularly, in relation to largely subsidized conventional energy input. As a result, it is yet to assume a scale of peoples' movement with increasing demand.

Lastly and perhaps one of the most important limitations of bioenergy programmes in India has been the emphasis on either a particular device or particular waste use or a particular end use.(e.g. cooking energy, motor power for irrigation, crop processing etc.) There has been very little attention so far in India to use biomass energy as a total system of integrated management of bioresources. As a result, the symbiotic relationships between various social, economic and cultural elements in a society are not sufficiently strengthened in order to create a synergic effect in the interaction of constituent processes and socio-economic parameters.

The last point can be illustrated in relation to India's biogas programme. Being over concerned and perhaps rightly so in view of the primacy of cooking energy need, biogas has largely been promoted as an alternative technology for cooking fuel. The benefits of biogas slurry as fertilizer input for enhanced food production - an obvious direct relationship in the food-energy pivot - has so far been given secondary importance. It was only recently the importance of biofertilizer as a process of direct intervention in the food-energy flow system has been emphasized. It was this renewed emphasis on multiplier effects and partly to overcome the technology specific resource constraints (cattleholding) for spread of biogas technology, a programme of large size community biogas programme has been promoted in India (Moulik _et al_ 1984).

But community biogas system alone is not a system of integrated bioresource management. It is soon realized that to be effective and efficient the bioenergy programme should necessarily be the key link in the overall food-energy nexus planning. In order to achieve this, what is needed is an integrated energy system, primarily based on bio-resources, with a mix of technologies matching the available resources and fulfilling the total energy input needs of a community, not merely for agriculture. To put it simply, the goal of integrated bio-energy system is not only to enhance the food-energy nexus, but also to generate related multiplier effects in generating employment, additional income through other economic activities, and to bring about a balance in energy flow, resource utilization and economic benefits. For, it is apparent that given the alternative uses of available resources and uneven socio-economic class/caste structure, an integrated energy system should necessarily be planned in such a way that it augments the symbiotic and synergic relationships rather than wasteful competition and imbalances.

It is with this objective in view, the Government of India has recently promoted a programme of Integrated Rural Energy Centres. What follows here is the planning parameters used for one of the first Integrated Rural Energy Centre based on biomass energy sources.

The village where one of the first Integrated Rural Energy Centre is in the process of being implemented is named Khandia in Baroda district, Gujarat. It is a relatively small non-electrified village, about 4 kms. away from the nearest all-weather metalled road and from the electricity grid. Khandia has a population of 800 comprising of 95 households. The total cultivable land of the village is about 160 hectares divided among 80 households. The agriculture is largely rainfed in the sense that only kharif crops of cotton, jowar, maize or paddy are grown. For the remaining period, the villagers migrate for labour employment.

At the time of site selection relevant infrastructural and energy consumption data for Khandia were collected as shown in Appendix I. However, the following critical observations about the relevant resource parameters should be discussed.

There are four diesel pumpsets of 5 HP each with four wells in Khandia. There is a big well in the village lying unused because it is located far below most of the farms and therefore needing very high lift for using it for irrigation and distribution system. However, a local voluntary development agency has developed a pond nearby. Thus, if these five wells and the pond could be used for irrigation, there is potentiality for multiple cropping on most of the land in Khandia.

The village water supply has been developed by the same voluntary agency. An overhead tank has been constructed and operated by 5 HP diesel pump. There are no other community facilities in the village. For primary health care, schooling and even for milling flour, the villagers have to traverse 4 kms. to a nearby developed village.

The village has adequate sunshine except in a brief spell of monsoon. There is also a significant wind potential. As far as biomass is concerned, two hectares of village waste land have been put under quick growing Eucalyptus trees, under the active development programme of the voluntary agency. An additional 14 hectares of waste land is available for extending similar forestry programme. It is estimated that the forest programme in 16 hectares would yield biomass of 100-300 tonnes per year.

The foregoing description of the village situation gives a rough indication of the level of energy needs. However, a summary of the existing level of energy consumption in the village is shown in Appendix II. The integrated bioenergy system should not only plan to meet the present level of consumption needs, but also should increase the level of consumption in consonance with the desirable socio-economic development plans for the village. Thus, apart from augmenting the energy inputs for irrigation and fertilizers (biomanure) for increasing the food productivity and providing for cooking fuel need, the integrated system should cater to some basic infrastructural facilities in the village, such as, primary health centre, community radio and television for education and entertainment, flour mill; and street lights. Thus, taking the future development plans in the next 10 year period, the likely future energy needs are worked out as shown in Appendix III.

The various energy needs listed in Appendix III can be basically categorised as applications requiring thermal energy and those requiring electricity or motive power. Besides, there is the energy need in terms of fertilizer requirements in the food production system. Given the available resource base in Khandia, and available bioenergy technologies it is possible to plan an energy system with a mix of technologies in order to meet the future energy needs. Accordingly, an Integrated Bioenergy System for Khandia has been planned (see Appendix IV).

The major criteria in planning the Integrated Bioenergy System for Khandia has been the following:

(a) The technology mix should be a minimum cost alternative

(b) It should meet the energy needs not only for agriculture, but also for other necessary social, infrastructural and agro-processing facilities.

(c) It should maximize utilization of the available bioresources with minimum harm to the ecosystem.

(d) It should benefit all sections/class of the villagers.

(e) It should increase food productivity.

(f) It should generate additional employment opportunities and off-farm income facilities.

(g) The technology system should be simple enough requiring minimum maintenance so that villagers themselves can eventually operate and manage.

The estimated cost of the hardware for the proposed integrated energy system for Khandia is about Rs 14 lakhs in addition to technical manpower requirement for the first two years of operation, which would cost about Rs 1.25 lakhs per annum. It was envisaged that the integrated system would ultimately be handed over for daily operation and management to a newly organized Village Energy Cooperative. During the implementation process in the first two years, some village youth would be concurrently trained on the job for operation/maintenance work. It was also envisaged that with the provision of a grant for the total cost of hardware and two years operational cost, the Village Energy Cooperative could build a development fund of Rs 60,000 by the end of first two years from the levy of Rs 25 per family per month.

The conspicuous physical impact of the proposed integrated bioenergy system can be easily be seen. With 100 per cent assured irrigation facilities, the cropping intensity in Khandia is likely to increase from the existing 102 to at least 260. The biogas system would ensure an increase in organic manure application per unit of cultivable land at least 2 times more than the present practice. As a result, the food productivity per unit of land in Khandia is estimated to increase about 6 times more than the present production level.

The food production chain itself would generate additional employment apart from the contribution from other economic and infrastructural activities. The 16 hectare forest plantation, for example, was estimated to generate a minimum of 5000 mandays of employment per annum. On a very modest assumptions, the proposed integrated energy system in Khandia is likely to generate about 68,000 mandays of additional employment opportunities. This should be sufficient to keep all the villagers occupied gainfully within the village all the year round.

The income effect of the proposed energy system among the villagers of Khandia is obvious. The increased food productivity and additional employment generation alone would contribute substantially to the income of village households.

Apart from the tangible economic benefits, there would be substantial change in the quality of life and environment. The infrastructural facilities like primary health care, radio/TV entertainment and street lighting would have a multiplier effect in Khandia's social life. Equally important would be the diminishing dependence of the villagers on external resources and control as far as food-energy nexus is concerned.

The proposed integrated bioenergy system in Khandia is already under implementation. Some renewable energy technologies are presently being installed. It is hoped that the total energy system would be operative by the end of 1984. A close monitoring for the period of next three years could tell us how far it achieved its goals. Nonetheless, a beginning has been made for a bioenergy alternative.

Appendix I

RESOURCE PARAMETERS OF KHANDIA VILLAGE

Sl.No.	Resource Parameters		
1	Taluka		Sankheda
2	Population		800
3	No.of Houses		95
4	Approach Road		Kachcha
5	Distance from main road (km)		2
6	Distance from Taluka-place (km)		25
7	Whether electrified		No
8	Distance from the grid (km)		5
9	Land pattern	(Hectares)	
		Irrigated	175
		Irrigable	12
		Government	1.2
		Pasture	13.5
		Barren	125
10	Cropwise distribution hectares	Cotton	85
		Bajra	15
		Tobacco	0
		Wheat	0
		Paddy	30
		Jowar	45
		Tuwar	6
11	Water Supply	River	No
		Community well	1
		Private wells	14
12	Water for Agriculture		
		No. of wells	1
		Pumps (diesel sets)	0
		Pumps (electric motor)	0
		Tube-wells	0
13	Fuel consumption per family per month		
		Firewood (kg.)	200
		Karatha (kg.)	0
		Dung (kg.)	0
		Kerosene (lit.)	6
14	Cattle stock	Buffaloes	50
		Oxen	250
		Cows	100
		Goats	400
15	No. of gobar gas plant		0
16	Feeling about wind		Very good
17	Use of agricultural waste composing Khadas (pits)		60

<u>Appendix II</u>

CURRENT VILLAGE ENERGY CONSUMPTION

Sl.No.	Activity	Fuel/Form of Energy	Appropriate Annual Consumption
1	Cooking and related activities	Fuelwood/Agriwaste/ Dung	360 Tons (Wood Equivalent)
		Kerosene	200 Lit.
2	Domestic Lighting	Kerosene	3000 Lit.(Estimated)
3	Village Water Supply	Diesel based pumping system	3650 Kwhrs/year (10 Kwhrs of shaft power per day)
4	Irrigation	Diesel based pumping system	3360 Kwhrs/year (4 sets of 3.5 KW capacity run 6 hours a day for 40 days in a year)

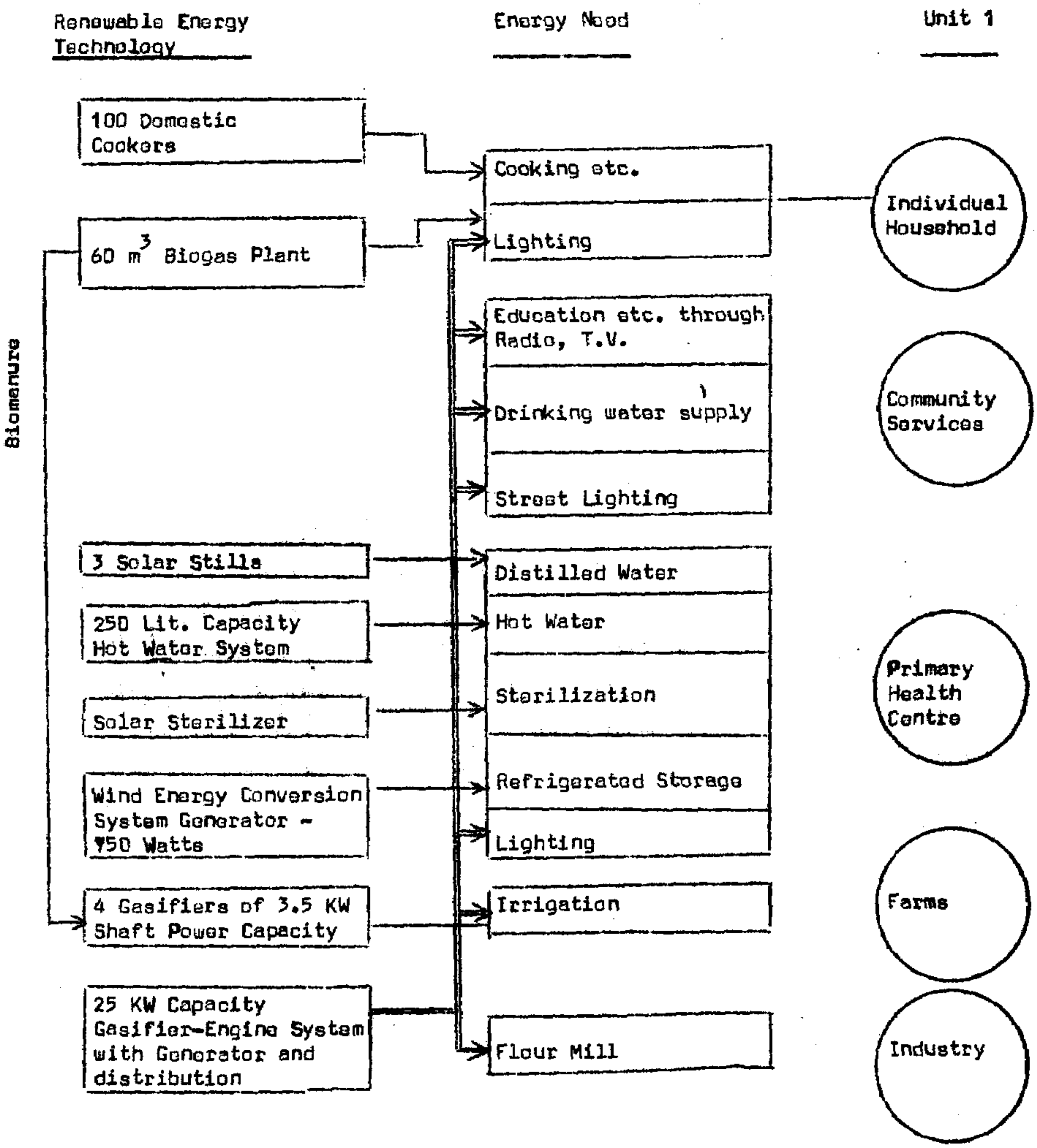
Appendix III

DESIRABLE FUTURE ENERGY NEEDS OF KHANDIA VILLAGE

Sl. no.	Activity	Likely energy consumption and its details	Remarks
1	Cooking and related activities	Energy equivalent of 300 tons of wood being burned at very low efficiencies (~ 10%)	For any new fuel/technology to be used, normal requirements can be assumed.
2	Domestic Lighting	On an average, 6 lamp-hrs. per household daily	600 lamp-hour or 36 Kwhrs per day spread over 3-4 hours every evening
3	Street Lighting	20 Street lights for 4-5 hours daily.	6 Kwhrs daily
4	Education/Extension through Radio, TV.	Total load of 250 watts for 4-6 hours daily	1 Kwhr. daily.
5	Primary Health Centre	o 10 Litres of distilled water daily o 250 litres of hot water o Refrigerated storage of medicine/vaccines o Lighting o Sterilizer	In addition to distilled water, hot water and sterilizer, approximately two kilowatt hrs. of electrical energy daily.
6	Irrigation	Four existing pumpsets and one larger pumpset (10-15 KW) with proper planning for water distribution	If two crops are taken the pumps should be available on demand between October and April.
7	Flour Mill	Use of 3.5 KW electrical motor for a few hours daily	Can be run as and when power is available.

APPENDIX IV

INTEGRATED BIOENERGY SYSTEM FOR KHANDIA



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