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# A FIELD EVALUATION OF THE POTENTIAL OF BIOGAS AND BIOMASS TECHNOLOGIES FOR RURAL DEVELOPMENT IN INDIA

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## INTRODUCTION:

The following is a report of a trip to India that I undertook during February to April 1980 with the following objectives: (1) To investigate the research projects in energy and rural development, particularly those projects related to biomass and biogas energy resources, technologies, and schemes, in order to identify areas of research that remain unexplored. (2) To investigate rural communities that already operate energy systems based on biogas and biomass resources with regard to the effectiveness of these new energy technologies in (a) achieving objectives of development, (b) their social acceptance, (c) compatibility with rural lifestyles and organisation. The objective was also to assess any perturbations caused in the rural societies due to the introduction of these new schemes. (3) To visit government and private research institutions and government agencies involved in research related to biomass and biogas energy resources and technologies in the context of rural development in order to identify their philosophies and goals, their problems in carrying out the research, and the ways in which this research is and can be syntnesized with policy and implementation. (4) To familiarize myself with the real problems of rural development by talking to the villagers about their day-to-day problems of energy and agriculture and also to understand the rural peoples' attitudes towards energy technologies and energy problems.

The above ambitious set of objectives had to be achieved in a relatively short period of six weeks. Therefore, it was decided to visit only those institutions and projects that had made significant contributions in the area of biogas and biomass energy technologies in the context of rural development. Also, the visits to the institutions were made with the narrow objectives of familiarising with those components of the research that were being applied in action-research projects. The real emphasis was on spending as much time as possible 'on site' at the projects and in rural areas in general, so as to 'observe' the operation of the projects and their impacts on the communities. Informal interviewing procedures were adopted for this purpose. In this way, I could obtain a synthesized picture of the energy technologies, their technical and economic feasibility, as well as the evaluation of the technologies from the perspectives of the communities in which they are implemented. The following is a description of the institutions, projects, and rural communities that I visited. The 'conclusions' are an effort at synthesizing my experiences into some hypotheses regarding the problems of energy and rural development in India. Suggestions are also made for further research and action-research projects.

## BOMBAY:

### The Khadi and Village Industries Commission:

I visited the Biogas division of the Khadi and Village Industries Commission in Bombay. Mr. H.R. Srinivasan, who heads the biogas division, discussed with me the biogas program of the Khadi and Village Indusries

Commission (KVIC). He said that over 70,000 biogas plants have been set up in the biogas program of the country, producing 152 million cubic meters of gas valued at Rs. 113 million. One and a half million metric tons of organic manure is also produced. During 1979-80, KVIC helped instal about 40,000 biogas plants in India. Various concerned government agencies responsible for the allocation of cement and steel have been storing and allocation steel and cement in favour of the biogas program.

KVIC is involved not only in the design and technical guidence for the setting up of the plants, but is also involved in financing of the plants. For gas plants to be set up by institutions and cooperative societies, 25 percent grant and 75 percent loan at 4 percent interest is made available. For registered institutions and cooperatives set up by 'scheduled caste' and 'scheduled tribe' people ('scheduled caste' and 'scheduled tribe' refers to people of the castes and tribes that have been granted certain concessions in the Indian constitution) living in notified/tribal and hilly areas, 100% grant is available. Seventy five percent of the estimated cost of the plant is given as a subsidy to the 'scheduled caste' and 'scheduled tribe' people living in any part of the country. Fifty percent of the cost is given as a subsidy to anyone living in notified/tribal areas and 25% of the estimated cost is given to small and marginal farmers for plants of 2 and 3 cubic meter capacity only.

The 'Films Division' at KVIC showed me a film regarding the principle of biogas, its advantages, the KVIC programs and subsidies, etc. KVIC has been involved with biogas technology since 1962 and has adopted a standard design for the plants based on designs evolved through efforts by various institutions such as the Indian Agricultural Researh Istitute in Delhi. KVIC has modified this design by its own R&D efforts being conducted at various research centers managed by it. The standard KVIC design now consists of a concrete digester built underground divided into two compartments, the inlet compartment and the outlet compartment. A mixture of cowdung and water poured through the inlet tube into the digester digests in the inlet compartment. When the level of the slurry rises over the compartment wall, the slurry flows into the outlet compartment. In this way, the possibility of scum-formation at the top because of the passage of dung directly from the inlet tube into the outlet tube without proper mixing is avoided. The gas- holder consists of an inverted steel container floating on top of the slurry in the digester. Gas is collected through a tube at the top of the gas-holder. KVIC recommends a mixture of water and cowdung in equal proportions. Therefore, assuming a yield of 1.3 cubic feet gas per kilogram of dung, a 250 cubic feet capacity digester is required for a 100 cubic feet gas-holder. The optimal diameter of this digester in order to produce maximum gas-yield is 5.3 ft.
I talked to Mr. Shrinivasan about the Janata design biogas plant and asked him why KVIC had not ventured into this field. Mr. Shrinivasan raised several objections to the recent euphoria regarding the Janata design. Firstly, he said that at KVIC research stations, experiments have been going on to determine the long-term performance of the Janata design plants. He claimed that it has been observed that the output of the Janata plant decreases after a few months because of formation of scum at the top. Since there is only one compartment in the Janata plant, the slurry can come in at one end and go out the other end. Also, gas cannot flow out very well if the surface of the slurry is covered with scum. I looked at the data from the tests being conducted at one of the KVIC research stations, which bore testimony to this claim. Mr. Shrinivasan claimed that since, in China, the

major objective of the biogas program is waste-disposal and production of manure, rather than production of the gas, the Janata design is suitable there. Also, in China, the batch process is used, so that the digester is completely dismantled every six months. The problem of scum-formation is thus automatically eliminated. Mr. Srinivasan also expressed some scepticism regarding the economics of the Janata design. The KVIC claim is that the Janata design is only about 30% cheaper whereas other institutions such as the Gobar Gas Research Station in Ajitmal, U.P., and the ASTRA group in Bangalore claim that the Janata design is cheaper by a range of 50-75% . Mr. Snrinivasan feels that the Janata design may be economical in regions such as Uttar Pradesh where locally manufactured bricks are available cheaply but in regions such as Maharashtra, this is not likely.

The KVIC has set up five research stations at five different locations in India in order to do research on biogas technology in a variety of climatic and geographical conditions. At one such station in Srinagar, Kashmir, where the gas yield in the winter reduces by 50% , experiments are being conducted to heat the input slurry using a part of the output gas. This particular plant is also constructed completely underground to reduce heat loss. At another research station at Gandhi Gram near Madurai in Tamil Nadu, six different designs for biogas plants are being tested.

I visited the Gobar Gas Research Station at Gore Gaon, Bombay, set up by the KVIC. There were various types of burners, lights, engines, etc., on display, similar to those displayed at Ajitmal. Right now, the research station is not involved in any more instrumentation. There were some earlier designs of biogas plants on display, including the design in which pulleys and vertical guides were provided to apply negative pressure to the gas-holder for increasing the gas-yield. As it turned out however, the negative pressure can cause dangerous accidents because the air from the stove can go back into the pipe and the gas-holder thus producing an explosive mixture.

I spoke to Mr. Patankar, the head of the research-station, about the Janata biogas plants. He also claimed that the Janata design would not be successful in the long run.

No experiments seemed to be going on at the research station on using other materials such as water hyacinth in the digester. The research station seems to have no plans regarding microbial research either. In short, the research-effort at the station seemed more routine rather than innovative.

KVIC arranged for me to visit a village called 'Bilarpada' in Thana district near Bombay. In this 'Adivasi' or tribal village, most houses have biogas plants. We saw various sizes of the KVIC design digesters. They all seemed to be in operation and the villagers seemed to have adapted to them rather well. The tribal people have received substantial subsidies ranging from 50 to 70 % for installing the plants. In contrast to Uttar Pradesh where even the upper-caste people seemed relatively poor, the villagers in Bilarpada seemed quite affluent. Most houses were 'Pukka' (permenant) constructions. The village is electrified and yet most houses with biogas plants have biogas lamps that hang from the ceiling. Ten years ago, this situation might have seemed ridiculous but, now, since electricity black-outs are very common in the region, the biogas lamps serve an important function. Every household had shining brass pots, the people wore clean and new clothes, there was a feeling of well-being in the village. This village is situated in the midst of good

agriculture land, and although it is a tribal village, every household owns some land. The labour supply for this village comes from the neighbouring tribal community that does not have as much land. Most households still seemed to use some firewood, particularly for heating water. Infact, behind the hamlet, we could see a heap of firewood collected from a tree. The region's main crop is rice. The village headman, with whom we managed to carry out a conversation with some difficulty, said that in the mansoons, when sometimes 25 people are employed on the farm and when gas yield is almost zero because of the cold weather, 80 kgs of wood might be consumed by a family of ten in two months. Therefore, the villagers tend to store firewood for the rainy season. This situation could be corrected by improved design of the digesters. Most villagers had made some minor modifications in the design of the plant, such as having a bigger outlet tank and a compost heap nearby. Ideally, the output slurry should be used immediately in the fields to utilize the nitrogen-content of the slurry which decreases with time. However, it is not practicable to carry the slurry every day to the fields. No studies have been made on the exact increase in productivity due to the use of the slurry as a fertilizer. Most villagers do claim that their agricultural output has increased.

KVIC has not made an attempt to set up community biogas plants. KVIC is mainly involved in providing finance and technical guidence to farmers and institutions interested in setting up biogas plants but has not played an active role with regard to the setting up of new schemes.

## Excel Industries:

Excel Industries in Bombay is a chemical industry that was started by a dynamic industrialist by the name of Mr. C. C. Shroff who has some unusual ideas about running an industry. A subsidiary of Excel Industries is the C. C. Shroff Research Institute which is doing a considerable amount of research in industrial affluent treatment, growth of various kinds of biomass such as algae, plants, fish, new energy sources based on biomass, etc.

I visited the C.C.Shroff Research Institute one afternoon. Dr. Ghatnekar, Head, Environmental Science Division, introduced me to the activities at the institute and showed me the various experiments being conducted.

Plants are capable of selective or differential absorption as far as chemical substances in the soil are concerned. Plants also degrade or break down the chemical pollutants from the soil. In this way, plants act as osmotic filters. Inspired by experiments being conducted in NASA for the recovery of toxic metals through water hyacinth, the institute started conducting experiments not only on water hyacinth but also on many other plant species. In Excel's Amboli unit , Malathion, a toxic pesticide is manufactured. The effluents from the plant contain traces of benzene, alcohol, toulene, DTA and DEM washings, etc. Part of the effluent is given the chemical treatment of oxidation and neutralisation, resulting in a solid sludge. This solid sludge is put in PVC bags to prevent seepage and plants are grown in the bags. Dr. Ghatnekar claimed that plants grew quicker and bigger in size than the plants being grown under normal conditions in a controlled plot. However, he said that only about 50% of the plants survived the experiment. The plants that I saw looked healthy. There were flowering

plants as well as fuelwood trees. The tree-species used in these experiments can be broadly classified into 10 groups listed as follows:

Large Crown:
1. Sesbania indica(Dhencha)
2.Glyrecidia sepium(Madre tree)
3.Millingtonia hortensis(Akashneem)
4.Tectona grandis(Teak wood)
5.Prosopis juliflora(Vilayti Babul)

Small Crown:
1.Casurina equisitifolia(Suru)
2.Eucalyptus globulus(Niligiri)

Snrubby Types:
1.Eupnorbia species(Cactus).
2. Sanseveria roxburghiana(Bow-string Hemp).

Non-edible Oil:
1. Ricinus communis(Castor).
2. Cymbopogan citratus(Lemon-grass).
3.Cymbopogan nardus(Citronella).

Edible Oils:
1. Sesamum indicum(Til).
2. Glycine max(Soya bean).
3. Brassica species(Mustard).

Vegetables:
1. Solanum melongena(Brinjal).
2. Hibiscus Esculentus(Lady's finger).
3. Lycopersicum esculentus(Tomato)
4. Capsicum anum(Chilly)
5. Cymopsis species(Clustered-bean). Variety Surti long.
6. Cajanus Cajan(Cajan Pea).

Oranmentals:
1. Canna indica(Kardal).
2. Bougainvillae species.(Bougainvel).
3. Aster species(Aster).

Fibre Yielding:
1. Gossypium harbaecum(Cotton).
   Var. 1007
   Var. H4
   Var. 97
2. Hibiscus cannabinis(Hemp).

Cereals:
1. Pennisetum typhoides (Bajra).
2. Sorghum Fulgare(Jowar).

Aquatic:
1. Lemna gibba(Duckweed).

A comparison was made between the growth of plants fed with water purified by oxidising and neutralising the effluent stream to a C.O.D. value upto 700 ppm, and those fed with diluted effluent stream (30,000 ppm C.O.D. diluted to 3,000 to 5,000 ppm C.O.D.). The comparison showed that the growth of plants fed with the effluent was much more than the plants fed with purified water. The concentration of heavy metals in the edible matter from these plants could be one possible problem. The experiments are quite revolutionary.

The other revolutionary concept that the C. C. Shroff Research Institute has developed is that of 'biodung'. Biodung is made by fermenting weeds, plant-wastes, and grasses in plastic bags exposed to the sun. The fermented mass thus produced is made into cakes similar to dung-cakes and are dried. These cakes can then be used directly as fuel or as feed in a bio-gas plant. The advantages of bio-dung are the following: 1. As the fermented mass has not undergone the digestive process weight per weight, it will have higher clorific value and will produce more biogas than cowdung and will also thus be a better fuel. 3. If the fermented mass is used to produce biogas, biogas will be within the reach of those who do not possess cattle. 4. Biodung will provide strong motivation for eradication of weeds, particularly water hyacinth and african payal. 5. If biodung replaces fuelwood, it will help in reducing deforestation and the resultant environmental effects. 6. The raw-material necessary for biodung is available anywhere.

The idea of biodung came from Mr. Dycus Roy, who wrote an article titled 'How to make cow manure without a cow' in The Mother Earth News in 1976. Dr. Ghatnekar at the C. C. Shroff Institute started experiments on it using the following materials:

1. Water Hyacinth (Eichhonia crassipes)
2. Water Lettuce (Pistia stratiotes)
3. African Payal (Salvinia auric;ulata)
4. Duck Weed (Lemna trisulca)
5. Water Spinach (Ipomoed aquatica)
6. Ramban, Cattail (Typha angustifolia)
7. Lucaena, Ipli-ipli (Lucaena leucocephala)
8. Morning Glory (Ipomoea pestigridis)
9. Paragrass (Brachiaria mutica)
10. Purple Nutsedge (Cyprus rotondus)
11. Darva Grass (Stylo species )

The experiments are carried out as follows: Various combinations of the above materials are put in opaque white and transparent polyethylene bags. The bags are kept in the hot sun for anaerobic digestion and opened every fourth day to release the accumulated gases, to add water, and to visually inspect the contents of the anaerobic digestion. It is observed that fermentation can take place in all types of bags. Fermentation is improved with the addition of cowdung. The fermented mass is made into balls and cakes and is dried. The biodung cakes thus produced are used for cooking in the institute cafetaria and also in the home of an employee of the institute. The cakes seem to give more heat than cowdung cakes. At present ,in Divi Tensil in Andhra Pradesh, a project has been started by Mr. K. C. Shroff, Jt. Mg. Director, for the mass scale utilisation of the process in ten villages. The institute feels that by popularising the process, a simple way of income generation can be made available to the rural, landless, cattleless poor because the raw material required for biodung is available in the countryside to whoever wants to collect it.

Trials were conducted to find out if biodung can be used to produce biogas. These trials were conducted in jars in the laboratory and the output was measured. It was observed that fresh biodung yielded more gas than dry biodung. Experiments are also being conducted to determine the usefulness of biodung as a fertiliser. Experiments in the growth of fish in industrial effluents are also being conducted at the institute. Carps being nurtured in industrial waste water in plastic tanks seem to be doing really well. In a

pond in the five-acre garden surrounding the institute, water hyacinth is grown and fed to pigs.

The institute is located on Excel Estate which is about 12 acres in area. A waste-water canal flows in the middle of the estate, dividing it in two parts. All the experiments in effluent-treatment are being conducted with the water from this canal. Also, trees are being grown on the banks of the canal. The 'ecological pond' gets its water from the subsoil region. Waste-water from the kitchen, the laboratory, and the bathrooms goes into the pond. The pond ecosystem consists of ABIOTIC SUBSTANCES such as water, $CO_2$, $O_2$, nitrogen compounds of calcium, and phosphorous, chlorides, etc. PRODUCERS such as aquatic weeds, algae; CONSUMERS such as fish and ducks; and DECOMPOSERS such as fungi and bacteria. More specifically, the pond acts as a habitat for ducks, crabs, snails, pigs, blue-green algae and green algae such as Ceratophyllum, Hydrilla, Trapa bispinosa, Duck Weed, Water Hyacinth, Water Spinach, Water Lettuce, Typha angustata, African Payal, Azolla pinnata, as well as fishes such as Gambusia Guppies, Chanos chanos, Tilepia rendalli, etc. Water Hyacinth seems to thrive on the polluted water, and so does duck weed. However, a startling discovery was made, viz., water hyacinth cannot grow with duck weed. Duck weed seems to dominate water hyacinth completely. Competition between the animal life in the pond was also observed. For example, Gambusia consume all mosquito breeding colonies floating on the surface of water. The ducks use weeds as food. In turn, the fecal matter of ducks is used as a food by the fish culture. Species such as Azolla, Marselia, Lemna, blue-green algae, are found to fix atmospheric nitrogen. These biofertilizers are used in the fruit and vegetable garden in the institute. Most of these aquatic species seem to clear waste water. Pigs also form a part of this system because they feed on the water hyacinth and their fecal matter in the pond can be used as a food by the fish larvae. The pig-dung is also used as input to biogas digesters. It was observed that the blue-green algae fix varying amounts of nitrogen ranging from 5.2 to 14.48 mg/100 ml of the medium depending upon the incubation time. When we visited the pond, it seemed to be in complete ecological equilibrium. Such 'aquasystems' can be used in the rural areas to provide the villagers with food and other biomass.

Among other experiments at the institute are those involving Volvariella volvacae or paddy straw mushroom. There is also a solar still in the yard that generates 60 liters of water every day, enough for the laboratory. Hydrophonic ponds are used for growing plants in the effluent water in order to purify it.

I was very impressed by the work going on at the institute and the dedication that the people at the institute have. However, the one question that needs to be answered regarding the experiments in effluent treatment is whether the concentration of poisonous materials in the plant material grown on the effluents will be harmful to the people using them. It seems that the institute has not paid enough attention to this question.

## Jambulpada Village:

Another unusual project that the Shroff Research Institute is engaged in is a biomass plantation in a rural area. Jambulpada village is located in Kolaba district which has been described in the context of the rubber

plantation earlier. Jambulpada is divided into two parts, the main village which is more like a little town. The other part is the 'Adivasi' or tribal village which is located some distance (2.3 miles) from the main village. Excel Industries selected this site for their study because the Visnva Hindu Parisnad, a religious organisation, was already involved in development work there. The government has given about 300 acres of land to the tribal people with the goal of achieving development. Traditionally, the tribal people have been doing a little agriculture on the denuded hills. Instead of growing rice, which is the major crop in the area, they grow a crop called 'Nachni'.

We visited both the energy plantation and the tribal village. I interviewed the villagers regarding their energy -consumption patterns. Excel Industries has also done a energy supply-demand survey of Jambulpada with the help of one employee, Mr. S.R. Potdar, who is working on a masters degree in industrial engineering at the National Institute for Training in Industrial Engineering at Bombay, and who is conducting this survey for his Master's thesis. However, one problem with the survey is that the households in the tribal village were not surveyed separately, but were treated as a part of the whole sample for Jambulpada. In the tribal village, one member from every household goes to collect fuelwood every morning. The hills behind the village which used to be covered with trees are now denuded as a result. It takes several hours to collect firewood. The fuelwood use is very high in the tribal village because the tribal people only have goats and chicken but no cattle. Thus, they do not use cow-dung for cooking but use only fuelwood. Traditional agriculture relies upon the 'slash and burn' method for preparation of seedlings, which works as follows: On a plot of land, cowdung is spread evenly. A layer of earth is spread over that, followed by a layer of twigs and trees. The twigs are burnt to produce the heat necessary for composting. After the dung is composted, the seedlings are planted in the plot. After the seedlings are grown a certain size, they are transferred to another plot of land. We saw quite a few trees being cut down for this purpose. Making a compost-heap would be a much more 'environmentally sound' practise but is more time-consuming.

Interviewing the villagers regarding their energy demand was not very easy because the villagers seemed to exaggerate the quantities of fuels consumed. However, the qualitative information they gave was quite useful.

From the land given to the tribal people by the government, an area of 10 acres is developed by Excel Industries. The energy plantation on this plot consists of local tree-species such as Neem, Babool, Gulmohar, Tamarind, Ashoka (Poplar), Khair, Ber, Lucaena (Ipil Ipil), Kasurina, Acasia, Amla, Cashews, etc. The plot is on a hilly and rocky terrain that resembles the countryside around it. Excel has dug a well near the plantation for the purpose of watering it. The villagers have their own well on the other side of the village. The planatation is surrounded by a barbed-wire fence and is carefully protected from intruders. The plantation is divided in four sections: One gets both water and fertilizer, the second one gets only water, the third gets only fertilizer, and the fourth gets neither water nor fertilizer. Thus, Excel hopes to study the plantation under different conditions including subsistence conditions.

The tribal people are employed by Excel to water the plantation. A villager from the main village of Jambulpada who belongs to another tribe is

appointed to oversee the care of the plantation. There seems to be a lot of mistrust between the tribal people and Excel Industries. The people from Excel were complaining bitterly about the tribal people's dishonesty. One tree in the plantation had obviously been cut during the previous week. Excel feels that it is providing employment and capital to the tribal people and that the tribals do not reciprocate the gesture in any way. When asked about the produce from the plantation, Excel representatives said that the produce will go to the tribal people. However, one does not see that as an obvious outcome of the project since, at present, Excel has complete control of the land.

In the meantime, the tribal people's life-style has not changed a bit since the advent of the biomass plantation. One of the major problems in the village right now seems to be that of the availability of pure drinking water. The tribe's well dries up in the summer and they start using the well near the plantation dug by Excel. However, the Excel well contains extremely polluted water. Every summer, the tribe is supposed to purify the water of the Excel well with the help of potassium permanganate before using it. However, when we visited the village, we were told that the villagers had already started using the Excel well without purifying the water. It was a fairly hot day and I asked for a glass of water. The villagers provided me with a glass of muddy water which was supposed to be from the village well. Several children seemed to be suffering from rickets. A shcool has recently been started for the tribe by the Vishva Hindu Parishad. Therefore, a woman-teacher walks everyday from the main village to the tribal village. When we visited the village, the villagers were all gathered in the yard of the village headman's house. They were all engaged in making baskets of bamboo strips. I was somewhat impressed by the cleanliness and the neatness of the houses. The kitchens all had brass vessels. Here again, the affluence of Maharashtra was pretty obvious. Compared to the tribes in Uttar Pradesh or Madhya Pradesh, the tribal people seemed better off and more aware, may be because of the proximity of the Bombay metropole.

It seems that the 'Adivasis' do not trust Excel Industries . The reasons for this mistrust are easy to understand. To the 'Adivasis', people from Excel seem to be alien and their motives are not clear. Although Excel Industries claims that it is providing employment and capital to the villagers, an observer could say that Excel is in a position to be able to exploit the villagers by using their cheap labour and free land to make an income from the plantation. Another criticism of the industry is that it is involved with rural development projects with the ultimate objective of seeking tax-shelters. A third criticism is that by getting involved with a few 'rural development' projects, industries will gain the confidence and the trust of the people and the government and thereby, at a later stage, get involved with projects that are not compatible with the objectives of rural development. The ultimate goal for the private companies manufacturing goods would be to create markets for these goods. Rural development aimed at creating a demand for goods presently consumed only in the urban economy could be disastrous for the country. In any case, the Excel project and similar projects need to be watched closely for the next few years in order to determine their overall desirability.

## Jambulpada Survey:

The population of Jambulpada is 1765 people. There are 360 families in the village. 170 households are electrified . The survey was conducted through random sampling technique. A sample of 60 households was selected from a total of 360 households. The per capita per day consumption of fuelwood in Jambulpada ranges between 1.8 to 2 kgs. This is higher than the all-India average of 1.1 kg. The high consumption of firewood could be bacause not much cowdung is used in the village. The cattle to human ratio is only .25 in Jambulpada (In contrast, the cattle to human ratio in Pura village is .5) and only 40 families out of 313 have cattle. Whatever cowdung is available in Jambulpada is used for plastering homes, etc. Crop-residues are also used for non-fuel end-uses such as grain-storage, manure preparation, thatching, etc. Fuelwood is sold in Jambulpada at the price of 25 paise or one fourth of a rupee for a bundle of three sticks of wood weighing about 2 kgs. (8 Rs.= $1, 100 paise = 1 Re.) Therefore, people who have to buy their entire supply of fuelwood must spend around 55 to 60 Rs. per month on just fuelwood. kerosene consumption for the whole village amounts to 2200 liters per month. This estimate was obtained from a survey of retail sales in Jambulpada. This amounts to 6 liters per month per family. In the families that do not use kerosene for cooking but only use it for lighting, the average consumption of kerosene is 5 liters per month per family. In those families that use kerosene for cooking as well as lighting, the consumption of kerosene for cooking only was reported to be as high as 16-18 liters per month. The price of kerosene is Rs. 1.30 per liter. There was found to be a discrepancy between the estimate for average consumption of kerosene obtained from end-use data and that obtained from statistics of retail sales. The retail sales estimates are probably more reliable however, because, from my experience of talking to the villagers, the villagers seemed to have a very vague idea about their energy consumption. The LPG users in Jambulpada buy a cylinder of LPG weighing 18 kgs that lasts them for 45 to 50 days on the average and costs Rs. 33 to 34. It is observed that whatever may be the fuel used for cooking in a household, fuelwood is almost always used for heating water.

The above estimates of energy consumption in Jambulpada seem to be very high and should be verified through another survey.

## Rubber Plantations in Konkan:

The Konkan region consists of three districs to the south of Bombay along the coast: Thana, Kulaba, and Ratnagiri. The Konkan region consists of hilly and rocky terrain. Historically, this region, which comprises of the foothills of the Western Ghats, consisted of hills covered with thick forests. Reckless cutting of trees, particularly during the second world war, has resulted in wide-spread deforestation. Ironically enough, this region receives over 100 inches of rainfall per year, yet, if one were to look at the land, it resembles a desert. This is because deforestation has resulted in loss of soil cover. The torrential mansoon rain washes away the top-soil every year with the result that one can see some of the worst soil-erosion in this area. By the side of the road, we saw huge trees with their roots exposed to a depth of 2-3 ft, making us wonder how the trees managed to survive. The ground water-table is also not very high. Most poor farmers in

the region do not have the capital necessary for building wells. On the slopes and in between the sloping hills, the poor farmers in the region plant rice during the mansoons. However, the produce is not enough for even the subsistence of most farmers. The land is essentially useless for the rest of the year. Many small farmers work for the big farmers during the paddy season to earn some extra income. However, this employment is also seasonal. A large proportion of the population has migrated to Bombay in the past to gain employment in the industries there. This migration is partly responsible for the ugly city that Bombay represents today, where the quality of life is very low because of shortage of housing, water, food, and rampant pollution. If local employment can be made available to the people of Konkan, their migration to Bombay will stop.

Big industrial houses in Bombay are moving into the field of 'rural development' now. Thus, they are setting up various 'rural development' projects in Konkan and other neighbouring regions. The motives of these companies are of course subject to question. Some critics claim that these rural development projects are a good tax write-off for the companies concerned, and therefore, are incouraged by the companies although they do not make any profits.

One example of such rural development projects is the rubber plantation being set up by Sudhagar Rubber Industries at Padghavli in Kulaba district. Sudhagar Industries claim that plantations are the best way of providing employment to the rural poor. They feel that small and large scale industries other than those based on agriculture have several disadvantages such as: resultant environmental hazards such as pollution, emergence of social disparities between the local unskilled labour and the skilled labour from the cities, the necessity to train the local unskilled labour, etc. There is a considerable amount of truth in this claim . Given that agriculture based industries are the logical answer, one can think of fruit orchards or other plantations that would generate regular income. However, fruit-plantations do not have regular requirements for labour. Also, fruits are perishable goods and require some fruit-preservation industry to make the venture profitable. Sudhagar Industries claim that in the next 25 years, it will be possible to produce 100,000 tons of rubber in Konkan worth 500 million rupees. Out of this 500 million, 150 million rupees will be spent on providing employment to about 75,000 people.

Rubber has never been grown in the state of Maharashtra. The only place in India where rubber is grown is the state of Kerala which has a very different climate from that of Konkan. Yet, Sudhagar Industries claim that since rubber was originally grown in Malaysia, where rainfall is available all year round, and was later successfully adopted to conditions in Kerala, where rainfall is available only for 3 to 4 months during the year, a similar transition will be possible in Konkan. Sudhagar also claims that even if rubber plantations require irrigation, they will still be economically and socially profitable.

## Tata Energy Research Institute:

The Tata Energy Research Institute is a research organisation like the Tata Institute of Fundamental Research, funded by the industrial house of the Tatas. At present, TERI is mainly involved with the coordination of research

activities in energy in all parts of India. This is an important function since India is a large and diverse country with many research institutions who are engaged in energy research. TERI is therefore serving a very useful function. TERI has sponsored several research projects related to Energy and Rural Development at various institutions in India. Some of them are: 1. Development of Biogas Technology, Indian Institute of Science, Bangalore, 560012. 2. Technology Forecasting of Energy Systems for India until the Year 2000, Indian Institute of Science, Bangalore 560012. 3. Anaerobic Digestion of Municipal Solid Wastes, National Environmental Engineering Research Institute, Nagpur 440020. 4. Development of Windmillls, Indian Institute of Science, Bangalore 560012. 5. Energy from Agricultural Residues, A Thermodynamic Evaluation, Punjab Agricultural University, Ludhiana 141004. 6. Assessment of Sugar Cane as Energy Crop in Punjab, Punjab Agricultural Univeristy , Ludhiana 605002. 7. The Study of Energy Plans and Flows in Five Typical Villages of Andhra Pradesh, Administrative Staff College of India, Hyderabad 500475. 8. Energy in Paddy-Rice Handling and Storage System, Punjab Agricultural University, Ludhiana 141004, and so on.

Besides these projects, TERI has its own Field Research Unit in Pondicherry where solar research is being conducted. Some of the ongoing projects there are: 1. Convective Solar Dryers for Agricultural and Industrial Uses. 2. Ladakh Solar Passive Building Project, Intermediate Technology Industrial Services, England, and Field Research Unit, Tata Energy Research Institute.

TERI is also working with Excel Industries on the biodung project. TERI's role there is to popularise biodung as a cheap and easily made fuel as well as a source of income for poor, landless people in the rural areas.

## National Institute for Training in Industrial Engineering:

The National Institute for Training in Industrial Engineering (NITIE) is an institute for graduate training in industrial engineering. Dr. K.K. Murthy has initiated a program in energy research at the institute. They are mainly involved with work on energy conservation in industries. Mr. R. Mehrotra, an assistant professor at the institute, is doing research on rural development for his doctorate thesis with Bombay University. Mr. Mehrotra, an engineer by background, is working on the sociological aspects of development.

Besides Mr. Mehrotra, Mr. S.R. Potdar, a graduate student, is working on a survey of energy demand and supply for Jambulpada village and also on a role of energy plantations for future development of Jambulpada, as explained above.

## BANGALORE:

I visited the ASTRA group at the Indian Institute of Science, Bangalore. The work that the ASTRA group is doing needs no elaboration since it has been

published in detail elsewhere. In short, one can say that ASTRA is an acronym for 'Application of Science and Technology to the Rural areas'. ASTRA has been carrying out research and action-research in various aspects of development. ASTRA's most significant work has been the monitoring of a biogas plant situated at the ASTRA laboratory in Bangalore. On the basis of the tests performed at the plant for two and a half years, ASTRA determined the performance of conventional biogas plants, and optimised the conventional design for plant demensions based on economic considerations. A community biogas plant of this optimum design is proposed to be installed in 'Pura' village. We saw draftsmen at the ASTRA laboratory prepare drawings for this plant. The 'Pura' village project is discussed in more detail below.

ASTRA has built a new and unique design for a biogas plant which has a solar heater at the top, i.e., the gas holder has a water tank at the top to reduce the temperature-fluctuation. As the water gets heated during the day and cools off at night, giving its heat to the plant, the temperature fluctuation of the digester is somewhat evened out. Another improvement on this design is to cover the heater with a polythene cover and collect the distilled water in troughs. Thus, a biogas plant is combined with a solar still. This is being successfully done at ASTRA.

Research is also being done on modifying the Chinese design for Indian conditions. The modified 'Chinese' or 'Janata' design has smaller inlet and outlet pipes and also has a partition in the middle to avoid the scum problem. It is claimed that the cost of construction of such a plant is even lesser than claimed by the Gobar Gas Research Station in Ajitmal. There are indications that the cost might be as low as 30% of the cost of construction of the KVIC design plant.

Howard Geller, an American researcher working on a Fullbright grant, is conducting experiments on wood-burning stoves with improved efficiency. The improved 'chulah' or stove has three burners. There is an air buffer between the first burner and the second burner for the regulation of the flow of hot air between the compartments. The second and the third burner are also connected but have a constant flow of air between them. The stove has a chimney in the right corner, which makes the chulan smokeless. The pots are set right inside the burners as opposed to being set on the top of the burners. Asbestos sheets with openings of the size of the necks of the pots are fitted around the necks of the pots. These facilitate better heat transfer between the pot and the flame as well as reduce the loss of heat from the opening around the pots. Tests are being conducted by heating measured amount of water to a certain temperature to determine the efficiency of this new stove. It is expected that the new stove is atleast 25% more efficient.

The ASTRA group is involved in the construction of low-cost solar collectors for heating water. The collctor is made with corrugated asbestos sheets painted black and covered with glass covers. Thus, the need for metal tubes etc. is eliminated resulting in a low-cost collector. This collector costs only about Rs. 1000 to construct.

Low-cost housing is one of the areas of interest in ASTRA. Infact, the ASTRA laboratory itself is located in one such building. The low-cost building is constructed with raw compressed bricks which are energy conserving as well as cheap because they do not need to be baked. Among other experiments being conducted at the ASTRA laboratory are those on simple water

heaters made form polythene bags placed in direct sunlight.

ASTRA has established a rural energy center in Ungra, a village about 100 miles from Bangalore. About 15 employees, scientists, engineers, ecologists, social scientists, live at the center, designing and installing pilot models of and actual village energy systems. The objective is to create a model of a rural energy center in order to study the diffusion of various energy technologies and energy systems in to the rural community and the resultant perturbations caused in the community. We spent a whole afternoon at Ungra.

A sail-type windmill of vertical-axis design is used for pumping water. The windmill has a capacity of 50 W and pumps water between 2000 to 15000 litres. It cost Rs. 1800 for construction. A biogas plant is also set up at Ungra as a pilot project. At present, the cowdung for the plant comes from the Ungra village. But low-cost shelters are being constructed for cattle in the village and therefore, in future, the cowdung will be available at the center itself for its own energy use

We saw some villagers making bricks by compressing red clay in a compressor. This technology has a lot of potential for rural development in the region because it is a cheap technology applicable with local resources. ASTRA is interested in developing this technology in the region not only with the objective of providing a small-scale industry to the villagers but also with the objective of providing improved low-cost housing.

Pura village, located at a distance of about 2 miles from the extension center in Ungra, is a rural community in which ASTRA plans to apply its rural energy systems models. With this in mind, a rigorous survey of energy supply and demand as well as energy resources in Pura has been conducted for a period of one year . An ecosystem survey of Pura in which all of the energy flows, nutrient-flows and natural resource flows were monitored has also been completed. The highlights of the energy consumption pattern in Pura are as follows: 'Commercial' energy , i.e., kerosene and electricity, account for only 3% of the inanimate energy used in the village, the remaining 97% comes from firewood. Only 4% of this firewood is purchased. Animate sources, i.e., human beings and bullocks, only account for about 8% of the total energy, but this constitutes 77% of the energy used in Pura's agriculture. Four electric pumpsets account for the rest, 23%, of the energy used in agriculture. Unlike some rural areas of India, dung cakes are not used as cooking fuel in the Pura region. Dung is used only as a manure. Large amounts of human energy are spent on firewood gathering: about 2.6 hours and 4.8 kms per day per family to collect about 10 kg of firewood. Fetching water for domestic consumption also utilises a great deal of human energy (an average of 1.5 hrs and 1.6 kms per day per household) to achieve an extremely low per capita water consumption of 17 litres per day) . Fortysix percent of the human energy is spent in grazing livestock (5.6 hr /day/household) which is a crucial source of supplementary household income. Children contribute a crucial 30%, 20% and 34% of the labour. Only 25% of the houses in the village of Pura have acquired domestic connections for electric lighting, the remaining 75% of the houses depend on kerosene lamps, and of these lamps, 78% are of the open-wick type. A very small amount of electricity, viz., 30 kwh/day, flows into Pura, and this is distributed in a highly inegalitarina way-65% of this electricity goes to the 4 irrigation pumpsets of 3 landowners, 28% to illuminate 14 out of 56 houses, and the remaining 7% for one flour-mill owner.

Based on the survey, the two most important energy needs in Pura seem to be those for cooking and for reducing the use of animate energy from a level of drudgery to that of necessary employment. The provision of a convenient water supply and the production of fodder and feed for livestock are other pressing needs.

Energy resources available to Pura mainly consist of animal and forest biomass. Of these, firewood is a rapidly dwindling resource. Yet, an energy plantation on 5 hectares of land planted with species such as Casuarina or Leucaena leucocephala, yielding 50 tons of dry wood per hectare, can suffice all of Pura's firewood needs. But, an energy plantation will require 5 Years gestation period.

Ethanol production from sugarcane is another possibility. One hectare of land produces about 100 tons of sugarcane yielding 4.4 tons of molasses from which about 670 litres of ethyl alcohol can be obtained.

Animal manure is another resource available to Pura. The energy survey indicates that Pura's cattle population of 143 yields about 1.02 tons of wet dung per day from overnight droppings alone. Therefore, a community biogas system is envisaged as a first phase of the proposed energy centre for Pura. Family size biogas plants were ruled out because only 71% of Pura's families own cattle. Besides, very few families-only about three- can afford biogas plants. Community biogas plants exhibit economies of scale because a community biogas plant costs only 6.3 times the cost of a family-size plant. It is estimated that even assuming a minimum yield of 0.034 cubic meters per kg of fresh dung, a 42.5 cubic meters per day plant can provide a surplus of 11 cubic meters per day. It is proposed that this excess gas be utilised to run a 5 HP biogas engine which will be able to pump all of Pura's domestic needs of water as well as the plant's need for water in 5.3 hours engine time. Excess gas will also be available to run an electricity generator that will provide electricity to Pura's households for 3 hours every day. The electricity generated will also be available to run a ball mill to grind rice husk and ash and lime for two hrs every day to produce saleable cement. In addition, the plant will yield 1960 kg of liquid slurry every day , having a nitrogen content of 1.9%, which is double the nitrogen content of fresh dung. Pipe system for the distribution of the gas will be provided. Also, overhead tank for storage of water will be provided. The capital cost of this entire project, i.e., the biogas plant, gas distribution system, biogas engine, generator, electricity distribution, pumpset, overhead water storage tank, ball mill for cement production, building and miscellaneous items, etc., is estimated to be about Rs. 70,000. The revenues on electricity and cement are envisaged to bring a return of 22% on this investment, corresponding to an undiscounted pay-back period of 4.5 years. This cost-estimate seems very modest compared to the parallel project in Fateh Singh Ka Purva, U.P., where Rs. 200,000 have already been spent.

In the subsequent phases of the project, a windmill for water lifting and a solar system for low-temperature water heating will be set up. An energy forest will be planted. Ethanol , biogas, and producer gas will be used for driving engines.

After our visit to Ungra, we visited Pura. Pura looked like a typical South-Indian village. The most significant difference between the South Indian and the North Indian villages seemed to be that in North India, the

caste-structure and its social manifestation is much more rigid than in South India. In the North, villagers of lower caste do not use the well that the upper caste people use. But in the South, this is not the case. There is a hand-pump and a well in Pura. Both are used by people of all castes. We visited the only village pond. Animals were grazing around the pond and were drinking water. The pond is also used for bathing, washing, etc., by the villagers. This pond is situated on one side of the village whereas the proposed community biogas plant is proposed to be located at the opposite end of the village. Thus, the water supply for the plant will have to be hand-carried unless the overhead storage tank is set up as proposed. The land for the community plant is to be donated by one of the villagers. On the day of our visit, the ASTRA researchers had come on a mission to measure the land for the biogas plant and to inform the vi agers about a religious ceremony which was to be performed within weeks to initiate the project. Since the ASTRA group did not approach the villagers through a government body such as the Block Development Office, ASTRA has to formalise its ties with the village through such traditional practices aimed at winning the confidence of the villagers. The religious ceremony conducted by ASTRA and the village-council together will also serve the important purpose of informing the villagers about the proposed project and convincing them of its benefits. We contacted the farmer who had promised the land, 2 gunthas or 1/20 th of an acre for the project. He seemed to waver at the last minute, so a long discussion ensued between the group of villagers and the ASTRA personnel. Finally, we figured out what the problem was: the farmer was afraid that he would loose his access to the road by giving up a plot of land next to the road. ASTRA needed the land next to the road however, to carry the dung and the water to the plant. Another problem that the farmer faced was that he had constructed a frame for a house that he wanted to build near the road. He was now afraid that he would have to move the whole structure to another location. The ASTRA group therefore pleaded with the farmer with regard to the proposed location of the plant and also promised to move the structure of his house to another location without any effort on his part. Ultimately, he agreed to donate the land as promised. The ASTRA researchers measured out the land, erected poles in the ground to indicate the boundary of the plot, and thus part of our mission for the day was accomplished. Since all the villagers including prominent citizens in Pura and curious children had gathered all around us by this time, it was easy to inform the villagers about the proposed religious ceremony.

After our day's work was over, we went to the local potter's house to see the pottery work. The whole family including children work on making the clay smooth, running the potter's wheel, beating the pots, glazing them, etc. The potter's house was full of clay and the people seemed to work very hard, in hot, humid weather and very poor working conditions.

On the way back to Ungra from Pura, we stopped at the village-school to inform the school-teacher about the upcoming religious ceremony.

## LUCKNOW:

The Gobar Gas Research and Training Center in Ajitmal has been set up by the Planning Research and Action Division (PRAD) of the State Planning Institute, U.P., with the objectives of doing basic research in biogas technology, and popularising biogas technology among the rural people. I visited the Research Center and spent half a day talking to its director, Mr. Anil Dhussa, a chemical engineer from Roorkie, and his associates, and looking at the various experiments going on at the center. Experiments in measurements of the composition of gas produced from different inputs such as paper wastes, water hyacinths, vegetable wastes, etc., are being conducted. The main constituents of the gas are: $CO_2$, $O_2$, and $CH_4$ (methane). Also, tests are being conducted on the digestion of various materials under laboratory conditions in small jars. The laboratory is well equipped to conduct measurements on the pressure and the flow of the gas. Experiments on the variation in the production of the gas with temperature are being conducted by digesting dung in jars immersed in hot water.

In the yard outside the laboratory, full-scale models of various types of biogas digesters are being tested. A floating-top digester with double-walled exterior filled with paddy husk for insulation was constructed to solve the problem of variation of gas-yield with temperature. It was observed that the gas-yield was higher by 15% in this digester. Two cylindrical black steel digesters were used for digesting vegetable wastes. These have not produced good results yet.

Studies are being made on the reduction of the retention time of the dung in the digester. Reduction of retention-time would mean reduction in the cost of construction of the digester, since more dung would be digested in a shorter time-period. Tests are being made on the use of water-hyacinth as an enoculum to accelerate the anaerobic digestion. Successful use of water-hyacinth would not only mean a reduction in the retention time, but would also mean that it could be used as a supplement of dung in places where dung is in short supply.

Experiments are being conducted to study the digestion process in two stages- 30 days in one digester and 20 days in the other digester.

The research center in Ajitmal is perhaps the only institution in India that has attempted to popularise the Janata type biogas plants (Chinese design). The Janata digesters seem to have several advantages: construction-costs seem to be reduced by atleast 50% compared to the floating-top digesters; maintenance is easier since there are no problems of corrosion encountered with the floating -top design; temperature-fluctuation inside a Janata plant is much less than that inside a floating top or KVIC digester because the Janata plant is constructed underground, thereby reducing the seasonal fluctuation in yield. The center, along with the State Planning Institute, has designed and installed many biogas plants of the Janata design in U P., particularly in Etawah. The center has also done some basic design and construction work to adapt the Janata design to Indian conditions.

Besides the above projects, the center has done work on the design and development of continuous as well as batch feed digesters, crop wastes digesters, two or three stage digesters using mixed feeds, insulated and water sealed digesters, solar heated digesters, rigid PVC and polythene gas bag digesters, fixed dome type digesters, and community size digesters. Studies regarding the manurial value of the slurry and its treatment for better application results are also being studied.

Various devices are being constructed for the proper utilisation of the gas, among which the most impressive are the low-cost burners. The traditional gas-stove, popularised by KVIC, costs about Rs.200, whereas the red and white clay stoves made at the local pottery project cost only Rs.2.00 and Rs. 10.00 respectively. Lamps similar to petromax lamps are being used for biogas-lighting. Biogas lighting seems critical in this region since the region experiences severe shortages of electricity. An electricity generator made by Williers company, with a capacity of 2.5 KW, is being used to generate electricity from biogas. The generator, originally designed for petrol, only needed a slight modification of the carburettor. The engine has a spark-plug starter. A 5 HP engine made by the Kirloskar company uses a mixture of 80% biogas and 20% diesel to pump water. The center has also devised a room-heater that utilises biogas.

Besides the research efforts mentioned above, the Center is involved in the design and development of new burners, pressure regulators, carburettors, and airfuel mixing chambers for internal combustion engines, improving the efficiency of gas production; optimisation of the fermentation cycle and the loading rate; economising the use of construction materials; and the simplification of construction methodolog, etc. Action research projects such as community biogas projects are being implemented as discussed below.

In the afternoon, we went to see several Janata design biogas plants operating in the community. The first house that we went to belonged to the Block Development Officer who is an administrative officer for a group of villages appointed and supervised by the Zilla parishad, which in turn is a government body administered by the District Collector. This household was therefore obviously affluent. Yet, the plant was not maintained properly. The output slurry seemed to have overflowed in the outlet tank and formed a poodle in the yard. Biogas technology is often claimed to be beneficial to the rural communities because it is supposed to improve sanitation. I wondered if improper management of the plants would defeat the very objective with which the technology was set up. The lady of the household demonstrated to us the use of biogas. This household had a more conventional gas burner of the KVIC design as opposed to the new, economical designs we saw later in many other households. The lady expressed complete satifaction with the operation of the plant and said that there was no significant fluctuation between the summer and the winter production of gas. In a family of 8 members, all cooking energy needs of the family are satisfied with the gas obtained from 5 animals.

From this household, we went to Fateh Singh Ka Purva, a village where PRAD has set up a community biogas plant.

Fateh Singh Ka Purva is located about 20 miles from Ajitmal but since there is no paved road leading to Fateh Singh Ka Purva, the journey is long, tiresome and dusty. A paved road is scheduled to be built sometime in the

future. The village, which is much smaller than average, has a population of 173, distributed over 27 households. Agriculture is the main source of livelihood of all the families and 18 families own over 3 acres of land each. The village has a cattle population of 127 which means that the cattle/people ratio is better in Fateh Singh Ka Purva than in the country as a whole. Before the setting up of the community plant, the families used keresene for lighting, and cowdung and crop- residues for cooking. Seven families used firewood. Thus, nearly half the available cowdung in the village used to be converted to dung-cakes.

About 1524 kgs of wet dung are available in the village every day, assuming an average of 12 kg. per animal per day. Most of the villagers belong to the same caste and most of them are related to each other, thus rendering the community more homogeneous than most communities in India. Two biogas plants of the KVIC floating top design, one with 35 cubic meters capacity and another with 45 cubic meters capacity have been installed in the village. Since the rate of production of gas varies from summer to winter, only 57,912 litres of gas are produced in the winter and 83,820 litres of gas are produced in the summer. Gas is distributed through 50 mm GI pipes to every household. The distribution pipes above the ground have a diameter of 15 mm. Both plants are connected to the main 50 mm GI pipe and can each be isolated through valves for maintenance. For lighting, a 3.5 KVA generator set running on a 6 HP dual fuel engine that uses a mixture of 80% gas and 20% diesel is provided. The electricity generated is enough for using two 40 watt bulbs in 23 homes and eighteen 40 watt fluorescent lights in the remaining homes and for street lighting. A 7 HP bore engine, which runs on a mixture of 80% gas and 20% diesel, drives a 4 HP pump thrugh a counter shaft to operate a tubewell. This engine also drives, at different times of the day, (sequentially) a flour mill (5HP), a thresher (5HP), and a chaff cutter (2HP). The machines are all located at the machine shed next to the plants. The original plan was to construct an overhead tank on top of the machine shed, with a capacity of 10,000 liters, to be filled from the tubewell in order to provide tap-water for drinking to the villagers. This has not been done yet. The total cost of the project has been Rs. 2,02,000 so far. The social cost-benefit analysis done by PRAD indicates, however, that the project is economically viable.

A voluntary organisation of the villagers was set up to run the system. This cooperative committee has appointed people to look after the plant, to collect the dung, turn the gas on, run the flour mill, tube-well, etc. We met with the supervisor of the project, who demonstrated to us the operation of the plants, the operation of the various engines, etc. The organisational aspects of the project seem to have worked very well so far since the plants as well as the other operations seemed to be well maintained.

My main objective in this trip was to talk to the villagers, particularly the women, about the project and their perceptions regarding it. We first visited the house of the supervisor of the project. This particular household, like many households in the region, seemed to be divided into two households belonging to two brothers. Women in this region observe the 'Purdah' system which means that they wear a part of their dress, the sari, over their heads, covering their faces, like with veils. In general, women are very seggrgated and do not go out alone. The 'Purdah' system offered me an ideal situation to talk to the women in relative isolation since the men-folk from PRAD who had accompanied me to the project had to stay outside of

most homes because the women were bashful of their presence. The women in this house demonstrated to us the use of the gas stoves. Since two women researchers from PRAD accompanied me to the village, it was easier to communicate with the women in the village because we formed a cosy group. The women were all praises for the new technology. Since, in the winter, the rate of production of the gas declines, and also since the number of cattle in the village has declined since the installation of the project, the gas supply to the villagers is restricted to only a few hours in the morning and a few hours in the evening. This did not seem to dissatisfy the women since most women seemed to be able to manage scheduling their activities around the few hours of gas-supply. The women also expressed satisfaction at the cleanliness, smokelessness, and odourlessness of the new technology. One older woman complained bitterly about the erratic supply of gas. However, this one dissenter seemed to prove the rule rather than disprove it, i.e., that the women were very happy with the marvels of the the biogas technology. It is amazing to see the smooth transition to a radically different technology that the rural folks seem to have achieved in this village.

Most women still keep firewood as a backup for cooking in case the gas runs out in the middle of cooking. Firewood is also used for water-heating. Some households apparantly hold back some dung rather than turning in the entire quantity of dung to the project. Dung-cakes are made out of this dung. PRAD staff was unhappy about this situation because this could be indicative of a more serious shortage of dung in the future. Firewood comes mostly from the fields and is collected by the menfolk on the way back from the farm. Because of the 'Purdah' system, the womenfolk do not go out to the fields at all. Infact, most women did not seem to know where their family's farms were located. This is unlike many other communities in India, particularly in the south, where women are mainly responsible for collecting firewood.

From the supervisor's house, we proceeded to visit every other house in the community. Very soon however, a group of villagers, mainly women and children, (the men had all gone to the fields) started following us around the village. We therefore sat down in the courtyard of one of the houses and started interviewing the women there.

Most villagers use the flour mill that runs on the biogas and are willing to pay for it. However, most villagers do not use the electric thresher, since most households have a manual thresher. Every household has been supplied with an electric connection for one bulb. However, most villagers have not bought bulbs for lighting. The villagers are unwilling to make an investment in the bulbs for several reasons. They do not seem to be desperately in need of electric lighting. They normally use the kerosene lamp which is portable and therefore serves the dual purpose of a stationery and a moving source of light. Most children do not seem to study at home, particularly the school-going girls who are supposed to be only trained in household tasks. Since most villagers are farmers by profession, they do not need lighting for their business and so the incentive to invest in light-bulbs does not exist. Secondly, the villagers have never used light bulbs and are not sure about their reliability. Thirdly, they secretly hope that PRAD will provide them with the bulbs if they continue to be stubborn about buying the bulbs. An average household's consumption of kerosene is only about 2 litres on the average for lighting and therefore, a household spends only Rs. 2.6 per month on the average for lighting. Buying of bulbs will result in a reduction of their monthly lighting bill, but they are aware that the

electricity will not be provided free of cost by PRAD in the future. PRAD wants to charge the villagers Rs. 5 per household per month for the electricity connections in order to generate income to support the operation and maintenance of the project. Most villagers are unwilling to pay this price. When I asked the women about the price which they would be willing to pay for the electric connection, they indicated that Rs. 2 per household per month would be acceptable to them. This is very interesting in the light of the fact the electricity provided from the state electric grid through the rural electrification project costs Rs. 8 per household per month, and that many rural households in the region (Not in Fateh Singh Ka Purva, there is no electricity in the village) are willingly paying that price.

The situtation with the biogas lighting highlights an important aspect of rural development, i.e., the participation of the rural population. The community biogas project in Fateh Singh Ka Purva was set up entirely due to the initiative taken by PRAD. Participation of the villagers was saught at the operation and management stage but the villagers were not involved in the planning and design of the project. It seems therefore, that the project was given to the community without their perceiving the need for it. If the initiative had come from them regarding the setting up of the project, they would not have expected everything to be given 'free' to them. Secondly, the fact that the villagers do not use electricity even if it is provided 'free' to them seems to indicate that electric lighting is not very high on their priority.

I interviewed the village women about their aspirations regarding life. They could not name very many 'felt needs'. This was very interesting in the light of the fact that so many rural development projects today talk of 'felt needs' of the rural communities. The only need that the women felt was for tap water for drinking, since the women, and particularly the younger women in the household, have the responsibility for fetching the water from the village- well. The low aspirations of the villagers are easy to understand if one realizes that most of the women that I was talking to had never been to a big city like Delhi . They visit the nearby town like Ajitmal only as frequently as once a year. Some of the villagers' children have gone off to big cities to earn their livelihoods, but yet, for most of the villagers, the urban life is beyond understanding and comprehension. The lack of aspiration is more startling, however, in the light of the fact that Fateh Singh Ka Purva is the first rural community in India to have a community biogas plant. One would have expected the awareness of the villagers to be at a much higher level than what was found in the community. This situation highlights another important reality of development, i.e., that development schemes have to be 'integrated' in their approach in order to succeed. In other words, if education, sanitation, health, family-planning, agriculture, energy, and other important aspects of rural life are considered simultaneously while planning for 'development', the 'development' plans have more chance of being successful.

After having seen the community biogas plant, we thought that it would be interesting to compare and contrast our experiences there with our experiences in communities that do not have such 'progressive' energy projects. Therefore, the next morning, we visited a rural community by the name of Dalelnagar which is located at a distance of about 20 miles from Ajitmal. Dalelnagar has about 785 households and a population of about 2800 to 2900. Dalelnagar is very different from Fateh Singh Ka Purva in the sense that in

Dalelnagar, there is more variation in several social and economic variables such as caste, religion, income, profession, etc . We went to the house of the village headman who took us on a tour of the village. The village looked quite unclean compared to Fateh Singh Ka Purva. We first visited a pond built by the villagers under the 'food for work' program. Under this program, during periods of draught (the state of Uttar Pradesh and several other northern states were going through a period of drought during my visit), the government funds such projects in order to provide employment to people suffering from the drought. The payment for the labour is made in quantities of food instead of money. The villagers plan to plant trees such as mango, babool, etc., around the pond. The villagers also plan to grow fish in the pond and sell the fish for income. The project will be supervised by the 'Gram Sabha' or the village committee. The trees around the pond will be useful in generating income through sale of firewood, fruits, etc.

Next, we visited the first and the only Janata biogas plant in the village which was under construction in a medium farmer's household. I was especially curious regarding a popularly made claim that family size biogas plants deprive the poor, landless labourers of a 'free' source of energy. I therefore interviewed this particular farmer regarding his pattern of use of cowdung before and after the setting up of the biogas plant. He said that before the setting up of the plant, the animals used to graze freely around the village 'commons' as they do now. The animal droppings are thus available to whoever wants to collect them. Only the dung collected during the night is put in the biogas digester. The PRAD researchers supported this statement. The villager also stated that he and the other cattle-owners never gave away the dung collected at night but that this dung was always used for the farmer's energy needs either through biogas plants or through dung-cakes and composting. If the landless, cattleless labourers did need fuel, they normally collected it from the crop-residues in the fields or from branches of trees, or sometimes even asked the landlords for some crop-residues stored by the latter. Thus, atleast in Uttar Pradesh, the claim that family-size biogas plants deprive poor villagers of a 'free' source of fuel does not seem to hold water, since the pattern of the distribution and the use of the cowdung does not seem to have changed after the introduction of the biogas technology.

Dalelnagar is even more interesting to study because a significant proportion of the population is muslim. Therefore, we interviewed an equal number of Hindu and Muslim households in order to get a reasonable idea regarding the communal problems, if any, associated with energy problems.

The second household we visited was that of an old muslim farmer who has 5 'beeghas' or 3 acres of land. He does not cultivate it himself but gives it to his brother for share-cropping. 'Jwar' or maize is grown in his land. I talked to the man about his energy consumption. His household which consists of himself, his widowed daughter,and her children, uses about 2 litres of kerosene per month. He has no electric connection since his house is not a 'pukka' or permanent structure. He uses mainly firewood from mango and babool trees for cooking. Firewood from mango trees is sold at a price of about 8 Rs. per mond (a mond is 40 Kgs.) , whereas firewood from Babool trees costs about 12 Rs. per mond. Most households use about 2-3 monds or about a quintal of firewood per month. I was surprised by this high estimate of consumption of firewood. Most farmers do not purchase firewood however, but get it from old or fallen trees and branches. This old farmer had made an agreement with his brother regarding the sharing of trees and crop-wastes in

the farm. When asked about the planting of trees, the farmer's response was a classic one. He said that since he had a small piece of land, it was just enough for fulfulling his needs with ragard to food, and therefore, the question of planting of orchards did not arise. So far as planting of trees in the marginal lands such as the border of his farm was concerned, the farmer's experience was that once a tree in the farm was cut down, the shade on the crops was gone and the crops grew much better in the unshaded areas than in the shaded areas. Therefore, the farmers refrained from replanting the trees. When asked about the situation with regard to firewood availability in the future, most farmers acknowledged that there will be a shortage of firewood in the community in the future. But the farmers felt that they could not do much about alleviating the shortage. Their approach to the whole situation seemed to be very fatalistic in the sense that the argument often put fourth by the farmers was that they would not be alive to experience the worst shortages. A part of this attitude stems from Indian culture, which, in general, is much more passive and fatalistic than western cultures. Since Dalelnagar and the surrounding region is experiencing a draught this year, many households had to buy saw-dust for cooking purposes, since not many crop-residues were available. Saw-dust is normally burned in a saw-dust stove which is a cylindrical iron vessel with a narrow cylindrical iron barrel in the center. The saw-dust is packed tightly around this barrel in the center after which the central barrel is removed so that a column of saw-dust stands. This column is set afire by burning wood in the center. Because of the draught, some households used as much as 20 monds of saw-dust this year. Traditionally, cowdung is used partly for fertilizer and partly for making dung-cakes.

Next, we visited the household of a big farmer who is muslim. He seemed to use more wood and kerosene per month. His consumption of kerosene per month was about 4 litres. The consumption might be high because the household seemed to burn one lantern all night. Thus, the average kerosene consumption in the village seemed to vary from 2 litres per month for the marginal farmer to 4 litres per month for the big farmer. Wood use varied from 2 carts to 4 carts a year. (one cart=12.5 monds), or 1 ton to 2 tons per year. For those households that had electric connections, however, the consumption did not seem to vary much with income. This may be because the minimum monthly charge for an electric connection is quite high, viz., Rs. 8 per month. This amounts to about 50 KWH per month. One important observation we made regarding electricity usage was that commercial use of electricity was more important than use for domestic lighting. In other words, households which needed electricity for their business, e.g., tailors, craftsmen, etc., bought electric connections more readily and were willing to pay the price. Here again, the use of electricity for lighting seemed to be a very low priority. When we talked to the tailor's household, we discovered that before getting the electric connection, the tailor used to spend 1 litre kerosene per day during the peak season, partly because most of the tailoring work was done at night, the tailor being busy working on his farm during the day. This consumption of kerosene amounted to an expenditure of 39 Rs. per month for lighting. Therefore, an electric connection that costs 8 Rs. per month is very very beneficial to this particular household. Also, the tailor earns about 200 Rs. per month from his tailoring business during the season (the tailoring season is during the wedding season which is traditionally during the summer), an electric connection is a profitable investment for him. Another interesting aspect of electricity usage in the village was that most households that did have connections seemed to keep atleast one bulb lighted

all night. This is probably a carry-over from the traditional life-style in which one kerosene lantern or lamp is kept burning all night for the members of the household to carry it around in case they get up to answer the call of nature. The all-night kerosene lamp also serves the purpose of ensuring the security of the household. Since lighting a kerosene lamp is not an instant-operation like lighting an electric lamp, and since the ready availability of the lamp is valued, traditionally, the custom of keeping one lamp lighted throughout the night has evolved. With the shift from kerosene lighting to electric lighting, the custom will slowly change but the community is still going through a transition period in which the old life-style seems to be still followed.

## DELHI:

### The Planning Commission:

Jyoti Parikh at the Planning Commission is involved in developing an energy demand forecasting model for India. She is very knowledgeable with respect to the subject of energy and economic planning for India. I talked to her about the international conference in bioconversion that had just concluded in Delhi. She seemed to think that alcohol fuels had very little potential for India and that the real solution was in biogas and fuelwood plantations.

### The National Council for Applied Economic Research (NCAER):

I met with Mr. Ashok Desai at NCAER regarding the survey of fuel demand in Northern India that was recently completed, and the survey of kerosene demand conducted earlier. The kerosene-survey was conducted mainly in Uttar Pradesh (U.P.) whereas the Northern region survey was conducted in U.P. and some other states in Northern India. Mr. Desai is not involved with the conduction of the survey and its conclusions but is working on the energy policy aspects emerging from the survey. Mr. Desai introduced me to Mr. Venugopal who is responsible for the surveys. He gave me the sample questionnaires and also a set of norms that were used regarding energy consumption.

### The Center for Developing Societies:

I met with Mr. Vinod Kumar from the center. Mr. Vinod Kumar is a Civil Engineer who has been working on land use planning and urban and rural planning. The Center is a private research organisation funded by various government agencies and private foundations. The Center conducts research on multidisciplinary areas related to development. Mr. Vinod Kumar himself is involved with a project in integrated rural development in the Mahanar block of Bihar. Mahanar is probably one of the most 'underdeveloped' areas in India. There, with the help of a group of volunteers, he is conducting a

survey of socio-economic conditions. I got a copy of the questionnaires for the proposed survey. Mr. Kumar plans to set up a new irrigation system in the village which consists of a combination of bullocks and sail-type windmill. When the wind-speed is too low, bullocks will be used for pumping the water. Other plans for development are also underway. Mr. Vinod Kumar seemed interested in collaborating with U.S. institutions.

## Department of Science and Technology (DST):

I met with Dr. Gururaja who heads the 'New Energy Technologies' group at DST. Dr.Gururaja was a little sceptical about the widespread concern regarding fuelwood use. He believes that fuelwood use is not the principal cause of deforestation but that other uses of trees, such as timber, might be behind it. He was interested in comparing the total efficiency of a biomass energy scheme such as a fuelwood plantation with a direct solar system using collectors. He claimed that the efficiencies would probably be comparable. I pointed out to him that, biomass plantations were not recommended on the basis of their efficiency but because they are within the reach of most rural folks. Secondly, if one looks at energy technologies from the point of view of performing specific tasks, fuelwood plantations have a definite advantage, since they provide a fuel that is ready to be used, whereas, most direct solar technologies need further infrastructure for their use.

Mr. Gururaja was very interested in the proposed collaborative research project involving RSI and ERG. I gave him a draft of the proposal.

## MADRAS:

I visited the Murugappa Chettiar Research Center which is a private research institution funded by a group of industries (mainly chemical industries), involved in doing action-research in integrated rural development schemes. Dr. C.V. Sheshadry, who used to be the Dean of Chemical Engineering in the Indian Institute of Technology, Delhi, heads the research center. There is a staff of about 15 people in the center, which consists of chemical and civil engineers, aquaculture experts, rural development planners, etc. The center has a few acres of land for its laboratory experiments. As stated above, the center is involved in research on integrated schemes in rural development, and, therefore, the energy-related rural development schemes form only a small part of the programs at the center. In the yard at the center is a new design for a well with a thatched roof to reduce the evaporative losses of water. The roof over the well resembles the roofs of the houses in the region which are thatched, conical shaped constructions on bamboo frames. The roof and the walls normally have a foot of gap between them-though the roof is supported by poles on the walls-in order to allow for ventilation. The same kind of roof is used with the wells so that the evaporation losses are reduced.

MCRC has done a lot of work in the design of low-cost, small biogas digesters. The new design uses a gas holder made of polyvynil shaped like a geodesic dome. Some weights have to be kept on the dome to prevent it from flying away. MCRC claims that the cost of this new biogas plant is only about

Rs. 1500 compared to Rs. 4000 for the conventional KVIC design and that the cost of replacing the plastic every now and then is still not significant enough to make the traditional design more attractive.

MCRC has built simple solar dryers for drying crops which consist of inclined jute-boxes with black polythene on the bottom and transparent polythene on the top. Water hyacinth is dried in these boxes to reduce its water-content to 20% and then the dried water hyacinth is fed to the animals. Drying of water-hyacinth is necessary before it is used as an animal feed because the water- content in water-hyacinth is too much for the animals and can be harmful to them.

MCRC is doing experiments in biodynamic gardens or, more simply, organic gardens where manure is used as fertilizer and natural substances such as extract from 'neem' leaves are used as pesticides. Mr. Roy, a scientist from MCRC, told me about a certain theory that postulates that if plants are planted on a full-moon-day, they show improved rate of growth.

Ponds lined with polythene are being used at MCRC for growing blue-green algae such as spirolina. Cowdung is added to these plants to catalyse the growth of the algae. On the roof of the laboratory, fish is grown in ponds containing cowdung. These fish ponds also act as a sky-therm roof because they are covered during the day, to reduce evaporation and to reduce excessive heating of the water which can be harmful to the fish. At night, the ponds are uncovered so that the water gets enough oxygen. Thus, during the day, the water in the ponds absorbs the heat from the building, and, at night, it radiates it away to the sky, thus moderating the temperature of the building. Since it is never really cold in Madras, and since the heat is a problem all year around, this system is effective in creating comfort conditions in the building. Compared to other buildings in the MCRC complex, this particular building did appear to be cooler inside. There is also a model of a uni-directional wind-mill on the roof.

We visited the 'Ijambakam' village next. This village has been 'adopted' by MCRC in the sense that an intensive program of integrated rural development has been undertaken by MCRC there through volunteer social workers as well as through MCRC researchers. We walked around the village. It is a typical coastal village with coconut and palm trees and houses with thatched roofs. We visited the only pond in the village. Unfortunately, this pond has water-hyacinth growing in it which means that the loss of water due to evaporation is excessive. Getting rid of the water-hyacinth is a real problem. MCRC employs villagers to cut the water-hyacinth which is then digested in biogas plants or is fed to the animals. To cut the water-hyacinth in the middle of the pond is a tricky operation, however, and is done by MCRC researchers with the help of canoes. The water from the pond is pumped by the villagers for irrigation purposes with the help of a pump provided by MCRC. The time of operation of the pump is shared by the villagers. The water thus pumped is put into irrigation canals which transport it to the fields. The one problem with this arrangement is that the seepage losses in the canals are too great because of the sandy soil. MCRC is thinking of making a polythene lining for the canals to prevent the seepage.

In the village, there is a long stretch of barren land that is unused right now. The land is barren because of the seepage of salt water from the sea which is not far away. MCRC is thinking of ways to reclaim the land, not

through planting of trees, but first by keeping the salt water away from the land thrrough civil engineering means. A civil engineer in MCRC is working on this.

A full-scale unidirectional wind-mill is used for pumping water from the earth into a fish-pond. Since Ijambakam is near the coast, the water-table here is very nigh and therefore, water can be pumped from the ground with the help of pumps. MCRC is designing a bidirectional wind-mill for the village.

Ijambakam village has a number of MCRC design family size biogas plants that use cowdung or chicken manure. We saw some under construction. A number of households have biodynamic gardens that use dung-manure as a fertilizer and neem-extract as a pesticide.

MCRC has also constructed polythene lined fish ponds (to avoid seepage) and has started cultivating carps in them. These fish ponds have been constructed in individual villagers' houses and the produce from them will be available to the villagers.

We visited a fishing village near Ijambakam. This village, since it is right on the coast, is often completely destroyed because of cyclones. The Red Cross has now constructed a cyclone shelter. Also, some government and voluntary organisations are involved in rebuilding the village completely. MCRC plans to set up a community biogas project there which will use the nightsoil from the latrines as an input. Apparantly, the villagers do not feel any taboos regarding the use of nightsoil in the digester, although in many other parts of India, this has been a serious problem.

## CONCLUSIONS:

The research related to biomass and biogas energy technologies and resources in India seems very impressive. I was particularly impressed by the work done by PRAD, Lucknow, by MCRC, Madras, and by the C.C. Snroff research institute, Bombay. Biogas research seems to have progressed much more than biomass-related research. The biogas technology in its various designs has been tested, implemented and proven to be economically viable. It is a more or less accepted technology in India, although some of the basic policy questions related to it, such as family-size versus community plants remain to be resolved. The basic question that needs to be answered with regard to the biogas technology is therefore, what policy should the government agencies such as KVIC adopt with regard to the biogas technology? Should they start research and development with regard to community biogas plants and give financial and other incentives to village cooperatives willing to set up community biogas schemes? Should KVIC and other concerned government agencies help rural communities in organising village cooperatives and generating the social and organisational infrastructure necessary for the setting up of such projects? In this respect, one interesting observation worth mentioning would be that at the 2nd International Symposium in Bioconversion, Dr. Nurul Hassan, the director of the Counsil of Scientific and Industrial Research, commented in his inauguratory speech that the biogas technology was an 'elite' technology that had widened the gap between the poor and the rich people in India. This comment created quite a stir in the press and the academic

institutions and government agencies. It seems clear therefore, that India has to make a policy-decision regarding biogas technology very soon. Looking at the research, action-research, and development programs of the leading academic institutions and government agencies and the direction that these programs are taking, I feel that the trend is towards community biogas projects.

So far as research priorities in biogas are concerned, research on low-cost and smaller scale designs seems to be required. Also, research on microbial aspects of anaerobic digestion process would be useful.

With regard to the social acceptability of biogas technology, I feel that no significant problems exist. Also, biogas technology does not seem to have caused any serious perturbations in the pattern of use and distribution of cowdung as well as in the social set up in the rural communities. On the other hand, it might have reduced some of the pressures on the energy supply situation in the rural areas.

Biomass technologies, on the other hand, are very much in the initial stages of development in India. Fuelwood is an established and traditional source of energy in India, and in that respect, biomass is not a new energy resource. But on the other hand, planned management of biomass resources has been conspicuous by its absence. The concern regarding biomass as an energy resource is relatively new in India. Fuelwood plantations and forestry projects seem to have a lot of potential and the governement and research institutions are seriously evaluating them as an energy resource now. Monitoring of fuelwood or energy plantations with regard to their growth, energy efficiency, economics , etc., has been done only in a few instances. MCRC in Madras is probably on the forefront of biomass research in India right now. With regard to research and development priorities regarding biomass, one can say that the area that needs most attention is the development of village fuelwood lots. Social organisational problems would have to be solved for a proper implementation of village-energy -plantation schemes. One area of scientific research that the devloped countries could help the developing countries in and which was brought to my attention by government agencies managing forestry projects was the analysis of photosynthetic efficiencies of different wood species and their resultant energy efficiencies.

So far as the acceptance of biomass technologies by the rural communities in India is concerned, one can say that the villagers understand the concepts but do not have the resources or the incentives to attempt a solution. It is clear however, from the experience with biogas, that the rural societies are easily adaptable to new technologies. Also, biomass technologies are not likely to cause social perturbations harmful to the rural lifestyle. In conclusion, one could say that prospects for both biogas and biomass technologies in India look very bright.

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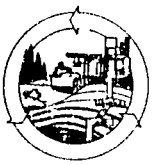

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**THE EAST-WEST CENTER**—officially known as the Center for Cultural and Technical Interchange Between East and West—is a national educational institution established in Hawaii by the U.S. Congress in 1960 to promote better relations and understanding between the United States and the nations of Asia and the Pacific through cooperative study, training, and research. The Center is administered by a public, nonprofit corporation whose international Board of Governors consists of distinguished scholars, business leaders, and public servants.

Each year more than 1,500 men and women from many nations and cultures participate in Center programs that seek cooperative solutions to problems of mutual consequence to East and West. Working with the Center's multidisciplinary and multicultural staff, participants include visiting scholars and researchers; leaders and professionals from the academic, government, and business communities; and graduate degree students, most of whom are enrolled at the University of Hawaii. For each Center participant from the United States, two participants are sought from the Asian and Pacific area.

Center programs are conducted by institutes addressing problems of communication, culture learning, environment and policy, population, and resource systems. A limited number of "open" grants are available to degree scholars and research fellows whose academic interests are not encompassed by institute programs.

The U.S. Congress provides basic funding for Center programs and a variety of awards to participants. Because of the cooperative nature of Center programs, financial support and cost-sharing are also provided by Asian and Pacific governments, regional agencies, private enterprise, and foundations. The Center is on land adjacent to and provided by the University of Hawaii.

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