NON-CONVENTIONAL ENERGY DEVELOPMENT IN INDIA

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A report of studies conducted through a
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based at the Indian Institute of Technology, Bombay,
and advised by Professors
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Dedicated to Surendra Bansode, his family, and the countless others whose warm generosity made this work possible.

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Everything in India attracts me. It has everything that anyone with the highest aspirations could possibly want. - M. K. Gandhi

Part I. Indian Development Experience

In the fall of 1997 I came to the Indian Institute of Technology, Bombay (IITB), to learn about energy development under the sponsorship of the U. S.-Indian Fulbright Exchange Program. Nearly every person who found that I was an exchange student asked the same question. "Why," came the query, "have you come to India to study? Your country must have better universities -- our best graduates are going there." Time and again I fielded this question. The point to make clear was this: I came to learn not just the technology of non-conventional energy -- for which the U. S. may well have been a better choice -- but also, and primarily, to learn about the application of that technology to the problems of the developing world.

In the area of practical development and utilization of non-conventional (in American parlance, alternative) energy sources, especially for the rural sector, India is far in advance of the Western world. This was my conjecture, when I first decided to come to India for study; the past year's experience here[1] has amply borne out the guess. India's advancement in practice, considering the fact of its extremely rapid (but still incomplete) industrialization, should come as no surprise. Unfortunately, little of the vast body of Indian experience on energy development is available to seekers outside of India, with the exception of technical reports and papers.

Although such reports may be useful to the relatively small community of scientists engaged in various aspects of energy development, they lack any context by which to evaluate their importance outside of purely scientific circles. This is a serious lack -- almost a guarantee that those in the business of development, without the benefit of direct experience, will work in virtual ignorance of India's energy-development scenario. The intention of this report is therefore twofold: first, to provide a comprehensive (though hardly complete) view of energy development in India; second, to enable other students (which for practical purposes includes any Western specialist without experience in the developing world) to come to India to study its development at the source -- to learn from its experts in immediate proximity to the urgent human need which should be the *raison d'etre* of any aspiring development specialist.

Accordingly, the report begins with a brief account to establish the scope of my work -- geographically, the environs of Bombay,[2] plus additional sites up and down the west coast of India; topically, most types of non-conventional energy, with the exception of geothermal. Then I recount in some detail my experience with various technologies for and approaches to energy development. This includes a number of criticisms and suggestions for improvement, and an outline of those ideas most promising for sustainable energy development. Following this, I present a gazetteer of

[1]I began this manuscript in Bombay.

[2]Although the city's name is officially Mumbai (as it has always been called by speakers of Marathi), Bombay is more commonly used when English (or sometimes even Hindi) is spoken. In this report, the English term is always used except in addresses and some place names (e. g., Mumbai Central Station). In Bombay, the two names are practically interchangeable.

ten development organizations which are explicitly inviting the participation of students and other seekers wishing to work in collaboration on problems related to energy development. These organizations form the core of my own learning experience, and it is principally their activities which I intend to publicize in this report.

I came to India with the benefit of very little knowledge of energy development, or of the thousands of organizations and individuals actively pursuing research and development in this field. I hope that this account of my learning will provide not only a means for others to discover the wealth of Indian experience with development, but also the inspiration to do so at first hand.

Necessity is the mother of all invention. - Anon.

Part II. Technologies and Approaches

Very broadly speaking, I spent my time in alternation between Bombay, learning technical and organizational aspects of energy development, and field sites outside of Bombay, getting a sense of the vagaries of practical implementation. Approximately nine weeks out of nine months were spent outside of Bombay on trips to Gujarat (solar cookers, Gandhian social development), Delhi (power-sector policy), Goa (rural development and tourism), Kerala (micro-hydroelectric power, ocean wave energy) and Pune (rural agroindustries, wind power). These trips were spread throughout the duration of the study, with the remaining time spent either visiting research and development organizations in Bombay (TIFR, IGIDR and others) or studying at IITB. The sponsored term of nine months was followed by three months of approved independent study. The relatively large scope of survey came at the cost of completeness: such major areas as solar photovoltaics and biomethanation receive only passing mention.[3]

My schedule of visitation and study was quite ad hoc, as I had nothing like a central database of activity to direct my work. I proceeded from group to group by word of mouth, obtaining new contacts from the organizations themselves. Broadly speaking, the organizations fell into four categories: government agencies (central and nodal), university departments, independent research institutes and private concerns or NGOs. All Government of India (GOI) activity in non-conventional energy development falls under the aegis of the Ministry of Non-Conventional Energy Sources (MNES), which operates at the state level via nodal agencies: Maharastra Energy Development Agency (MEDA), Gujarat Energy Development Agency (GEDA), etc. Many organizations of the non-governmental categories work in formal or informal partnership with these government agencies. Much of the development work I reviewed was centrally planned -- undertaken and directed by government, rather than private or commercial, initiative -- but my general conclusions remain valid for modes other than central planning.

The role of MNES and the nodal agencies in the overall scheme of non-conventional energy development warrants some explanation. The principal function of these agencies is to encourage the diffusion and adoption of technology utilizing non-conventional energy sources: in other words, these agencies do little direct R&D. Their aim, rather, is to support the initial stages of technical and commercial development of relevant energy technologies, as well as to encourage further (commercial) development with financial and fiscal incentives. The agencies also play an active role in the fashioning of GOI policy guidelines amenable to non-conventional energy development. Because each nodal agency generally works in all areas of non-conventional energy (i. e. solar thermal and SPV, wind, hydropower, biomass and integrated rural energy planning), they receive no further description here. Further information on MNES and the nodal agencies may be found in part III, **Key coordinating organizations**.

For the sake of coherency, the material presented in this report does not reflect the

[3]See the sections **Biomass energy** (for biogas); **Approtech and rural development** and **Other solar technologies** (for SPV).

haphazard way in which I gathered it. Rather, it is necessarily organized by topic, in terms of either technology *per se*, or its application. Where application of technology is concerned, there are many instances where the marked difference between urban and rural circumstances necessitates careful distinction. Not every topic was covered equally, so that some technologies (solar cookers, microhydel) receive critical evaluation at much greater length. The material which is not technology-specific (i. e., which concerns more than one technology) is discussed according to field of application -- rural development, education, agriculture, etc. A few of the many controversies surrounding the field of energy development are discussed, since they illustrate the way in which the problems hindering basic infrastructure development are seldom purely, or even principally, technical. Finally, I attempt to deal with the integral and implicitly global nature of energy development.

Many of the organizations mentioned or footnoted below appear again in part III with more detailed information about their areas of interest and how to contact them.

Solar cookers.[4]

The idea of utilizing solar radiation for cooking, at its present level of technical refinement, is a superficially attractive notion which largely fails to improve upon conventional cooking modes. Solar cookers are among the "advanced" devices which are supposed, by virtue of their basis in scientific knowledge, to bring modernity to backwards areas. The promotion (and outright marketing) of such hardware, thanks to the persistent confusion of technology with the physical devices that manifest it, continues to dominate the paradigm of development in all sectors, not just energy. The scores of broken, non-functional and otherwise disused solar cookers (and other renewable-energy gadgets) which litter some villages in Gujarat, among other states, exemplify the inadequacy of mere hardware diffusion as an approach to infrastructure development.

In the case of solar cooking, the technological difficulties associated with concentration of solar radiation and its direction to a cooking surface largely offset the supposed advantage of using a "clean" energy source. Solar cookers fail to live up to their promise in at least three ways: their high capital requirement (especially relative to traditional sources, i. e. dung or firewood) makes them seldom cost-effective; intrinsic limitations (e. g., dependance upon the presence of the sun) require logistically or culturally unreasonable changes in the content, preparation and timing of meals; and even a fully utilized cooker does not unequivocally "save" the environment. These points will be clarified for the case of one parabolic cooker (designated the SK-14) currently promoted by a German solar development group.[5]

The cooker in question, essentially meant for use in rural villages, is promoted as being easy to construct with indigenous material and labor, powerful and hot enough for any kind of cooking (including baking and frying), and advantageous in saving time, health and trees. These claims are

[4]The conclusions of this section are drawn from my visit to the organization ICNEER, but do not necessarily represent its views. See the entries for ICNEER in part III, **Collaborating organizations**.

[5]EG Solar. See appendix A.

superficially correct: the cooker's frame can be fabricated from common mild steel stock, nuts and bolts and requires no welding; with a diameter of about a meter, the reflector in full sun effectively delivers around 500 watts of heat (in tropical latitudes) to any black surface placed at its focus, so that it does boil water quickly and is easily capable of attaining the temperatures required for frying and baking. When used as intended -- according to promotional literature, with dark glasses and a shaded chair next to the cooker -- an hypothetical cook would be exposed to no smoke and could prepare a meal in comfort while saving several kilos of wood per hour of preparation.

However, these advantages are fatally offset. First, the reflective surface is made of special aluminum material that must be imported from Germany and is relatively expensive, hurting both cost-effectiveness and the goal of making the technology self-sustainable. Second, frying in an open container is out of the question because the splattering oil would quickly degrade the reflecting surface, meaning that any food requiring frying in any stage of its preparation cannot be made without risking the integrity of the reflector. This is a serious limitation, as many popular and traditionally necessary foods are fried. Third, the cooker requires more or less constant monitoring to track the sun (needing adjustment at least every twenty minutes) and is generally inconvenient to use -- this statement is based on my own use of the cooker in question. Having to rotate the reflector out of the way to check the food, intense glare from the reflector and exposure to sun and wind all reduce the relative advantageousness of the cooker compared to cooking indoors over a fire or chulha. Finally, the cooker cannot be used early in the morning or at night, when meals are commonly required, nor during the monsoon. Use of the cooker therefore eliminates neither wood-gathering nor cooking over smoky fires. There is no guarantee that the amount of wood saved during the lifetime of the cooker even balances the energy consumed in and environmental impact of fabrication of the steel stock and aluminum reflector. To the extent that the SK-14 embodies the qualities of a typical parabolic cooker, the rationale for promoting solar cookers -- rather than, for instance, working to develop the infrastructure of conventional utilities -- remains dubious at best, not least because the promoters themselves seldom if ever use the gadgets they promote. It makes little sense to popularize a clean-energy device on the basis of hazy or cosmetic benefits while neglecting the possibility of superior alternatives.

Notwithstanding the drawbacks of most concepts for solar cookers, the use of solar energy for cooking should not be dismissed out of hand. At least one clever design, a large-diameter paraboloid[6] meant for community cooking, manages to overcome most of the conceptual faults of the conventional parabolic cooker. Employing a fixed focus to the side of a 7-m^2 flexible collecting surface (tiled with conventional flat mirrors) which tracks the sun about a polar axis via a mechanical clockwork, this cooker is designed to be installed along with a custom-made stove and kitchen built, in essence, around the focus. In cloudy weather or at night, the stove can operate in a conventional wood-burning mode. The design is tailored to the needs of a community kitchen and amply meets them; it is easy and convenient to use, powerful and rugged. Though far more complicated than a conventional parabolic one, this cooker can be constructed entirely with indigenous material and labor, so that the technology can, in principle, be locally sustainable. This cooker comes as close as any to the ideal of a technology which puts freely available energy at the disposal of people who need it.

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[6]This cooker is deployed by the German group ULOG, also working through ICNEER.

In spite of the relative maturity and success of this cooker, it is not immune to the faults of implementation which defeat many otherwise well-executed development programs. A study monitoring the use of 31 installed units in 17 locations in India showed that the cooker's cost would break even with the price of wood saved over its lifetime only under the most favorable circumstances -- i. e., consistent cooker operation resulting in wood savings of at least 50% of optimum, and high wood prices.[7] The study concluded, as well, that the amount of wood saved in actual use of the cooker was only 25% of expected optimum. Moreover, fully two thirds, or 21, of the units did not function at all due to lack of maintenance or other organizational malfunction.[8] For instance, it was not uncommon for the person initially in charge of managing the cooker to move on without training a successor. In another case, an administrator who was quite keen on using the cooker was replaced by one who was not. Such failures are organizational rather than technical, but ruin the cooker's effectiveness just the same. A final point is that, even under conditions of optimal utilization, this large, expensive and complicated cooker scarcely accomplishes more than a few dozen box cookers which are, in sum, far less expensive in capital and labor. It is not at all clear that the large cooker represents a better allocation of resources than a comparable collection of box cookers.

Ultimately, the successful implementation of such a cooker, or any related technology, will require cognizance of not just bald technical parameters, but all of the factors of economy, society and culture which affect the use of the device. First and foremost, is the cooker cost-effective compared to wood, kerosene or other conventional modes? Given the relatively high capital costs of solar technology, the possibility that a conventional utility infrastructure is economically, socially and even environmentally more sound -- especially in the context of rural India's needs -- must be objectively weighed. In particular, it simply cannot be assumed that solar cooking necessarily has a more favorable impact on the environment than conventional fuel-based cooking.

Other factors affecting the use of cookers are plain to recognize, but rather difficult to analyze. For instance, subsidy is often regarded as an easy way to impose cost-effectiveness on otherwise inefficient technology, but the results of subsidized energy programs are often unexpected and unintentional, if not downright disastrous; the general tendency (as with other subsidized public services) is for people to abuse or exploit the subsidized item without care for its condition, since they have no personal stake in its proper use and maintenance. Another example relates to gender sociology. Although women do most of the cooking in Indian households (as elsewhere), and presumably decide how and with what utensils to do it, they do not necessarily have commensurate command over the household's finances. A man may agree to buy or use an unfit or inconvenient cooker without the consent or feedback of the wife, mother or daughters who actually use the device -- or, contrariwise, he may refuse to purchase a good cooker on his own grounds, though the cook may be amenable to its use. The diffusion of cooking (or other domestic) technology is not only a matter of utility and cost, and to quantify the effect of customary gender distinctions on purchasing choice in these circumstances far surpasses the current fledgling state of social science.

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[7] Sutter, pp. 23, 29.

[8] Ibid, pp. 12, 23, 19.

Aside from such complications, the most important determinant of the success of a cooker must be its basic utility. It follows that an accurate evaluation of solar-cooking technology in terms of utility (under realistic conditions) must precede any rational program to promote it. Failing sufficient utility, the technology must be redesigned -- a point too often ignored by impetuous promoters. However, not even utility is sufficient reason to push solar gadgetry, when more conventional infrastructure development may be the proper technological input. No responsible energy planner can ever afford not to weigh conventional (fossil-fuel based) options against renewable energy, notwithstanding valid environmental concerns: use of renewable-energy technologies does not guarantee environmental preservation, any more than use of fossil-fuel technologies precludes it. This point is obvious, but too often ignored in the heat of environmental zeal. Although the debate of fossil-fuel energy versus renewable energy certainly bears on any decision to pursue solar-cooking programs, this debate is far from unequivocal, especially with the naive emotional bias towards superficially "clean" and "green" practices which is in vogue.

Finally, the implementation of solar-cooking technology must be careful and conducted in at least minimal awareness of the socioeconomic environment to which it is expected to contribute. An implementation program must provide for maintenance if the technology itself does not obviate such a need. Those who consider themselves development experts must recognize that technology consists of ideas more than devices, so that a true transfer of technology is seldom as simple as introduction of commodities to a new market. Responsible planning must acknowledge and address all of these considerations, in the energy sector no less than others.[9]

In optimizing the allocation of time and resources, the choice of whether to pursue solar-cooking (or other solar-energy) technology is seldom clear-cut. Without doubt, such renewable-energy devices as solar cookers can ameliorate the energy supply crisis in some areas, under some circumstances. Actually making them do so is far from an easy task, but worth pursuing. The basic box cooker -- an insulated box with a glass top and a secondary reflector in the lid -- provides a slow but easy and foolproof way of cooking rice, lentils and vegetables, and remains the best design overall. However, neither this nor any solar cooker (with the exception of hybrid designs) can possibly replace conventional modes of cooking, at present. In my experience, the real utility of solar energy lies not with cooking, but in the other applications of solar-thermal and SPV devices.

Other solar technologies.[10]

The basic factors of success and failure for solar cookers are virtually the same for other renewable-energy devices, such as the solar water heaters, distillers and dryers, SPV pumpsets and lighting systems, windmills and other demonstration gadgets which have been distributed in relatively large numbers[11] by MNES nodal agencies. Mature technologies -- i. e., technologies

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[9]Of course, planning is not the only paradigm for development. See the end of part II, Integration.

[10]Strictly speaking, the term should be "solar-energy technology," but in context the energy component should be clearly implicit.

[11]As of 1997, MNES claimed the achievement of 400 000 square meters' area of solar-thermal

which have been optimized in terms of design, operation, and production -- carefully introduced and maintained generally succeed. Unfortunately, early attempts to promote renewable energy were characterized more by gadgets distributed without adequate knowledge of (or even need for) their use and without provisions for maintenance, demonstration devices which are poorly functional or otherwise inconvenient, and development campaigns ignorant of the basic circumstances they intend to improve. A general failure of such half-hearted, cosmetic efforts to effect any lasting change can hardly be surprising. Though obvious failings are easy to criticize, correcting them is another matter. Fortunately, the nodal agencies and other organizations are beginning to incorporate effective changes on the recognition of obvious problems in their earlier approaches.

Solar water heating systems enjoy wider use than any other solar-thermal device in India. Many of the early solar hot water systems subsidized and distributed by the government nodal agencies are not now working, due to a lack of care and maintenance. However, the agencies have accomplished their main purpose where solar hot water heating is concerned, namely to popularize its use and enable its commercialization. This is one technology which has been commercialized fairly successfully, if one is to judge by the visible proliferation of solar panels, especially at hotels and tourist lodges.[a]

The majority of water heating is for domestic use, but research interest in industrial and commercial applications is gathering steam. Although direct generation of process steam with solar heat is of interest, the relative expense of concentrating versus flat-plate collectors has, according to conventional wisdom, made solar pre-heating of boiler water (followed by conventional boiling) more cost-effective per unit of solar energy utilized than direct solar steam generation.[12] Preheating is also more amenable to retrofitting, since no special changes need be made other than installing the solar heating system and diverting cold input water through it to the boiler. Applications for the resulting steam (and heat) include dairy and other food processing, textile manufacture and conversion to turbine shaft power. Poor conversion efficiency of heat into electrical power[b] at the relatively low temperatures (below 200 degrees Celsius) attainable with most collector systems generally precludes the cost-effective production of solar-thermal power, though this is not necessarily the case with hybrid systems. MNES is planning a 140 MW hybrid solar/conventional power plant for a site at Jodhpur (Rajasthan).[13]

Although SPV systems for rural lighting have been widely distributed by the nodal agencies, they generally suffer from lack of maintenance and deterioration of the semiconductor cells. Their high cost currently precludes commercial viability in India. The same can be said of SPV pumpsets. However, there is a key difference between the two. Even in theory, nighttime lighting is not an ideal use of SPV power, since there must obviously be batteries or some other

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collectors, 430 000 solar cookers, 2.5 million biogas plants and 23.7 million improved chulhas nationwide (MNES Renewable Energy p. 8).

[12]However, at least one developer of a solar-steam system, Dr. S. Kedare, has found the difference in cost between flat-plate and concentrating collectors to be negligible in the case of his own system. See the entry in Part III, Solar technology.

[13]See under *Power from Renewables* in appendix B.

means of storing the energy during the day; even when relatively cheap lead-acid batteries are available, their use becomes problematic under the wide distribution needed for substantial solar electrification. There would be the additional requirement of inverters, if lighting was to be of the more efficient tube (fluorescent) type. One the other hand, SPV power would be ideal for agricultural pumping, if the cost were low enough: electric pumpsets are already widely available, and scheduled irrigation could be accommodated with storage tanks, continuously filled when sunlight is available and gravity-discharged as needed. Since there is every indication that the cost of SPV technology (per unit of power produced) will go down, with incremental improvements in light transmission and conversion efficiency and semiconductor-crystal manufacture, water pumping is an application for SPV technology eminently worth pursuit.

Other applications of solar thermal energy are feasible but remain slow to be developed. Perhaps the most useful of these, considering the abundant insolation of the subcontinent, is solar-powered heat pumping. One device in this vein is the vapor-absorption refrigerator (VAR). The heat pumping of this device depends upon the high absorbency of a reservoir of material to maintain low vapor pressure above a fluid which is boiled at the temperature of refrigeration, carrying heat in latent form in the vapor, to be rejected at a passive heat exchanger. With no moving parts, this refrigerator is (in theory) easy to construct, durable and (again in theory) can use water as the working fluid. A sensible use of the VAR would be for cooling during the day, such as maintaining a cold room for storage of produce. In a room with the correct heat-transfer properties (i. e., efficient external insulation and internal walls with high specific heats), active cooling only during the day would maintain temperature at all times within a proper range. Unlike electrically or mechanically (diesel) powered refrigerators, the VAR would not generate heat in excess of solar influx. Although ideal in concept, this application remains to be proved viable.[14] (A related concept, vapor-adsorption refrigeration, has already been proved to a certain extent and is briefly discussed in the final section of part II).

A number of institutes are working to develop, in addition to those already reviewed, solar-thermal devices for distillation of water and drying of agricultural products. Some of these institutes work closely with the nodal agencies in their development activities. For instance, the Sardar Patel Renewable Energy Research Institute[15], in addition to its normal research regime, contracts under GEDA to evaluate renewable energy devices submitted for inclusion in GEDA's subsidy scheme. Devices which pass muster are eligible to be financed by IREDA soft loans at a rate which depends on the device and user.[16]

A final concept worth mention is that of the solar pond. Although only a few of these have been built, the prospect for cost-effectiveness (especially in dry, high-insolation areas) seems good. A large solar pond in Gujarat which produces hot water for a dairy processing plant has been

[14]See the entry for Dr. P. R. Apte in part III, Solar technology.

[15]See Appendix A, under solar energy.

[16]For solar thermal systems, excluding solar cookers, the rate varies from 2.5% for domestic users, to 8.3% for for-profit industrial users (MNES Renewable Energy p. 18).

shown to compare favorably in cost with conventional (coal) heat generation.[17]

Wind power.

India's wind-electric-generation capacity is relatively insignificant compared to conventional sources (including large hydro) -- 823 MW out of over 80,000 MW total capacity, as of 1996 -- but there is great potential for its expansion. MNES estimates total available wind-generated capacity to be at least 20,000 MW,[18] although it should be understood that even a realized wind capacity of this size would not be comparable to conventional capacity of the same size, due to the much lower availability of wind power.[c] Among non-conventional sources, in spite of its low availability, wind is currently the most likely candidate for cost-effective, large-scale generation of electrical power.

The distribution of wind farms is concentrated in Tamil Nadu and Kutch (Gujarat), those two states accounting for over 750 MW of the installed capacity. The large majority of all wind farms (accounting for 775 MW of the total[19]) are commercial undertakings. In Maharastra, four demonstration wind farms are currently operational. I was able to visit only one of these sites, a grid-connected 2.77-megawatt installation at Chalkiwadi, built and operated by the Maharastra Energy Development Agency.[20]

The Chalkiwadi site, about four hours' journey (over bumpy roads) south and west of Pune, is located at the top of a wind-swept mesa near the western side of the Deccan plateau. The site is principally comprised of eight 250 kW asynchronous wind generators manufactured in Holland and finished in India: the nacelle covering and tower supports (of 30 and 40 meter heights) are supplied by Bharat Heavy Electricals Limited (BHEL). Three additional turbines of other types supply the remaining capacity. Each turbine has at the foot of its tower a bunker housing the power equipment and computer controls; the entire network is coordinated from a central control and observation building. The generators have two stages, six- and eight-pole, for two ranges of wind speed: 3 - 6 m/s and above 6 m/s.

I witnessed start-up of the installation in the late afternoon of a partly cloudy day, following a scheduled maintenance shut-down. I watched from the foot of one of the support towers. The entire procedure is computer-controlled; only exceptional circumstances require operator intervention. First the turbine blades are unlocked, allowing them to turn. With a 25-meter diameter, the trefoil blades at close range are an impressive sight, especially as they begin to rotate, turning silently except for a slight hiss from the wing tips as the rotation picks up speed. At about 20 rotations per minute, the second-stage generator energizes, drawing power from the grid to

[17] TERI "Solar Ponds" brochure, Table 1. Cf. Kishore and Kumar, "Solar Pond: an exercise in development of indigenous technology at Kutch, India". See the entry for TERI in part III, Key coordinating organizations.

[18] MNES Annual Report pp. 50, 54.

[19] Ibid, p. 54.

[20] All data on the Chalkiwadi installation were supplied by project officers at the site.

increase the frequency of rotation until it reaches 30 per minute. Then the first-stage generator energizes, bringing blade rotation up to about 40 per minute, corresponding to synchronous speed. When the wind pushes the blades still harder, the generator begins to feed power back to the grid. An audible hum penetrates the rhythmic hiss of the airfoils.

On this day, ten sets of blades swept the wind in unison as the sun slanted down past low clouds scudding along the mesa. Tendrils of mist alternately obscured and revealed the trefoil machines, confirming the gargantuan power that is concealed in clear air. To tap this power is not only possible but economically feasible, a fact with exciting implications for India as well as the more-developed countries.

Wind-electric generation is not without its difficulties. Maximum wind velocity (and therefore maximum power potential) is generally during the monsoon season, in which violent weather can take a heavy toll on even the sturdiest equipment. At the time of my visit, well before the monsoon, a recent lightning strike had disabled a turbine. The BHEL engineer repairing the damaged explained that lightning strikes, in spite of conduction rods, electromagnetic shielding and other precautions, can easily damage the fragile electronic sensors and logic chips on which the turbine's operation depends. However, with improvement in durability and maintenance routines, such vagaries need not seriously impair the functioning of even a large-scale wind-electric installation. Wind-electric power stations have the potential of being run at an extremely low cost of operation, since they can be almost completely automated; in the case of the Danish/BHEL turbines, autonomous computer control is intrinsic to the design, so that full automation does not add significantly to cost.

Although the average supply cost of wind power is still significantly higher than for thermal power,[21] three factors mitigate the disadvantage. Firstly, it is reasonable to expect that the costs of hardware and installation will reduce as the technology improves. Secondly, the costs of operation and maintenance can be much less (ideally, almost negligible) than for thermal power, since a wind-power station can be almost fully automated. Third, the contribution of fuel to cost is obviously nil, whereas for thermal power the portion of total cost consumed by fuel is likely to increase.[d] Fuel cost is a serious demerit for oil-based thermal power in India, since the oil must be purchased with scarce and costly foreign exchange reserves. Although difficult to gauge accurately, the cost of foreign exchange and the related impact of foreign oil dependance on India's economy may become the most compelling reasons to invest in non-conventional energy utilization.[e]

MEDA's success with the Chalkiwadi installation has prompted a commercial undertaking, a joint venture between an Indian independent power producer and a German turbine manufacturer, to build a 60 MW installation a few kilometers the Chalkiwadi site. This installation will consist of several hundred turbine units of a novel design. While many well-tested concepts are available, plenty of room remains for innovation in aerodynamic and electrical design to optimize the efficiency and cost of wind generators. That this relatively immature technology is already on the verge of becoming cost-effective is a cause for optimism about the future of non-conventional energy development.

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[21]Expected average supply cost was 2.87 Rs/kWh for wind versus 1.50 for coal-fired power in 1997 (Banerjee, Table 5).

Ocean Energy.

Ocean-energy development in India is presently limited to a handful of projects in the proposal stage, and a few experimental stations. Examples of the former are a 3.5 MW tidal power project which has been proposed for the Sundarbans area of West Bengal, and a 1 MW OTEC plant to be situated on Kavaratti Island, Lakshadweep (west of the cape of India).[22] In the interest of brevity, only one relevant station -- the Vizhingam wave energy pilot project in Kerala -- is described in any detail, following a few general remarks.

Tidal energy could only meet a small portion of India's energy needs, with only two areas (the Bay of Bengal and the Gulf of Kutch) even possible for tidal energy generation. The potential of wave energy would seem to be much greater, with an average power on the order of 100 kilowatts[23] per meter of wavefront (100 MW per kilometer) available for extraction, at least in theory. Naturally, this "average" value varies widely between winter and monsoon seasons, with the range from calm to stormy waves being on the order of 20 to around 200 kW per meter. In practice, generating on the order of 10 megawatts from a kilometer of wavefront might be feasible. Obviously, utilizing every kilometer of coastline (approximately 7,500 km in length) is not practicable, even aside from environmental considerations. Assuming that 5% of coastal wavefront were intercepted, the total wave power practically available could not exceed the order of 3,750 MW. This limitation might be overcome with floating offshore wave generators, which would in effect increase the length of intercepted (linear) wavefront.

If OTEC can ever be made cost-effective, India is ideally situated to use it, with its large length of coastline adjacent to the deep off-shore waters of the Indian ocean. However, the engineering difficulties associated with bringing cold water from kilometer depths to the surface (not to mention low Rankine-cycle efficiencies at the typical 20-degree temperature difference available with conventional OTEC designs) have not diminished since the brief burst of enthusiasm which ocean energy enjoyed in the 1970s. The most optimistic expectations for OTEC predict a cost on the order of ten times greater than for conventional fossil sources. Regardless of potential, making any amount of ocean-based generation capacity cost-effective will remain a formidable challenge for many decades.

An argument against the development of ocean energy which is based on considerations of cost-effectiveness must, like all such general argumentation, admit the possibility of useful *a priori* exceptions. That is, there may be special circumstances in which a particular ocean energy scheme will be the cheapest option -- for instance, where the cost of a conventional energy supply is prohibitive (as it might be in some very isolated areas). Among ocean energy concepts, wave power is the most likely candidate for such occasional success.

The wave energy pilot project at Vizhingam,[24] an undertaking of the National Institute of

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[22]MNES Annual Report 1996-97, p. 88.

[23]It should be understood that all capacity figures given "on the order of" a certain amount are necessarily rough estimations whose accuracy may be little better than to the order of magnitude.

[24]See the entry for the Vizhingam wave energy project in part III, Ocean energy and hydropower.

Ocean Technology (NIOT) at IIT-Madras, aims to gather technical data on the oscillating-water-column (OWC) concept. An impressive endeavor, the pilot project is operated from a field office a kilometer from the harbor. The wave energy installation itself is located at the end of a tetrapod breakwater protecting the fishing harbor. From the end of the breakwater, a catwalk extends about 20 meters seaward to the top of a six-story[25] surge chamber which is open to the sea just below water level. Ten meters' worth of wavefront translate their energy to oscillation of the water level within the surge chamber. Pressure oscillation effected by the surging water column drives a stream of air through a double turbine arrangement atop the chamber. The turbines are unidirectional, thanks to movable turbine vanes: a change in the direction of air flow changes the attitude of the vanes, but turbine impulse remains in one direction. Nominal (rated) capacity of each generator is 150 kW, or 300 kW for the system,[26] which is connected to the grid.

Three hundred kilowatts represents a realistic maximum output for this system, even though the nominal average power of ten meters' wavefront translated to the surging water should be (taking 100 kW/meter as the approximation) on the order of a megawatt. The difference lies in unavoidable losses in translation of wave power outside to inside the surge chamber (90% efficiency),[27] conversion from hydraulic to pneumatic form (60%) and again from pneumatic to mechanical at the turbine (40%). With this particular OWC design, total power conversion efficiency is unlikely to exceed 25%, even discounting an imperfect conversion of mechanical to electrical energy: actual efficiency (including generator loss) at present is in the range of 10% - 12%. Indeed, only in unusually high seas could the instantaneous output ever approach the rated maximum of 300 kW. Average capacity lies between 50 and 100 kW, with very low availability (and output) during calm seas. During the monsoon season, the capacity and availability become substantially higher, easily double. This kind of seasonal variability (not to mention the intrinsic unevenness of the wave source) can be difficult to accommodate as a design parameter. As with the Chalkiwadi wind generators, in calm conditions (turbine below synchronous speed) the generator actually draws power from the grid.

Sporadic and highly variable power output is one difficulty which wave energy has in common with wind energy. The similarity should be exploited: a solution in one case (for instance, use of sophisticated computer automation in wind-electric systems) may be a solution in the other case. Aside from this, the wave nature of the source driving an OWC system suggests that some sort of phasing arrangement could be used to smooth out power fluctuations. For instance, suppose Fourier analysis determines that a wavelength of ten meters is expected for the principal component of incoming waves, when the characteristic width (FWHM value) of power peaks corresponds to a one-meter length. Let there be four surge chambers placed at successive 2.5-meter intervals (measured parallel to the wave direction) with power output in parallel. Then each generating set would produce largely the same power profile, but shifted in phase by the order of

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[25]Measured from the ocean floor.

[26]The capacity and efficiency figures cited for the Vizhingam project are based on communication with project staff, as are other technical details of the project.

[27]These parenthetical figures are rough estimates, intended for illustration only.

the largest fluctuations, so that the combined output would be considerably smoother.[f]

The obstacles to wave power production are (at this stage of development) mainly technical: a design which will withstand the battering of waves, cost of special materials and techniques for construction, and maintenance of equipment and infrastructure in a corrosive environment, as well as the problems related to efficiency and source variability. The capital cost of the Vizhingam installation (not including the breakwater, which was built with the harbor) was about Rs. 1.8 crore; taking this as the cost of any similar installation (based on the OWC concept), and assuming an optimistic capacity of 200 kW after efficiency improvement, wave energy can be expected to cost about Rs. 9 crore per megawatt, assuming no economy of scale. This figure is comparable to the capital cost of nuclear power (Banerjee, Table 5), placing it among the most expensive of options even without considering its unavoidably low availability. Returning to the example at the beginning of this section, to intercept just 1% of available coastal wavefront would require 100 wave caissons for each of 75 kilometers, producing 1500 MW total (assuming 200 kW capacity per improved wave caisson) -- on the order of a single large conventional power station. Wave energy cannot at present compete with conventional sources or even wind power.

One trick which can mitigate the cost of wave energy is to build wave energy caissons in conjunction with harbor or breakwater construction. Otherwise, the cost of a bridge, trellis or breakwater connecting a wave energy installation to the shore must be accounted. However, not even building in conjunction is sufficient: while typical breakwater construction costs Rs 12 lakh per ten meters of length, a wave energy caisson of the type at Vizhingam will cost not less than Rs 150 lakh. To offset the cost difference, a caisson could be designed to double as a harbor dock segment on its lee side. One proposal under consideration for a site at Thangaserry would incorporate facilities for rare earths storage into a series of ten wave energy caissons, with the cost essentially financed by storage fees.

A simpler alternative may lie among the many other concepts for wave energy. One of the simpler and cheaper ones is that of wave run-up: a submerged slope and side walls of suitable configuration guide breaking waves up a ramp into a reservoir a few meters above sea level. One possibility that should be examined in this context is the feasibility of focusing incoming parallel waves to converge at a point, increasing the mean wave energy there. This might be accomplished with a parabolic reflecting wall, bottom contouring, or some arrangement of flexible vertical sheeting to change wave direction. Successful wave focussing could dramatically improve the economics of wave energy in general, not only for wave run-up schemes. The technology may take decades to mature, but wave power is an option worth pursuing.

Small hydro.

The development of small-scale hydropower has lagged far behind that of large-scale, although a few organizations (e. g. the Intermediate Technology Development Group) have been promoting mini- and micro-hydroelectric (microhydel) technology since the 1980s. MNES has undertaken a number of mini-hydro projects (up to 3 MW capacity), as of 1997 amounting to 133 MW installed and 247 MW ongoing, mostly in hilly states.[28] Although this kind of government-

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[28]MNES Annual Report, p. 59.

sponsored hydropower development has been reasonably successful, it is not widely noted that projects based on private initiative have also succeeded. This section highlights the results of one such initiative in the state of Kerala.[29]

Based in the town of Payyanur, a small group of social activists and engineers has been responsible for the installation of four microhydel projects in Kerala, all funded by local donation of capital and labor. I visited the most recent of these projects, a 14 kW installation in the western hills near the village of Pathanpara, about an hour's drive from Payyanur. During the dry season, the typical output of the installation is around four kilowatts, and this only for about four hours per day -- a limitation imposed by scarcity of water.

Power depends on three trickles feeding a small catchment basin. The basin is located several hundred meters upslope from the pumphouse, giving a pressure head of 70 meters. A high-density PVC pipe, four inches in diameter, conducts water from the basin to a Pelton wheel arrangement within the pumphouse. The Pelton wheel turns a three-phase motor which has been reversed for generation. A smaller secondary generator can be run when there is sufficient water. A bank of electronics regulates the power supplied to the village, a quantity sufficient to provide each of about sixty families with tube lighting, leaving enough power for a number of appliances (TV, radio) held in common. Power is transmitted untransformed through multiple heavy-gauge wires to the village, about 500 meters from the pumphouse. Except for the regulating electronics, the installation was completely engineered and realized by the Payyanur group, as is operation and maintenance.

The cost of the Pathanpara installation was about Rs 2 lakh, an amount which was collected from the beneficiary families (over Rs 3000 per family) in addition to a substantial commitment of labor. This represents a fairly huge investment for an agricultural family (on the order of a years' income), yet the situation of state-supplied electrical power is such that the village was willing to put up the money. Villages which are currently electrified experience scheduled power loss in the evening and other times of heavy load, and unscheduled outages can last for hours to days. Villages like Pathanpara which are not yet connected to the grid can wait for years before the state apparatus for electrical power development reaches them.

Although small-scale hydropower is not technically as efficient (energetically or economically) as large-scale, there are clear circumstances in which it deserves consideration as a better alternative. For example, a large dam, given the ubiquitously high population density of most of India, almost always displaces hundreds to thousands of people (or more), disproportionately those from a poor and oppressed background. Resultant forced migration is extremely problematic, given the constant pressure on, and competition for, locally available resources of land and water. Government resettlement or reimbursement seldom compensates the impact on these people. This impact is not confined to the immediate community of displacement, but can have far-reaching social and political repercussions. The section on **Development controversies** observes that the social and even political consequences of insensitive large-hydro (or other large-scale power) development can easily negate the benefits of additional power capacity -- the mere observation of which, to be fair, does not necessarily invalidate such development.

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[29]See also part III, **Grassroots organizations**.

Another factor to consider is the high cost of large-scale hydropower development. Economies of scale, although they ideally make the per-megawatt cost of power less, are not always relevant in a pragmatic context. In the case of Kerala (as in most states of India), the difficulty of mobilizing sufficient funds for very large development projects, not to mention the bureaucratic and political difficulties associated with heavily centralized decision-making, reduce the theoretical cost advantage of operation on a large scale. The bare outlines of the social and economic costs of large-scale hydropower development are only two reasons thus far given to justify an alternative, yet for even these few reasons it is incumbent to weigh alternatives (of which reduction of scale is only one). Other reasons to favor decentralization will be found in the final section of this part, **Integration**.

The efforts of the Payyanur group have at least demonstrated that microhydel power is a realistic alternative to KSEB power. Whether microhydel technology can be truly viable remains to be seen. In the case of Pathanpara, the question of economic viability is moot: since Pathanpara's residents chose this means of producing their own power, the technology is *de facto* viable. Similarly, though no one will deny that community housing can be substantially cheaper and more efficient per unit than a single house, it would be not only inaccurate but also irrelevant to conclude that single homes are not economically viable. The conventional wisdom that centralized utility-supplied power should be more cost-effective than power supplied by a diesel genset is clearly rendered untrue in the case of India. If there is a market for gensets, there is also potential for renewable alternatives.

Responsible utilization of small-scale hydropower requires the accurate discrimination of the circumstances in which mini- and microhydel projects are demonstrably superior to large-scale. That is, under what circumstances can a given capacity of small-scale hydropower be convincingly shown to be cheaper than an equivalent capacity from a single large dam? Though microhydel power has intrinsic shortcomings (among them the lack of a large reservoir for assured power production), these are compensated by the absence of reservoir-area flooding and consequent social and environmental costs. There is also a considerable cost necessitated by the extension of transmission and distribution networks to remote regions, which would be greatly reduced by a decentralization of power production.[30] For the many villages without any power, the salient point is that any low-impact electricity, even at very high cost, is preferable to no electricity at reduced cost, especially when the strain on conventional utility power has mostly negated its advantages (dependability, stability, load capacity) over the probable vagaries of a decentralized supply.

Prerequisite to the success of small-scale hydropower for rural development will be a number of technical improvements. Foremost among them may be water management -- strictly speaking, this is not a technical concern at all, yet it is of vital relevance to the technology. Consider the Pathanpara installation, which is limited -- in capacity and availability -- to less than a third its potential, except during heavy monsoon rains. The techniques of watershed management which have been developed for low-input modes of agriculture might be adapted to provide for storage of seasonal runoff without relying on conventional reservoirs. These considerations aside,

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[30]The very cost of extending the grid to remote, especially hilly, regions is one reason why the state electricity boards may be unwilling (or unable) to pursue rural electrification with any alacrity.

there is a dearth of technical data and field experience in a number of relevant areas: pump reversal, Pelton wheels and other turbine arrangements for a small-scale context (low pressure head or low flow rates), and reversal of electric motors for use as generators. Although only one kind of microhydel technology has been considered here, there are any number of other schemes for utilizing river and canal (so-called run of the river) sources as well as downsizing conventional dam hydropower. All of these comprise the small scale; any one of them could become a viable alternative to large-scale hydropower development.

The rest of part II is devoted to technologies and applications which mainly concern rural development. The first technology area is biomass energy, which includes biogas production (from dung, agricultural residue and other sources) as well as biomass conversion, or gasification. The next is low-input agriculture, a designation which masks the fact that low-input farming techniques (unlike those of the "green" revolution) are largely a re-invention and rediscovery of farming techniques which were common long before the advent of industrialization. Following this will be the important topic of education, which is highly relevant not only in the context of diffusion of technology, but also to social development. This leads to a discussion of "approtech" and integrated rural development programs, followed by the concerns of grassroots action and participatory planning. Part II closes with a brief analysis of some of the most controversial development projects and the crucial issues underlying and integrating them.

Biomass energy.

Two ways of utilizing biomass energy indirectly (i. e., other than directly burning) are in practice. Biogas, or gobar gas -- dilute methane gas produced by bacterial digestion of cow dung or other organic residue -- has been used for decades, though with a patchy success record. A more recent innovation (though hardly new) is biomass gasification, in which the volatile compounds of wood or other organic matter are released by heating to form a "producer" gas of low to medium energy density (half or less that of conventional fuel gases). Both technologies suffer from a number of limitations which may not be fatal, but seriously complicate the effective indirect utilization of biomass energy. For convenience, consideration of direct burning of biomass (e. g., in stoves, kilns and braziers) is deferred to the discussion of appropriate technology and rural development.

As with so many technologies intended for rural betterment, effective utilization of biogas is hampered mainly by a lack of support for the technology. Past efforts to promote biogas have simply built large numbers of biogas plants, seldom providing for adequate training in maintenance or use. In some cases, biogas simply does not meet the needs of cooking as well as petroleum gas or kerosene, for instance where dung or water is scarce. Even when organic matter and water are plentiful, it may be the case that intended beneficiaries would rather use a conventional fuel. To change their minds is an endeavor likely doomed to failure, and justly so, since biogas promoters so seldom use the technology themselves. Where there is no intrinsic opposition or limitation to this technology, there must be sufficient provision for education and training which will in turn assure proper use and maintenance, or there must exist external arrangements for maintenance.[31]

It is worthwhile pointing out that there is at least one option for biogas which has not been well explored, namely the use of other organic material than cow dung, which is sometimes scarce and of greater value than the gas and fertilizer it would produce. There is no lack of cases where

[31]Lest these remarks seem overly self-evident, I can only point out that the difference between success and failure for most of these energy alternatives lies with the mundane and obvious considerations discussed here perforce. If there is a better explanation for the poor success record of biogas in India, I do not know of it.

the introduction of biogas caused competition with or otherwise harmed other traditional dependents upon dung. Even in the absence of a conflict of uses, the poorest do not have either the land or the livestock to produce dung. Hence the use of cheaply grown, low-input vegetable matter as biogas feedstock merits examination. At least one research foundation in Pune has already done considerable research on the use of non-edible oilseed meals and other agricultural residues for biogas production.[32]

The limitations of biomass gasification are, compared to biogas, more technical in nature. Indian literature on alternative energy abounds with optimistic predictions for tree plantation and wood gasification to meet all rural energy needs, but unfortunately the technology has not been so cooperative. A typical gasifier, of the downdraft type, contains a column of material slowly moving downward (by gravity), along which four stages of reaction convert the feedstock into producer gas and ash waste. In practice, gasifiers are difficult to run consistently and difficult to maintain, excepting those with feedstocks which are relatively homogenous and of fine consistency (e. g., rice husks or sawdust).

At saw mills, there has been some successful captive power generation from the conversion of waste sawdust by gasification. However, when the feedstock supply is not constant or is irregular in shape or composition (as in the case of crop residue or wood pieces), optimal gasification is virtually impossible under field conditions. Problems range from irregularity of mass flow to imperfect cracking of volatile organics and impurity of the resulting gas. Small gasifiers (below 50 kW capacity) are especially problematic, according to one of the pioneers in the field, Dr. P. P. Parikh.[33] Nonetheless, there is scope for replacing up to 75% of the oil fuel consumed in certain industries. Diesel engines can be modified to run in a dual-fuel mode, burning a mixture of producer gas and diesel fuel in a ratio of 3:1. At the current state of development, such an engine produces comparatively dirty exhaust. While it is unlikely that gasification can be anything like the panacea it may have seemed a few decades ago, there is certainly room for its use in specific circumstances.

Agriculture.

Only recently have agricultural scientists thought it worthwhile to corroborate the empirical knowledge of traditional low-input techniques with the scientific insights of microbiology and biochemistry. It is productive, in this context, to keep some distance between the facts of agriculture development, and the many claims attached to the theories which attempt to explain those facts. An unfortunate habit of turning theory into ideology has polarized the field of agricultural development: those that believe in purely conventional, mechanized "modern" farming scoff at claims of superior traditional methods, while those who believe in purely organic and "natural" farming techniques hallowed by tradition are mistrustful of high-intensity farming, to the point of virtual hostility.

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[32]See the entry for BAIF in part III, **Rural development and agroindustry**. See also the section below, **Approtech and rural development**.

[33]See appendix A, under biomass gasification.

Such emotional biasing can only be counterproductive, given the magnitude of the problems which both approaches aspire to solve. Indeed, acrimony over developmental agriculture has been particularly effective in obscuring and confusing the important issues, among which the passe debate of old-versus-new has no place. There is mounting evidence that land farmed with a high input of chemical fertilizer and water gradually loses fertility, not to mention cost prohibitions and obvious impacts on soil and water parameters. Likewise, traditional farming (which includes slash-and-burn techniques) does not necessarily preserve the vitality of arable land, and it is undeniable that its lower productivity requires more land to produce the same output. To wit, since the 1950s the amount of land under cultivation has remained almost constant, compared with a historical trend of increase -- a fact due almost solely to the so-called green revolution of high-yield farming. Whether high-yield farming can also be sustainable is entirely a separate question, unfortunately beyond the scope of this report.[34] The point to retain is that any honest debate between the opposed camps in agriculture development must remain equivocal, even if there ever comes to be unbiased evidence decisively in favor of one approach. As in the case of other controversies in the field of development (which are discussed in some detail at the end of part II), it is only the ideologies which are mutually exclusive, not their subsequent theories and approaches.

The effective and economical use of agricultural resources is vitally important to the majority of Indians who live by farming, not to mention the large and still booming urban-industrial working class -- a group particularly susceptible to economic shocks which disproportionately weaken their ability to purchase food.[35] Although hunger is an obvious concern, a more powerful reason for effective agriculture is the potential it affords for economic development in the rural sector. (This is discussed more fully below, in **Approtech and rural development**). My experience with agricultural development is limited to a few field visits, but despite its lack of depth, some exposition is warranted because of the importance of agriculture, which is too frequently ignored or overlooked in energy research.

It is useful and though-provoking to regard photosynthesis as a sophisticated biological solar-energy system. There has been some amount of study on the efficacy of tree farming as a means of energy production, specifically of fuel wood for direct burning, or conversion to gas. A related concept is the production of alcohol from grain or sugar grown for the purpose. While it is fairly straightforward to determine energy conversion efficiencies and hectare input requirements for a given output, such simplistic reduction overlooks the intricacy of what is, after all, not a physical but a biological system. For the sake of developing a more realistic and useful model of that complexity, the claims and concepts of organic farming deserve serious evaluation.

One model farm, about 100 km north of Bombay, makes a good example of the preceding points. This farm originated as the experiment of a venerable gentleman by the name of Bhaskar Save. Although he has taken some of his ideas from the Japanese organicist Fukokawa, his farm is patterned mainly along lines dictated by traditional farming wisdom.[36]

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[34]The M. S. Swaminathan Research Foundation is one reputable organization working in this area. See appendix A.

[35]See Amartya Sen, Poverty and Famines.

[36]My comments in this section, while based on the author's visit to the farm in question, have not

Save characterizes his approach to farming as essentially "do-nothing": once the soil structure and crop plants have been established, the farm should take care of itself in every aspect. He considers a number of points essential. Soil is the single most important element of a farm, and on this basis he advocates the farmer never to break or till the soil after growth has been established, though it is permissible to cut plants back. Likewise, weeds should be left to grow, unless they are clearly detrimental to the farm habitat. The entire farm should preferably be covered by natural flora, as this assures a continues injection of (solar) energy and organic (leaf) matter into the soil, bolstering its microbial life and structure, as well as helping to trap moisture during the dry season and recharge groundwater during the monsoon.

Irrigation comes from ditches, which should be kept even with the edge of the plants' overstory to encourage horizontal root growth. The ditches may be filled with large branches or organic detritus, in lieu of chemical fertilization and to reduce evaporation loss. To Save's thinking, for instance, palm trees "feel" unstable in very wet ground, so as the trees grow their irrigation ditches must be moved out to stay just under the outer reach of the fronds. This assures proper drainage and a broad root base, and Save claims that this alone will dramatically increase output as compared to conventional coconut farming. He feels that any plants growing as units of a complete ecological system can subsist on much less externally-supplied water than with conventional farming methodologies. Coconut palms, for instance, can be grown in a circle and both fed and watered from a central pit with as little as ten liters a day for a dozen trees.

Intercropping makes the fullest use of available space. Save has found that he can grow twice as many coconut trees as recommended in government guidelines, so long as there is room above the ground. For instance, palm trees planted in a dense line will naturally lean away from each other in alternating directions, effectively using a greater area of insolation for the same area of ground, effectively increasing productivity per area under cultivation. Sugar cane and other tropical fruit plants can be grown in the space under or between rows of trees, depending on their requirements for sunlight and water. The farm can be made quite productive economically by choosing high-value crops such as chikoo and pomegranate. Groundnuts (peanuts) may be grown for an occasional season to enrich the nitrogen content of the soil. Exceptionally poor soil may require an initial input of organic manure, but once its biosystem has been established, the entire farm should be self-sustaining in its fertility, with more than enough produce left over for human and animal sustenance.

Save claims that his approach to farming results in higher yields than conventional high-intensity farming (using large inputs of water and chemical fertilizer) while maintaining rich and healthy soil, and that it can resurrect even the most degraded land. He cautions, however, that there is no formula that works for all farms, and that each farmer must develop an approach which is tailored to the individual farm. There are other limitations, obviously; it is not clear, for instance, how Save's approach would be adapted to the cultivation of grains or other annual crops which must be seeded over large areas. Moreover, Save's approach, in spite of its do-nothing ideal, can be labor-intensive.

It would be worthwhile to evaluate the claims and methodology of an organic approach

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been validated by Mr. Save.

such as Bhaskar Save's. Most important is to investigate the concept of a farm as a biological energy system with inputs from the sun and soil and outputs back to the soil, quantifying the effect of insolation on the physical, biochemical and microbial characteristics of green (untilled) versus bare (tilled) land. Findings in this area could have dramatic consequences for conventional high-yield farming, the basis of the green revolution which won its initiator the Nobel peace prize,[37] although its ultimate effects are still hotly debated.

In the last few years, any number of generally organic approaches to farming have been promoted, some of which are undeniably successful. Unfortunately, many of these approaches have been mystified with highly speculative (and largely irrelevant) theories and then popularized as part of ideologies whose aims and origins are dubious at best. It is important to separate the wheat of actual success (by whatever method) from the chaff of accompanying justifications and explanations of untested validity. Otherwise, sincere agricultural activists will waste their time pursuing such red herrings as the so-called vortex theory, which crops up in many ideologies parading behind the banner of alternative action.[g] As long as a theory is unapproachable by any logical verification, by rights it should be thrown on the garbage heap of pseudoscience. Such garbage does, however, serve at least one useful function, in that it may become compost to nourish the seeds of valid scientific theories.

A final idea which must be mentioned here is that of tree farming, which has been put forward any number of times as the solution to India's poverty. It is possible to come up with numbers to show that there is sufficient land for each family in India to produce enough calories of food and fuel to meet all of its needs, and even to produce electricity and industrial steam with wood-fired boilers or gasifiers. There has been some serious research on energy production from farming of fast-growing tree species, and the numbers (for whatever they are worth) from such forestry work are promising. In theory, tree farming can be a significant source of income, although the land and means to plant and maintain a teak grove, for example, is beyond the means of most poor farmers. Whether tree farming can live up to its promise still remains to be seen.

Approtech and rural development.

The hazy concept of appropriate technology, or approtech, remains one of the most important, but least understood, ideas in the development field. Although the kinds of devices which are considered appropriate for the needs of rural technology are quite simple, years of development in this area have had relatively little impact on rural India as whole. Rural areas may be the best candidates for non-conventional energy development in terms of unmet need, but are often the worst from a practical point of view: new technologies are almost inevitably more expensive than old ones, especially for energy production, and rural areas in India are generally the poorest in capital. There may also be barriers of custom which hinder the adoption of new ways of doing traditional tasks. Although a few organizations dedicated to rural development have managed to overcome the capital barrier, technology diffusion in rural areas (as elsewhere) is governed largely by the usual economic considerations of utility and cost-effectiveness.

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[37]Norman Borlaug (1970).

A real scarcity of basic information on the rural regions of India makes any kind of technology-impact assessment problematic. Not even the worth of existing development attempts is reliably known, much less the (potential) impact of new technologies. Nonetheless, a few organizations have taken the bull by the horns in tackling the multifarious problems of development in rural India. Probably the largest and most comprehensive of these is the BAIF Research Development Foundation,[38] which manages programs ranging from renewable energy development (mostly bioenergy) to agricultural development (livestock improvement, sericulture and vermiculture) and community health and social improvement programs. The government nodal agencies also administer Integrated Rural Development Programmes which attempt to deal with complications of rural growth in an integrated manner, for instance by combining the setup of basic community services with physical infrastructure construction (e. g., building hospitals and schools supplied with biogas and solar electricity). Reliable information on the effectiveness of such programs is scarce at best.

Other groups have tried to approach the problems of employment and income generation with technology designed to make traditional industries and agriculture more efficient and competitive. Such efforts have resulted in quite serious proposals for the generation of mechanical (shaft) power for small industrial use, and electrical power for various uses, from bullock power or human pedal power. Whether capital investment in such labor-intensive technology is better in the long run than investment in labor-saving technology is a complicated question which lies at the heart of rural economic difficulties. If an answer exists at all, is beyond the scope of this report. At any rate, there is a large potential for improving the situation of rural agriculture with better implements and farming tools priced within the reach of the many poor laboring families whom the green revolution bypassed.[39]

Although conventional development aid focuses on effecting the transition from the methods of traditional agriculture to the technology of full industrialization, between these extremes there is quite a large intermediate space whose possibilities have scarcely been explored. It may be that some unorthodox combination of mechanical technology with human labor will prove the solution to India's constant crisis of poverty.

While some organizations have concentrated on the tangible aspects of infrastructure and employment, others have chosen to focus on the less well-defined qualities of social justice and sustainable living, in the tradition of Mahatma Gandhi. In spite of whatever criticism may be leveled at Gandhian philosophy, I will maintain that the associated tradition of social activism, however problematic for politics and efficiency, is vital to just development. The rest of this section describes the socioeconomic-development activities of one explicitly Gandhian organization, the Sampoorna Kranti Vidyalaya, or Institute of Total Revolution.[40]

This group was founded in the 1950s, for training students in the practice and dissemination of nonviolence. While nonviolent philosophy remains a facet of the Vidyalaya, the larger part of its

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[38]See the entry for BAIF in part III, **Rural development and agroindustry**.

[39]See the entry for CTARA in part III, **Rural development and agroindustry**.

[40]See the entry for SKV under part III, **Grassroots organizations**.

work pertains to the practical application of its ideals of self-sufficiency and egalitarian society. In this area of application, the Vidyalaya's underlying conviction is that the obvious problems of poverty in rural areas cannot be apprehended without addressing the social conditions in which such poverty perpetuates. The Vidyalaya has implemented ideas in a number of areas, from nonconventional energy and low-input agriculture to low-cost housing techniques; whatever the approach, the aim is always to find a practical innovation which will ameliorate the restrictions of class and poverty which still bind the majority in rural India. As such, it is not sufficient simply to find or invent an item which improves on some aspect of traditional functionality. The item must be acceptable to its intended beneficiaries and amenable to their habits of living; it should reduce their cash dependency (for instance, by being easy to construct with locally available materials) and, ideally, give them a means of income which is independent of pre-existing restrictions of class or caste.

Past innovations include a variety of clever farming implements (seeders, specialized hoes and the like), the rope-and-washer hand pump, and empirical results on a number of low-input farming techniques. The basic concept is generally more important than any resulting physical instrument or production method, as a farmer in possession of the former can often himself come up with better ways to accomplish the latter. However, knowledge alone is not always sufficient; many useful innovations would involve a radical change of custom or habit which is effectively impossible. The potential of an intended change must always be balanced against the resistance it will face, and the effort that may be required to overcome that resistance. More than one well-intentioned idea has been pushed upon unwilling recipients with such force as to create a resentment far outweighing any effect the idea could have had in the first place. Unlike many agencies for development which work at the level of government or industry, the Vidyalaya takes as its most important external factor the wishes and wants of those who will be affected by its activity.

Some might argue that an undue concern for the wants of the populace hamper the effectiveness of any organization dedicated to positive change, as such change sometimes goes against the immediate wishes of a populace. The general drift of such an argument is that the well-educated few who direct development activity know better than the ignorant masses what is good for them. While this may, on occasion, be factually true, to adopt such a stance of superiority runs contrary to the ideals of liberal democracy and generally rationalizes the kind of grossly unjust and unkind activity which has given large-scale industrial development a bad reputation in India. (Whether this reputation is accurate will be considered in **Development controversies**, below.) It is not my concern here to uphold the values of democracy (or any other ideology) as a paragon for progress, but rather only to point out the authoritarian character which many of the largest development projects have taken. Intellectual arrogance has glibly justified such authoritarianism in every major conflict of this century, and will do so in the future: let that arrogance not dominate economic development as well.

In this way I maintain the importance of a social conscience for development work, regardless of whether it is "effective". Nominally effective social work devoid of concern for its subjects is pointless, not to mention potentially destructive. In the same way, the promulgation of ideals which one does not follow in practice is worthless as well as hypocritical. Both faults still plague the superficially well-intentioned activity of many socially oriented organizations.

Hence it is of utmost importance to their aims that the members of the Vidyalaya practice the ideals of farming, egalitarian society and low-demand living which they advocate. This follows from the Institute of Total Revolution's founding philosophy, that a personal revolution within the individual must precede and accord with a successful nonviolent external revolution. Such a philosophy has had two important results. First, it guarantees that the development activities of the Vidyalaya are responsible and wanted. Second, it has lead to the Vidyalaya's involvement in some eminently tangible issues related to community health and nuclear energy. See part III, **Grassroots organizations**, for an account of this and other related activism.

Participatory planning.

The grassroots social activism of recent years has influenced one novel mode of development, known as participatory planning, which is now gaining momentum in some states of India (as well as some in Latin America). This approach to development planning has had notable success in Kerala. Ideally, it involves the people of rural communities in every stage of development planning, from surveying available physical resources to deciding where to allocate funds for further development. Although participatory planning is not originally political in its motivation or method, it has fallen into somewhat coincidental alignment with the kind of grassroots political movements whose nominal aim is to reclaim central authority for the laboring poor, under the banner of "people's power". Whether this political association will affect the success of participatory planning for good or ill is unclear.

Participatory planning lacks any formal methodology, at least as it exists in India. It is essentially an outgrowth of participatory primary resource mapping, which is an innovation of field anthropology relying upon local knowledge of land, water, agricultural and other resources to compile detailed maps of those resources.[41] An anecdotal account of resource mapping in Kerala relates how, in one community, the exercise of compiling and mapping the public consensus of community resources (wells, buildings, fields and property lines) gave the community as a whole a new awareness of its own physical assets, including the unseen lack of a school in one densely populated area. This enabled not only a quick consensus on the need for a new school, but the collective will to demand it from the government.[42] Such a demand was politically feasible, for the communist government of Kerala does not incline towards authoritarianism.

My direct experience with participatory planning is limited to an interview with a commissioner in one of the Kannur (Cannanore) district offices of the KSSP, the Kerala state planning commission. Originally, infrastructure development funds were distributed from a central board to individual districts, and again from there to townships, according to various estimations of growth and need. Early successes in the participatory mode convinced the planning commission to support it on a trial basis. According to the commissioner, participatory planning has become so effective a tool for distributing funds where they are needed that it now directs 40% of Kerala's current five-year Plan allocation for infrastructure development. These funds are given directly to

[41] See the article by Bocco and Toledo included in the references.

[42] This anecdote was related to me by residents of Payyanur connected with small-hydro development, as well as by workers in other parts of India.

development projects which have been proposed at the community level and approved by a central board. The next Plan is supposed to reserve fully 50% of its development allocation for participatory planning.

Such success has been disparaged (mainly by cynical political pundits in Bombay and Delhi) as meaningless and unintentional, along with Kerala's other demographic achievements: they are dismissed as flukes of an unusual sociopolitical climate. Such a claim is of doubtful objectivity, although it must be admitted that the relationship between Kerala's politics and demographics is not a simple one of cause and effect. During my short stay in Kerala, I perceived a striking, pragmatic egalitarianism which is quite lacking in other states of India. It would be foolish to claim that this attitude has nothing to do with the state's prosperity, which itself seems largely based on the high mobility and level of education of its citizens, many of whom work abroad. At any rate, if Kerala is especially well suited to a participatory approach to development, this does not mean the approach cannot work elsewhere. As with other promising development alternatives, the successes which have been claimed for participatory planning must be objectively evaluated. If they prove valid, a radical and needed alternative to macro-level planning will be on the horizon.

Education.

Insofar as energy development has to do with the diffusion of technology, the importance of education in the context of development should be clear. It is obvious (especially in retrospect of India's development) that an unfamiliar machine given without the knowledge of its operation is a useless gift. This is not to imply that the rural poor of India are wholly ignorant of modern technology. In point of fact, they know as much of its workings as the average American (which is to say, virtually nothing), the only difference being that they have much less empirical familiarity with it. Even this difference is rapidly diminishing, with the ever greater penetration of high technology into traditional communities. Unfortunately, those who have grown up with the technical gadgetry of the industrialized West are more likely to confuse technology with its mere physical expression, resulting in the false conception of technology transfer as a marketing of high-tech commodity items.

The mechanical devices of modern technology are its least important aspect, ranking far below the scientific principles on which a television (for example) is based, while these in turn rank in impact far below the myriad unspoken beliefs concerning the place, purpose and rightness of devices dedicated to comfort, entertainment and convenience. Technology is no less than an amalgamation of devices, ideas and beliefs, and to take the device as the most (rather than the least) important component of the mix is a serious misapprehension. Technology-oriented development aid rooted in this misconception has consistently misfired, trying as it does to transplant one aspect of an integral system -- namely, the physical devices of a technological culture -- into what were, at one time, self-contained agrarian cultures, in which the devices still have little connection to the local reality.

At any rate, physical technology cannot effectively operate free of a basic knowledge of its working. More importantly, there can be no operational infrastructure of training, maintenance or management of the technology without the educational and social media which produce and sustain it. Whether the society which necessitates such an infrastructure is really desirable or should be emulated is another question entirely, which must be deferred. Likewise, there is not space to do any justice to the role of technology in socialization, an extremely important topic in this day of consumer capitalism going hand-in-hand with an exponential proliferation of technology devices. Leaving aside any value judgements, it is clear that education has everything to do with the process of development, social as well as technological.

Science education is not really a new idea in India, although its implementation has not necessarily been along Western lines. Likewise, the relationship of education (in general) to the intellectual and social components of technology has long been recognized, if not always without distortion. Tagore and Gandhi both tried to make explicit use of schooling as an instrument of social change. More recently, the system of schooling set up along Gandhian lines at various Gandhi Vidyapiths (rural agricultural colleges) has been augmented by the introduction of Rural Science Extension Centres, one of which I visited at the Gandhi Vidyapith in Vedchhi, Surat district (Gujarat).[43]

The Rural Science Extension Centre in Vedchhi is meant to be a place for teachers as well as students from rural communities to experience hands-on, pertinent science education. Since the majority of schools still take the rote-memory approach to teaching, even a single exposure to learning by doing simple experiments has a lasting impact. Until recently, the Extension Centre was run by Mr. Vasant Vadawale,[44] a skilled educator committed to spreading the learning-by-doing approach to municipal government schools. He has been retained for just this task and is currently upgrading the science curriculum of a dozen schools around the city of Vadodara (Baroda), using a series of textbooks which have been specifically designed for hands-on science instruction. The books include a series of experiments which require no expensive instruments or glassware. These books have been developed, in part by Mr. Vadawale, as the latest project of the non-profit publishing group Eklavyer, based in Madhya Pradesh. Eklavyer started as the instructional wing of an NGO dedicated to the improvement of rural communities in M. P. and has subsequently become quite successful in bringing improved science-educational materials to rural schools.

Even the best science teaching can be only one part of a complete curriculum; a small but growing number of independent schools are trying to shape such a curriculum. I had the privilege of living and teaching for three weeks at a unique home school near Panchgani (Maharastra), two months after its inception. This school, located at a small organic farm,[45] incorporates the hands-on mentality into an extremely diverse curriculum including farm work, drama, art, music and intensive personalized study in mathematics, science, history, English, Hindi and the humanities. This curriculum was not arbitrarily selected, but rather has evolved from the needs of students and the experience of the teachers as to what kinds of activities are most stimulating for the students. Because the students of this school have played a direct role in molding the structure and content of

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[43]This is also, not quite coincidentally, the location of the Sampoorna Kranti Vidyalaya (see above).

[44]See appendix A for a contact address.

[45]See the entry for the Redstone Farm in part III, **Grassroots organizations**.

their classes, they need no compulsion to learn. Indeed, on one holiday the students had to be coaxed to put aside their mathematics homework to go for an excursion outdoors! After only two months, these students' natural brilliance was flourishing, finding expression not only in their zest for study, but in the considerable dramatic and artistic talents they expressed. Most remarkable is the strength and maturity of their interaction as a group, which is more characteristic of a college level than of their median age of 12 years. No child could fail to grow and learn in such an encouraging environment as at this home school.

To maintain the school is no easy task, its founders are quick to admit. Just keeping the school provided with food and other essentials can be difficult, particularly in the rural setting of the school, not to mention the organization and preparation required for classes. Although there are (at the time of this writing) only seven students[46] whose instruction is rotated among four adults, teaching them can be quite as exhausting as it is rewarding. It might be argued that such schooling is entirely impractical for all the but the rare few who can provide the time and resources for it. However, the precocious success of the Panchgani school has convinced me that the means for such a school should be seen as a necessity, rather than a luxury. The education of children deserves the highest priority.

Education has the potential to dominate every other consideration in the development of a country. It may enable the poor to improve their condition, or their children's; in India, it is just as likely to maintain the barriers between rich and poor (which still largely coincide with old lines of caste and class), unless there is some focused effort to counteract such division. The same may be said about education in other countries with gross (and growing) disparities between the rich and the poor, Brazil being the prime example. Conflict arising from such disparity is likely to be the dominating event of the next century.[47] For this reason, education should be treated as perhaps the single most important aspect of development, deserving of at least as much research and experimentation as any mere technology.

This applies not just to education in rural communities, or in poor schools, but also -- indeed, especially -- to well-established schools of the elite, whence the future decision-makers of India are likely to come. From such schools will come those who will be responsible not only to make sense of the welter of conflicting information with which they are already bombarded, but also to make vital decisions on the basis of that sense. Into their uncertain hands the future is already committed; their readiness depends on the educators of today.

Development controversies.

Economic development in India is torn by a number of heated controversies. While some of these controversies stem from clearly irresponsible (if not downright criminal) decisions, the most intractable controversies are rooted in judgements about development which are far from being black and white. The case of the Enron Corporation's Dabhol power project is probably an example of the former, while the Sardar Sarovar dam project planned for the Narmada valley

[46]As of November 1998, the number of students had grown to eleven.

[47]See Hobsbawm, chapter 19, in particular pp. 569, 577.

exemplifies the latter.

The Enron Development Corporation, or Enron, is an American multinational corporation (MNC) involved in oil and gas development.[48] In 1992, it signed a memorandum of understanding with the Government of Maharastra to build a combined-cycle gas turbine power plant of about 2000 MW capacity at a location near the port of Dabhol, south of Bombay in the Konkan region of Maharastra. Enron, with backing from General Electric and Bechtel, formed the Dabhol Power Company (DPC) in India to manage the project. Enron (through DPC) was to build, own and operate the plant, selling its power to the Maharastra State Electricity Board (MSEB) at rates which would guarantee a return on its investment over twenty years. The power purchase agreement which defined these rates was negotiated in private.

Following a change in the Maharastra government, this agreement was reviewed and rejected by the new administration on the grounds that the project was too expensive and would give Enron an excessive rate of return on its investment. Some specific objections were that the capital cost of the plant had been grossly overstated, the internal rate of return was projected to be as high as 40%, and that the agreement required imported fuel (supplied by Enron) which would unduly tax India's foreign exchange reserves. Amid charges of corruption and unscrupulous business practice, Enron made the original power purchase agreement public. Further criticism of the project was widespread and ranged from economic to social and environmental concerns. It was objected that the project had been commissioned without any competitive bidding, that the power purchase agreement would impose exorbitant payments on MSEB which could not be recouped from consumers, that the plant was located in an environmentally fragile area and that it would negatively impact the rural population of its environs. The power purchase agreement was subsequently renegotiated, but the changes failed to address many objections to the project.

Unfortunately, much of the anger over the Dabhol project has been aimed at Enron, rather than the governmental mismanagement which effectively approved an expensive project of doubtful value. Whether or not the many allegations against Enron (including claims of police brutality against anti-Enron demonstrators) are true, the project could not have begun in the first place without governmental cooperation. As long as ineffective regulation and bureaucratic confusion allow it, companies like Enron will continue to take advantage of the recent course of liberalization and privatization to which the government of India is committed.

The need for restructuring and better regulating India's power sector has long been recognized by its professionals. However, exactly what and how to change is less than clear. While it is obvious, for instance, that the state electricity boards are losing money due to irrational power tariffs, inadequate (often nonexistent) metering and theft of power, fixing any one of these problems involves increasing the amount consumers must pay for electricity, a move which is politically next to impossible. Simply privatizing power production is not at all guaranteed to provide power to all consumers at reasonable rates, since the cost of supplying low-income and rural areas will be disproportionately high compared to expected return. Aside from its direct impact on the economy of the power sector, the lack of rational and effective regulation has the

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[48]The following details are cited from Wagle, pp. 5-10, but the facts of the case are widely known and available in Indian publications and newspapers.

effect of translating shrewd business practice into exploitation. That is, if the many MNCs which have become interested in India's power sector pursue the most profitable courses they can, capitalizing on the vagaries of India's development, they are sure to become exploitative in effect if not also in fact. This will only worsen the popular demonization of MNCs which is already distracting attention from more serious problems. Although MNCs do sometimes abuse the relative power they may wield in developing countries, such abuses are generally symptoms rather than causes.

The controversy over Enron has to do with a much more general dispute over regulation and how much of it is needed for effective development. As in the related debate over *laissez-faire* economics, objective clarity about regulation in the context of global development is hard to come by. Too many large corporations have a vested interest in maintaining the dominance of one or another point of view. One important point to recognize is that it is not necessarily possible to meet the many requirements of power-system (or other utility) development at a profit. That is, much of the kind of infrastructural and municipal development which is desperately needed all over India cannot possibly be accomplished at a conventional profit, except by incurring huge debts to extranational sources. This observation does not, unfortunately, much clarify the way to proceed with regulation. If any judgement of the Enron case can be clear cut, it is only relative to the obscurity of underlying issues. Herein lies the importance of such a controversy as Enron: as difficult as controversies may be to resolve, they must not be ignored or dismissed as popular agitation, for they strike to the heart of the deepest uncertainties which limit our understanding of the modern age.

Another controversy widely known in India concerns the proposed construction of a reservoir in the Narmada Valley, which lies in the states of Gujarat and Madhya Pradesh. The Sardar Sarovar project, as it is known, has earned a storm of grassroots opposition on environmental and social grounds. The most problematic aspect of this project may be the large numbers of subsistence agriculturalists and tribal people it will displace in flooding the valley. The threat of uncompensated displacement has been the basis of popular agitations and protests against the project. The salient point with this project is not an evaluation of its hydrologic merit, but rather the way in it has come to symbolize all large reservoir and hydropower projects. Many dedicated activists hold sentiments to the effect that virtually all large government and World Bank-funded projects are "the biggest scams in India," to quote a recent newspaper[49] interview of Medha Patkar, who leads the most active opposition to the Sardar Sarovar project, the NAPM (see part III, **Grassroots organizations**).

Such opposition cannot easily be dismissed, and indeed should not be. Firstly, many of the points raised by popular opposition, though perhaps not all of them, are quite valid: the Sardar Sarovar project will, if it proceeds, have a serious and probably irreversible impact on a large population which is unlikely to receive adequate compensation. Proponents of the project claim that the interference of a misguided few is holding up the construction of a vital component to India's power and water resources, which will benefit many more in the long term than it hurts in the short term. While this claim may be valid, it does not address the basic reason for the

[49]The Indian Express.

interference, which is that the needs of the displaced have not been given adequate attention. Secondly, whether or not the project's opposition is meritworthy, it is likely to continue until the issue has been resolved in a way satisfactory to them. So far, the opposition has been quite effective in discrediting and delaying the project.

The seriousness of this controversy has resulted in a distinctly ideological division between sides. Some advocates claim the whole mess as proof that the ignorant poor are not fit to govern themselves, while detractors warn that such development is the guise of a new capitalist oppression that will be at least as bad as British rule was. Both poles of judgement are rooted in reasons of undeniable experience, and both result in the same extreme conclusion (or confusion). Both sides believe that the dam project cannot coexist in any form with the people it would displace: it must be one or the other. The battle line is drawn with a sharpness that obscures the patent fallacy of this mutual exclusion of alternatives. It is not inevitable that large-scale development projects come at some irreparable cost to the nation, to be borne by the underprivileged. However, because of the ideological cast of this and other such debates, the task of reaching a consensus has become immeasurably more difficult.

Disasters like the explosion of the Union Carbide plant in Bhopal, not to mention a long history of invasion and colonial domination, have left a permanent and understandable bitterness towards an unseen, deadly enemy in the West. That this enemy may have neither identity nor literal existence hardly matters to those who live under its shadow. Relatively innocuous development projects are seen as one of a kind with the worst disasters, differing only in the degree of impact. Such sentiments must be accounted; the disasters must be acknowledged and conciliated, though not excused. Regardless of the actual causes of a serious conflict over development, misunderstandings and misconceptions both underlie and exacerbate it. Social violence too often permeates and perpetuates the conflict; peacefully resolving it requires a constructive effort greater in magnitude than the violence.

Although I have occasionally adopted a definite stance on the controversies discussed here, I do not mean to argue my views. Rather, it is my intention to advocate the validity (but not the exclusivity) of the many points of view held over these important conflicts, for each one represents the most deeply held convictions of its supporters. The circumstances of a conflict such as in the Narmada valley are a matter of life and death for those of at least one side. As such, those most closely involved in these controversies are often committed to defending their respective positions at all cost. Nonetheless, each side must realize the equivocal nature of its convictions: there would be no controversy, of one side was absolutely wrong and one, absolutely right. The very equivocality of these disputes signifies the potential for groundbreaking change which is inherent to them. A reconciliation of the best points of each side of a dispute is the beginning of a map for action which both sides will accept. The bitterest controversy can be a catalyst, speeding powerful and effective action where it is most needed.

Integration.

There is at least one perception which is essential to understanding the reality of India and other developing nations. That is to see the intrinsic continuity of the many issues which have some connection to the process of development. This process, although it occurs within frameworks of varying circumstance, remains essentially the same for all countries, including those which are ostensibly developed. The most industrialized countries are neither static in their own development, nor isolated from the rest. Given the growing speed and penetration of global influences, the problems of the disadvantaged[h] will soon come to trouble the privileged, if this is not so already. In the long view, naked self-interest should be reason enough (if reasons are required) to hold India's most pressing concerns in common with those of all nations. Unmitigated self-interest will not, however, form the basis of any lasting global prosperity; it must give way to a recognition of the continuity of humanity.

In the field of energy and development, isolated issues which appear self-contained will reveal, to a broad perception, connections of no trivial relationship. The solid technical details of non-conventional energy utilization merge with the socioeconomic conditions which determine the success and purpose of pure engineering. Energy alternatives must include the improvement of conventional energy utilization, for reasons of cost and efficiency as well as the impact of environmental degradation on human health, thus linking the subjects of environmental engineering and energy efficiency. As pollution becomes decreasingly tolerable, the conditions of poverty which degrade air and water perpetuate a kind of socioeconomic pollution, which may pose an even greater threat than environmental toxins. As industrialization and its consequent urbanization spread, the differences between rural and urban diminish, while the gap between rich and poor widens, and human society everywhere further dissociates from its pastoral roots, its kinship with nature. Yet the field of agriculture remains a vital ground common to economics and energy both. Energy again intersects the economy in the arena of politics, sometimes explosively -- as in Pokhran,[50] whence nuclear shock waves spread throughout the fabric of the world. To discern the fundamental threads in this fabric is the charge of education, which cannot be removed from its subject, since it is the myriad stresses within the fabric that reveal individual threads most clearly. Yet clarity is seldom found in the ambiguous confusion which dominates all development paradigms in vogue.

A few difficult questions cut to the center of our uncertainty on the most important aspects of development. Under what circumstances is technology investment most cost-effective, and what other considerations should subordinate cost efficiency? Are limited funds best spent on capital-intensive, labor-saving technology, or will the conscientious expansion of labor-intensive production better improve economic conditions? How could proper management and strategy make agriculture a viable means for the destitute? Can organic, low-input agriculture supplant the production of modern high-intensity farming? Will a decentralization of energy and other resources result in their more equitable distribution, or less? Is demand-side management an effective and realistic alternative to supply (capacity) expansion, and can the approach be extended to other resource sectors like water and commodity goods? Should state ownership of various utilities be privatized, or are there other alternatives? Finally, is it realistic to plan for a future of equitably

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[50]In June 1998, five nuclear devices were detonated underground in the desert of Rajasthan, near Pokhran, barely a month after the election a new government (the BJP) desperate for consensus. The tests, widely hailed in India as proof of technical and military might, were ostensibly prompted by concerns over China's nuclear capability.

lessened consumption and growth trends, or must unrestricted demand, wastage and degradation be the foregone conclusion? Notwithstanding what self-proclaimed experts may hold on such questions, the controversies they provoke have no clear-cut solutions in a contemporary global context. What answers there may be, inevitably change with the continued explosion of the new into the old, the interpenetration of the most innovative and the most traditional.

I see two relatively unexplored areas which hold particular promise for the future of non-conventional energy development. One is the old concept of total energy utilization: structuring energy production and conversion so that primary electrical generation from fuel supplies the heat required for other industrial processes, as well as for domestic use. Efficiency of conventional energy use must become a leading concern of non-conventional development, since foreseeable improvement in conventional energy use will have incomparably greater impact than speculated advances in non-fuel energy utilization. In particular, the prospects for using waste heat to drive thermodynamic systems (heat pumps or prime movers) have been largely ignored in the frenzy for superficially advanced technology. At least one researcher at IITB[51] has had dramatic success in this area. Activated carbon-ammonia adsorption cycles, for instance, can provide cheap and effective cooling (at a rate as great as 50 watts, supplied by only a few kilograms of equipment) powered by solar or waste heat, such as from diesel engine exhaust. Research in this area should be integrated with the impending deployment of fuel cells, which represent another highly promising concept. A more speculative idea, that of the solar-based production of hydrogen or other energetic gas (e. g., methane), relates to hydrogen fuel-cell development as well as to biotechnology, which may provide unforseen bacterial or photosynthetic means of solar energy conversion.

Many other known energy-related concepts and technologies are important, but being relatively well in hand, they receive no further mention here. My concern is to bring attention to those areas which have been least adequately explored relative to their potential.

The second area with important bearing on non-conventional energy has to do with finding a new approach to development, considering energy, technology and development in their myriad aspects and broadest senses possible. What this approach will be has yet to be defined: it may involve new modes of living or new ways of utilizing energy, but above all it must be guided by an awareness of unalienable social and personal exigencies. Like the approaches taken at the Sampoorna Kranti Vidyalaya and the Panchgani home school, it will be an alternative to macro-level planning for a mass-production society. The difficulties associated with responsibly planning for the contingencies of a multifarious society like India's are presently intractable, leading me to consider a mode of action which does not always require comprehensive planning or foreknowledge to engender certainty.

Such a mode certainly exists, for we seldom know in advance every circumstance which pertains to the choices we make. Just as an individual can act with responsibility and power without planning his actions in detail, even in completely unfamiliar situations, so should it be possible to address the apparent problems of conventional development in a direct and open way, without necessitating a theoretical framework for guidance. Rather than keeping to familiar ground

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[51]Prof. M. V. Rane. See appendix A. Prof. Rane supplied the data on carbon-ammonia adsorption cooling, the subject of his research.

which has been trodden to death, the profession of development must enter the unknown territory of humankind. Reality, not theory, should direct action. A useful framework of theory may, it is true, be found: the history of science follows a pattern of breakthrough and discovery which shows no sign of ending. The next revolutionary understanding may be in the human rather than the physical sciences. In the meantime, there is much urgent work to attend.

An incident from the Panchgani school highlights the promise, and difficulty, of proceeding in unthought-of territory. One day during a tea break I was standing alone in the school kitchen, stuck in indecision over how best to conduct an upcoming class. I wanted to introduce an abstract topic in a way that would engage the students, but I had no experience teaching and could not know in advance what approach would work. One of the older students, coming to take her tea, noticed my frown of concentration and asked what I was looking for. "I'm trying to find an answer," I said, "but I don't know where it is."

"I know where," she immediately replied, as though I were a dunce. "It's in the place you haven't looked yet."

Many times, I have stood at the window of a friend's comfortable Bombay apartment, looking down past a security wall topped with glass shards, out into the chawls and cluttered streets beyond. More often, I have been on the outside of the wall, surrounded by the life and energy of a dozen languages and cultures. Between the people of either side, there is no difference that matters, yet the wall dividing them maintains an ineluctable presence.

I often wonder if such division is to be the future of India: small islands of the wealthy surrounded by oceans of poverty. That vision, I venture to say, is less upsetting than it once was, since the ocean of humanity has buoyed rather than drowned me. But if extreme division is to be the future of India, it is likely to be the future of a global majority, and this could indeed be terrifying. Few cultures of my experience would survive the conditions which India tolerates daily, without descending into overt violence.

Lest a legacy of intolerance, partition and violence become the future of every country, we must look for developmental solutions we can hold in common. If answers lie in the unseen directions of unimagined methods, we need only open our eyes to find places to start.

Oh, East is East, and West is West, and never the twain shall meet,
Till Earth and Sky stand presently at God's great Judgement Seat;
But there is neither East nor West, Border, nor Breed, nor Birth,
When two strong men stand face to face, though they come from the ends of the Earth! - R. Kipling[52]

Part III. Collaborating Organizations

In view of the sheer wealth of development experience available in India, not to mention the body of technical and research data, field results and practical feedback, it is incumbent upon sincere global thinkers in the energy and development fields to explore the possibilities of collaboration with their Indian compatriots. The organizations featured in this part are just a few of the many hundreds engaged in superb, often highly innovative work.

There are many avenues leading to India, none of which should necessarily be neglected, but the initial contacts identified here have two distinct advantages. In the first place, they are the principal source of the insights which inspired this report; they are directly associated with the possibilities I have outlined. In the second place, I have personally approached each organization, usually in several visits and with follow-up communication. I found each one to be, to the best of my judgement, eminently suitable for the purposes of research collaboration and a general sharing of experience -- especially considering the steep learning curve expected in the context of an alien culture and country.

Each organization listed below believes in the fundamental importance of research exchange in the area of energy and development. Each believes in its potential for contribution -- not only to science in the abstract, but also to humanity in the everyday. Each organization is committed to this ideal of collaboration and has agreed to provide institutional support for visiting research scholars, students and others -- i. e., to furnish letters of invitation for obtaining a visa, to assist in finding suitable accommodations, to provide access to institutional library and computer resources, etc. With a few exceptions, these organizations are centrally located and provided with computer facilities and other amenities (as indicated in each entry).

These organizations are grouped according to four broad categories: rural and agricultural development (including biomass energy), solar technology, ocean/hydropower development and grassroots organizations. Following this is an account six important grassroots organizations. For the sake of clarifying the central role of a few key governmental and other agencies, an outline of their activities in the states of Maharastra and Gujarat may be found at the end of this section, in **Key coordinating organizations**.

Finally, it should be understood that these organizations are not, generally speaking, well-funded. Unless explicitly stated otherwise by the organization in question, it may be assume that any expenses incurred in a visit (e. g. transportation, lodging, special materials, incidental fees) must be the responsibility of the visitor. This should present no difficulty, as travel within India is

[52]From "The Ballad of East and West" (1889). In spite of Kipling's covert bigotry, there is some truth to his image of juxtaposition.

extremely cheap for foreign visitors supplied with hard currency.

** Note on telephone numbers: All numbers listed below must be prefixed with 91 when calling from outside India; within India, STD (long-distance) calls must be prefixed with 0.*

Rural development and agroindustry.

BAIF Development Research Foundation, Pune (Maharastra)

ENERGY INTERESTS:
Biogas production and biomass gasification. Promotion of improved chulhas (woodstoves) and solar energy devices.

OTHER ACTIVITIES:
Livestock development, land and water resource development, vermiculture, sericulture, mushroom cultivation and tree-based farming systems. Rural community health programs; training and empowerment of tribal women. Management training for development programs. Environmental awareness workshops and education.

LOCATION:
Principal facilities are the Manibhai Desai Management Training Center (MDMTC) and a Central Research Station, near Pune (Maharastra). Regional management training campuses are in the cities of Valsad, Surat, Baroda and Ahmedabad (all in Gujarat), and Tumkur (Karnataka). Development activities are in the states of Maharastra, Gujarat, Karnataka, Rajasthan, U. P., M. P. and A. P.

STATEMENT:
"Our Mission is to create opportunities of gainful self-employment for rural families, especially disadvantaged sections, ensuring sustainable livelihood, enriched environment, improved quality of life and good human values. BAIF is a non-political, secular and professionally managed organisation." (From the pamphlet "BAIF: Dedicated to Sustainable Rural Development".)

GLOSS:
This organization, known simply as BAIF, is dedicated to sustainable rural development. BAIF is among the largest and most active foundations of its kind, and may be the most successful at tackling the multifarious problems of rural development in an integrated manner. Although BAIF's principal activities are livestock and agricultural development, bioenergy remains a strong component of its research program, in particular biomass gasification and biogas production from non-edible oilseed meals.

FACILITIES AND OTHER INFORMATION:
"The MDMTC is located at Warje, on National Highway No. 4, approx. 12 km south-west of Pune City. The campus houses offices and training facilities; the latter consists of four large classrooms,

library, computer center, a hostel with 20 double rooms and dining hall. Field training is being imparted at the BAIF Lachhakadi campus, a MDMTC sub-centre, in Vansda, Valsad district, Gujarat. The research activities function on the philosophy of 'having no walls', and working in close collaboration with the community and programme staff of BAIF as well as other organisations engaged in developmental activities. *The MDMTC is keen to work with 'like-minded' organisations who would benefit from and contribute to our mission and activities. Do get in touch with us*." (From the pamphlet "Dr. Manibhai Desai Management Training Center".)

CONTACT:

Dr. A. L. Joshi, Programme Director
BAIF Development Research Foundation
Dr. Manibhai Desai Nagar, National Highway No. 4
Warje, Pune 411 029
Maharastra, INDIA
tel: 212-365944
email: baif@wmi.co.in
(specify "Message for A. L. Joshi" in the title field)

Center for Technology Alternatives for Rural Areas (CTARA), IIT-Bombay, Mumbai (Maharastra)

ENERGY INTERESTS:
Improved technology for production of brick and charcoal, improved chulhas, pedal-driven machines. Biomass and wind energy.

OTHER ACTIVITIES:
Development and evaluation of appropriate technologies for agriculture (improved bullock cart, seeder, power tiller). Combined water management and housing improvement. Suppression of pests and rot in grain by carbon-dioxide fumigation.

LOCATION:
CTARA is located on the campus of the Indian Institute of Technology, Bombay, in the suburb of Powai, about an hour's ride (by train) north of downtown Bombay.

GLOSS:
"The Centre was established... for the purpose of developing technologies in relation to the specific needs of a small region." The following are the major goals of CTARA: 1) to develop appropriate technology and concepts based on the application of basic sciences and engineering; 2) to work on the relevant problems of two regions, namely the Konkan (west coastal) region of Maharastra and the vicinity of Bombay; 3) to disseminate information on successful technology developments, and to demonstrate the same to increase popular awareness of it; 4) to analyze the micro-level impact of technology and development. (From the CTARA prospectus.)[i]

FACILITIES AND OTHER INFORMATION:

The IIT campus is among the greenest and most quiet locations in Bombay, located along the northeast shore of Powai lake in the suburb of Powai. Guest housing is available if arranged well in advance (weeks to months, depending on the season). Provisions may be made for long-term visitors to use the library and computer facilities, but this also should be arranged well in advance of arrival.

CONTACT:

Prof. Narendra Shah, Director
CTARA
IIT Powai
Mumbai 400 076
Maharastra, INDIA
tel: 22-578 5377 (residence)
576 7870, 576 7874 (office)
fax: 22-578 3480

Sampoorna Kranti Vidyalaya [Institute of Total Revolution], Gandhi Vidyapith [Gandhi Rural College], Vedchhi (Gujarat) *See also under Grassroots Organizations*.

ENERGY INTERESTS:
Rural energy development. SPV lighting systems. Nuclear-energy controversies and publication of the journal *Anumukti*.

OTHER ACTIVITIES:
Organic and low-input agriculture, community health programs, low-cost housing techniques, teaching of Gandhian nonviolence philosophy.

LOCATION:
The Sampoorna Kranti Vidyalaya is located on the grounds of the Gandhi Vidyapith between the towns of Vedchhi and Valod, about 30 kilometers east of Bardoli in the district of Surat in Gujarat.

GLOSS:
The Sampoorna Kranti Vidyalaya, originally a center for Gandhian nonviolence training, has expanded its scope of activity to include sustainable development and social justice. The Vidyalaya is an informal but dedicated organization, consisting of the family of Narayan Desai and a handful of students and others. Residents at the Vidyalaya live what they promote, practicing and refining their ideals of sustainability, community and socially just development.

FACILITIES AND OTHER INFORMATION:
Staff housing and student/guest rooms, a small community kitchen, gardens and a library building comprise the physical structure of the Vidyalaya. A number of renewable energy devices have been collected on the grounds, including a Scheffler-type solar community cooker, a conventional parabolic cooker, and a number of frames and panels for SPV systems. The Vidyalaya lies within

the campus of the Gandhi Vidyapith, a rural college run according to Gandhian principals of self-sufficiency and simple living. The campus is surrounded by agricultural fields and grazing pastures and is almost 100 km from any major urban center.

CONTACT:

Suren Gadekar or Uma Gadekar
Sampoorna Kranti Vidyalaya
Gandhi Vidyapith, Vedcchi
District Surat 394 641
Gujarat, INDIA
phone: 02625-22074
email: admin@anumukti.ilbom.ernet.in

Solar technology.

The International Center for Networking, Environment, Education and Re-integration (ICNEER), Valsad (Gujarat) *See also under Grassroots Organizations*.

ENERGY INTERESTS:
Solar cookers (box-type, parabolic and Scheffler-type community cookers).

OTHER ACTIVITIES:
Environmental education and awareness, environmental/social activism, and reintegration of expatriate Indian nationals into rural communities.

LOCATION:
ICNEER is located on the premises of the Industrial Manufacturing and Engineering Company, a few kilometers north of the town of Valsad (also called Bulsar) in southern Gujarat. Valsad is about three hours' journey by express train from Mumbai Central Station.

GLOSS:
ICNEER (meaning "one stream" in Sanskrit) is one of the few development organizations in which intellectual idealism remains rooted in ground realities: the bulk of work actually involves direct action at the community level, including all aspects of manufacturing, training and technical self-reliance in the operation and maintenance of solar cookers. This organization represents the life work of Shirin and Deepak Gadhia, who remain involved in various issues related to social as well as technological development. The principal effort at ICNEER is currently the development and promotion of two types of solar cookers, a conventional parabolic cooker (designated SK-14 by its inventor) and a Scheffler-type community cooker. (See section II, **Solar cookers**, for an evaluation of these cookers.) ICNEER already collaborates with two German development groups on these cookers, EG-Solar for the SK-14 and ULOG for the Scheffler cooker (see appendix A).

FACILITIES AND OTHER INFORMATION:

The Center is comprised of a large machining area and metal workshop, living quarters and offices in a single building, and a few hectares around the building. ICNEER frequently works with German and Swiss development organizations and can provide lodging and board for a limited number of people, at a cost of about US$200 per month.

CONTACT:

Mrs. Shirin Gadhia or Mr. Deepak Gadhia
IME Co., Plot No. 86
Old GIDC Gundlav
Valsad 396 035
Gujarat, INDIA
tel: 2632-20703
email: admin@icneer.ilbom.ernet.in

Prof. P. Apte, Tata Institute of Fundamental Research (TIFR), Mumbai

ENERGY INTERESTS:
Solar-thermal vapor-absorption refrigeration for the cold storage of fresh produce.

LOCATION:
TIFR is located on the southernmost tip of the peninsula of Bombay proper, just a few kilometers from downtown.

GLOSS:
Prof. Apte is currently working on a prototype for a cold storage room which would be refrigerated by a vapor-absorption system driven by heat from flat-plate solar panels on the roof of the room. The absorption cycle is based on water and a synthetic absorbent material.

FACILITIES AND OTHER INFORMATION:
TIFR is the premier theoretical research organization in India and ranks as a world-class institute for advanced fundamental research. Facilities include laboratories, guest hostels and dormitories, a cafeteria, sports and recreational facilities, an extensive technical library and the Homi Bhaba auditorium. Further information may be found at the TIFR home page (http://www.tifr.res.in).

CONTACT:

Dr. P. R. Apte, Scientific Officer
Solid State Electronics
TIFR
Mumbai 400 005
Maharastra, INDIA
tel: 22-215 2971, ext. 2314 or 2231
fax: 22-215 2110

Dr. S. Kedare / SARMET, Mumbai

ENERGY INTERESTS:
Solar-thermal steam generation and rural energy technology. Development of technology with a high energy gain ratio.

OTHER ACTIVITIES:
Research & development of renewable materials for lower-cost construction. Commercialization of renewable-energy technologies. Science and technology for village industries.

LOCATION:
Dr. Kedare's work is based in Bombay, with a principal industrial collaborator in Kolhapur (Maharastra).

STATEMENT:
Dr. Kedare is dedicated to the development of appropriate technology for the solution of energy- and environment-related problems, especially in rural areas. His principal goal is the successful commercialization of energy technology tailored to the needs of the less privileged and utilizing indigenous, cheap and environmentally sound materials.

GLOSS:
Dr. Kedare is closely involved with energy development for the rural sector. He is presently overseeing the completion of a prototype parabolic Fresnel collector for industrial low-pressure steam production, located in Kolhapur. The system will have a point focus and tracking about a polar axis. The prototype has an area of 10 m^2, with 20- and 40-m^2 units projected. In addition, Dr. Kedare is now a technical consultant to the Khadi and Village Industries Commission of the Government of India, in the field of Science and Technology for Village Industries and Artisans. He also works with the Society for the Advancement of Renewable Materials and Energy Technology (SARMET), investigating such options as the replacement of steel re-bar with bamboo in concrete construction.

CONTACT:
Dr. Shireesh Kedare
Aditya Renewables
11, Supriya, Plot 709
Parsee Colony 4th Lane
Dadar (E)
Mumbai 400 014
Maharastra, INDIA
tel: 22-415 8168 (residence)
437 6441 (office)
fax: 22-437 4871
email: bpapte@bom2.vsnl.net.in

School of Energy Studies, University of Pune, Pune

ENERGY INTERESTS:
Solar thermal systems for water heating, distillation, steam generation and drying of agricultural and industrial products, and the use of heat pipes in such systems. SPV systems. Biogas and biomass gasification. Wind modeling.

LOCATION:
The School of Energy Studies is situated within the building of the Department of Physics, on the campus of the University of Pune, a few kilometers from downtown Pune.

STATEMENT:
The School of Energy Studies' main objective is to undertake teaching, training, research and development and extension activities in the field of energy with special emphasis on utilization of non-conventional energy sources. The School works in close collaboration with industries, national laboratories, nodal agencies and non-governmental organizations.

GLOSS:
The School of Energy Studies is an interdisciplinary school established by the University of Pune. As such, teaching and research are key activities surrounding the school. The faculty and students within the school are working in three main areas: solar thermal, SPV and biomass energy.

FACILITIES AND OTHER INFORMATION:
Research facilities at the School include a diagnostic assembly for monitoring the performance of flat-plate collector systems, a laboratory for studying the performance and characteristics of materials used in SPV cells, and a computer room. The Department of Physics has additional facilities which can be available for special research needs. The University of Pune is situated on a sprawling, exceptionally clean and quiet campus.

CONTACT:

Prof. M.G. Takwale, Director
School of Energy Studies
Department of Physics
University of Pune
Pune 411 007
Maharastra, INDIA
tel: 212-355201
fax: 212-353899
email: mgt@physics.unipune.ernet.in

Ocean energy and hydropower.

Central Water and Power Research Station (CWPRS)

ENERGY INTERESTS:
Hydroelectric power engineering and ocean energy.

OTHER ACTIVITIES:
Hydrology and water resources analysis, reservoir and appurtenant engineering, study of ship hydrodynamics, applied earth sciences and mathematical modelling.

LOCATION:
CWPRS occupies a large plot in the countryside about ten kilometers' drive to the south of the city of Pune.

GLOSS:
As a large central-government research organization, CWPRS is responsible for hydrologic and energy-related studies for many large dams, harbors and other structures around the south Asian region. Although ocean energy development is not specifically a mandate of the Station, Mr. Anil Kale and Mr. Vilas Joshi, chief research officers in the division of Coastal and Offshore Engineering, are interested in assisting in joint research projects for ocean energy development.

FACILITIES AND OTHER INFORMATION:
Research facilities are quite comprehensive, including extensive physical modelling capabilities, large hydrodynamic ship-testing tanks, turbine and pump test rigs, seismological and vibration-analysis systems, instrumentation labs and equipment for stress/strain analysis. In addition, the Station includes a comprehensive library and information center.

CONTACT:

Mr. Anil Kale, Chief Research Officer
Central Water & Power Research Station
Khadkwasla, Pune 411 024
Maharastra, INDIA
tel: 212-592511
email: root@wapis.nic.in
(specify "Message for Anil Kale" in the title field)

Society for Eco-Friendly Development, Payyanur (Kerala) *See also under Grassroots Organizations*.

ENERGY INTERESTS:
Small-scale (micro- and mini-) hydroelectric power development, decentralized energy options.

OTHER ACTIVITIES:
Participatory planning and involvement with "people's power" movements.

LOCATION:
The members of this organization live in and around the village of Payyanur, about an hour's bus ride north of Kannur (Cannanore) in northern Kerala. Working headquarters are located at the Ampere Technical Institute, near the Gandhi Maidan in Payyanur.

GLOSS:
This organization has completed four successful microhydel projects in Kerala, all without external funding (see section II above, **Small hydro**). Mr. K. Sahadevan is primarily responsible for the organization's public relations. Also active in the group are engineers, a journalist and other local professionals and students.

CONTACT:

Mr. K. Sahadevan
Society for Eco-Friendly Development
Karamel, Payyanur 670 332
Kerala, INDIA
tel: 498-502294

Wave Energy Pilot Project, Vizhingam (Kerala)

ENERGY INTERESTS:
Ocean wave (OWC-type) power production.

LOCATION:
The Wave Energy Pilot Project is located at the Vizhingam fishing harbor, a few kilometers from Kovalam beach and about 20 km from Trivananthapuram (Trivandrum). The wave power caisson sits at the end of the harbor breakwater, while the project office is located about a kilometer north of the breakwater.

GLOSS:
An undertaking of the National Institute of Ocean Technology (IIT-Madras), the Wave Energy Pilot Project stands as one of the few serious attempts to develop a technology of wave power production (see part II, **Ocean energy**). Using an OWC design to transfer wave to pneumatic energy, the wave power caisson encloses a volume of (very roughly) 250 m^3 above the water surface, with 5-10% volumetric oscillation during average wave conditions. The oscillation drives two Wells-type induction generators of 150 kW capacity each, which are mounted in parallel in modules above the caisson dome. Average output ranges between 50 and 100 kW. The installation is fully instrumented for monitoring of pressure and other operational parameters.

CONTACT:

Dr. M. A. Atmanand, Senior Project Manager
National Institute of Ocean Technology
IC&SR building, IIT Campus
Madras 600 036
Tamil Nadu, INDIA
tel: 44-235 1365, ext. 2419
fax: 44-235 3686
email: atma@niot.ernet.in
web: http://www.niot.ernet.in

Grassroots organizations.

Some of the most dedicated individuals in the development field prefer to work in a mode which I call, for lack of a more precise term, grassroots. That is, they are less concerned with maintaining a professional appearance and presence, and more concerned with making their work relevant to and successful in communities. Many of my most fruitful field visits were to groups working principally at a grassroots level, in particular the following four.

The Sampoorna Kranti Vidyalaya (SKV), or Institute of Total Revolution, was founded by Narayanbhai Desai,[53] the son Mahadevbhai Desai, Gandhiji's colleague and secretary (who translated, among other works, Gandhi's *Autobiography*). The Vidyalaya was founded as a school for training in the philosophy of nonviolence, and Narayankaka still teaches a handful of students; this may be called the internal activity of the school. Instruction takes place much as it did forty years ago, in a simple building with stone floors and little furniture. The curriculum includes farm work and such duties as cooking and cleaning, which rotate among the students, in keeping with the aim of egalitarian self-sufficiency. By Western standards, the Vidyalaya is austere, but not extreme.

Although an independent entity, the Vidyalaya may be informally associated with the Gandhi Vidyapith to which it is proximate. The Vidyapith is a rural agricultural college, one of several across India, founded by a colleague of Gandhiji[54] and still maintained as the kind of self-sufficient farming commune which Gandhiji espoused. Although the Vidyapith has been at times inimical to any introduction of the modernity of the industrialized West, it did incorporate a Rural Science Extension Centre on its campus, for the purpose of introducing basic scientific concepts in a hands-on manner. Not far from the Vidyapith, a number of Gandhian ashram schools (for primary education) may be found.

Narayan's daughter Uma and son-in-law Suren are responsible what might be called the external activity of the Vidyalaya, which is strongly environmental in outlook and social in intent.

[53]The words "bhai" (brother) or "ben" (sister) are commonly suffixed to first names in Gujarat, as a title of respect. Narayan Desai would be addressed as Narayanbhai or, in deference to his age, Narayankaka (uncle).

[54]The suffix "-ji" is a term of respect (analogous to "Mister" in English parlance). M. K. Gandhi was widely known by the endearment Gandhiji, as he is still called in his home state.

In the past this has included exposition of unreported accidents and blatant worker-safety violations at nuclear power stations, marches and yatras to mobilize public awareness on nuclear and other public-safety issues, and public health initiatives and other community-oriented programs (see part II, **Approtech and rural development**). Surenbhai is principally responsible for activity on nuclear issues, including publication of the journal Anumukti, while Umaben's expertise lies in the health sector. The two arenas are frequently joined, as for instance when the Vidyalaya conducted a detailed study to show that a village directly downwind from the Rajasthan Atomic Power Plant exhibited a significantly higher incidence of birth defects, mutations and cancers among its population than a statistically similar village upwind.[55]

It should not be inferred that Surenbhai and Umaben are rigidly anti-development; their views are neither rigid nor extreme. In point of fact, their activism is aimed at projects which are clearly harmful to the public and of little benefit except in building government prestige. It must be understood that this kind of activism represents a serious commitment. It is seldom seen in a kind light by the central government, and incidents of state-sponsored violence against protest demonstrations are not unknown.

The second organization of note is ICNEER, which has worked with SKV on environmental issues as well providing it a variety of solar cookers for experimental implementation. As mentioned above, this organization is the life work of Shirin and Deepak Gadhia, a couple whose privileged upbringing and European education inspired them to return to India with their talents, unlike the vast majority of expatriates. The Gadhias' method is to work principally at the level of individuals and communities, networking with other like-minded activists to achieve a broader scope of effect. The intent of their work is to improve the livelihoods of the rural poor while simultaneously addressing the abysmal state of environmental awareness, especially among local chemical and other manufacturers whose industrial processes remain highly productive of toxic effluents. In addition to practical engineering and nonprofit production initiatives for the solar cookers, the Gadhias have undertaken a number of efforts for basic environmental education, including workshops for schoolchildren and for villages. Shirin in particular has been active in this area, as well as in movements for improved low-input and organic methods of agriculture, and in such controversies as the Sardar Sarovar project.

The Gadhias and their colleagues across India exemplify the kind of idealism which has evolved within a history of gross oppression, violent conflict and drastic change. Their efforts are sorely needed to ease and improve the transition from agricultural to industrial livelihood which is probably inevitable, albeit far from painless, for India. Those cynics who view this kind of idealism as anachronistic, as having no place in a modern industrial world, would do well to remember that the socioeconomic rights they take for granted -- labor laws, the minimum wage, free education, civil and women's rights, consumer safety and product standards, not to mention the protection of air and water quality -- were fought for and won by idealistic and often radical social and political

[55] The study was first published in Anumukti, Vol. 6 No. 5, April 1993. Portions of it have been reproduced in the International Journal for Concerns in Public Health, Vol. 10, and in Chernobyl, a book brought out by the "Ten Years of Chernobyl" conference in Vienna, 1996.

activism.[56]

The farm-cum-school in Panchgani, known as the Redstone Farm, is a third locus of grassroots activity worth mentioning. Like the Gadhias, with whom they have collaborated on farming and other projects, Peter and Mona Patrao grew up within a privileged upper class which they later disowned. Longtime activists in many areas, as well as trained teachers, the Patraos have brought their experience and dedication into the foundation of the school. Impetus for the school came partly from a frustration with the dismal lack of stimulating liberal education, which the Patraos faced in the upbringing of their daughters (the younger of whom is a now a student at the school). Even at expensive boarding schools for the elite, they found, education consisted of little more than mindless rote memorization and authoritarian discipline.

Although the school has already enjoyed spectacular success, the Patraos would like to have more students from disadvantaged rural backgrounds -- there is currently just one -- while maintaining a liberal atmosphere. These goals are somewhat in conflict, given the huge disparity (in terms of culture and society, as well as wealth) between the enlightened and egalitarian setting of the school, and the pre-industrial, sharply caste- and gender-conscious society of surrounding villages. That is, the sort of education that the Redstone school provides could have the effect of altogether alienating a rural child from his kind in the village -- a possibility of which the school's teachers are keenly aware. Some amount of clashing between liberal (Western) education and traditional (Indian) culture is unavoidable: it is an expression of a conflict that grips all of India -- indeed, all of the developing world -- in its transition from pre-industrial to industrial modes of livelihood.

These two modes, although they cannot coexist in stasis, need not be in absolute mutual exclusion (nor in fact are they, anywhere in India). Likewise, a liberal western education need not be incompatible with functionality in the rural Indian setting, although both would require a high degree of tolerance and adaptability. Between the historical extremes of revolution and reaction lie a dynamic mean, towards which the Patraos are striving with their lives. If there is to be any equitable, peaceful resolution of such problems as modern India faces, I believe it will be in part through the disproportionate and sane influence of such endeavors as the Redstone school. (See appendix A for contact address.)

A fourth group of note is the Society for Eco-friendly Development, which is connected (but not quite identical) with the Payyanur group covered in part II, **Small hydro**. The Society's chief organizer and spokesperson, Mr. K. Sahadevan, was (not coincidentally) a student of Narayankaka at the Sampoorna Kranti Vidyalaya and was active in many of SKV's external concerns. Mr. Sahadevan played a principal part in mobilizing support for the Payyanur group's small-hydro initiatives and helped arrange my own visit there.

The Society's general aims and interests coincide with the movement towards participatory planning which seems to be gathering momentum in Kerala. State acceptance of participatory

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[56] I am thinking of Jane Addams, a key figure in American (and world) history in this respect. See, for example, her classic account of activism in Chicago, Twenty Years at Hull-House.

planning, as well as popular enthusiasm for movements which are vaguely self-characterized as "people's power", may in turn be seen as a part of the sociopolitical atmosphere of India's first communist state. Thanks to such revolutionaries as E. M. S. Namboodiripad -- a contemporary of Gandhi highly esteemed for his role in the independence movement and credited with the social revolution that swept Kerala -- the citizens of Kerala (insofar as I may generalize from the few dozens with whom I chatted) display a keen awareness of local and national politics, usually coming from a distinctly Marxist point of view.[57]

It is tempting to associate Kerala's political and social history with its present state, which is remarkably egalitarian and educated. Official demographics claim near 100% literacy, not to mention negligible growth of population. Although the literacy figure is almost certainly exaggerated, and although Kerala's enlightenment has yet to realize anything like full gender equality, the state's populace as a whole enjoys far greater liberty, social equity and material wealth than almost any other state of India. The state's difference is undeniable, although the nature and degree of the difference could be equivocated. Although my basis for judgement is probably inadequate, I would rate Kerala as among the most fertile areas for grassroots activity of every kind.

Although most grassroots organizations are deliberately local in their focus, I have encountered two whose activity is broad in intent and nationwide in scope. The All-India Women's Conference (AIWC), among the first of its kind, is active on many issues pertaining to the rights of women, especially in rural areas where gender equality is furthest from reality. AIWC is involved in the implementation of many governmental and non-governmental rural development initiatives, in particular for biogas and improved chulhas (see appendix B, under *Rural Energy*). The National Association of People's Movements (NAPM), a politically active and outspoken organization which grew out of opposition to the Sardar Sarovar project in the Narmada valley of Gujarat, now coordinates the actions of a number of organizations, mostly of agriculturalists, fisherfolk and others adversely affected by large development projects. Although I do not agree with NAPM's stance on development in general, I have met some of its leaders (including Medha Patkar) and I do believe they are sincerely committed to the well-being of the defenseless poor they represent. Both of these organizations have offices in Delhi and would be helpful, albeit not unbiased, as sources of information on rural development issues. They would better represent the views and experience of the rural populace than would large government or professional non-profit agencies. (See appendix A for contact addresses.)

Key coordinating agencies.

The Ministry of Non-Conventional Energy Sources (MNES) was promoted from Department to Ministry status in 1992. The preceding Department of Non-Conventional Energy

[57]My hosts in Payyanur estimated that at least 80% of voters in Kerala were members of the Communist Party. At the time I did not think to ask whether this meant the Communist Party of India (Marxist) or another. The CPI(M) and the CPI, the former a rival offshoot of the latter, are but two of the nominally communist parties extant.

Sources (in the Ministry of Energy) was established in 1982, based on the success of the Gujarat Energy Development Agency (GEDA), the first governmental non-conventional energy agency in India, which became the first nodal agency. Others soon followed: MEDA in Maharastra, the Agency for Non-conventional Energy and Rural Technology (ANERT) in Kerala, etc. MEDA and its state nodal agencies are responsible for the planning, coordination and implementation of central-government-sponsored renewable energy initiatives. In particular, "the following specific items have been assigned to the Ministry:

1. Commission for Additional Sources of Energy
2. Integrated Rural Energy Programme
3. Research and development of biogas and programme relating to biogas units.
4. Programme relating to improved chulhas and research and development thereof.
5. Mini-micro hydel projects below 3 MW capacity and geothermal energy.
6. Solar photovoltaic devices, including their development, production and application.
7. Tidal energy, wave and ocean thermal energy.
8. Indian Renewable Energy Development Agency (IREDA)."[58]

Roughly the same activities are undertaken by the nodal agencies, with emphasis on specific programs varying from state to state. Organization of activity is more or less hierarchical (along the lines of governmental administration), descending from the national (Ministry) level to regions and states, districts, panchayats and villages at the local or field level. See appendix B for a brief overview of MNES activities, which may be taken as an outline for the nodal agencies as well.

It must be noted that the national and nodal agencies are not collaborating organizations in the sense of those listed in prior sections of part III, and should not be presumed upon for exceptional assistance. However, I made a number of visits to MNES in Delhi, GEDA in Baroda and MEDA in Pune and found the individuals in these agencies consistently helpful and willing to assist me insofar as they were not limited by constraints of time and duty.

A second key agency is the Tata Energy Research Institute (TERI), which is to my knowledge the best of its kind for engineering, environment and policy studies related to non-conventional energy. TERI is comprised of the following divisions: policy analysis (with areas in energy and the environment, information technology and statistical analysis), energy technology (biomass, chemical/hydrogen, industrial and renewable areas), renewable resources management, biotechnology and information services; several centers operate within these divisions. The Centre for Global Environment Research strives to frame effective policy initiatives: "These initiatives would address global environmental challenges by striking a balance between international concerns and developing countries' national priorities."[59] Studies include global warming, the reduction of greenhouse gas emissions and database development. TERI's Centre for Information Technology, having networked TERI's facilities and many of its collaborators, now coordinates

[58]MNES Annual Report 1996-97, p. 7.

[59]TERI Annual Report, p. 9.

GIS-based field research among the divisions. In the Energy Technology Division, "the Chemical and Hydrogen Energy Area has already tested the feasibility of producing electricity in a bench-scale MCFC monocell using simulated coal gas, and is currently developing an MCFC stack in the 1-5 kW range. It is also planned to couple an MCFC stack with a coal gasifier to demonstrate the concept of an integrated coal gasification MCFC system for power generation using high-ash Indian coal. The Area is also actively exploring the potential of using membranes in various separation applications..."[60] In the Renewable Resources Management Division, "the Centre for Biodiversity seeks to develop and facilitate the evolution of systems and models for sustainable utilization, conservation and management of diverse ecological and biological resources in India."[61] Major objectives include conserving, monitoring, managing and protecting biodiversity.

TERI's activities are sponsored by a number of national and international agencies, including UNDP and UNEP, the World Bank, the Swiss Agency for Development and Cooperation, the Ford and MacArthur Foundations, NREL and many other European, Asian and American agencies, institutes and universities. In addition, TERI is a Global Environment Outlook (GEO) Collaborating Center for the Division of Environment Information and Assessment of UNEP, and has launched the international GREEN India 2047 project to assess and understand environmental degradation and human-linked changes in the periods 1947-97 and 1997-2047. TERI has a branch office in Washington, D. C. (The Tata Energy and Resources Institute - North America) and is a member of the Asian Energy Institute, a network of policy research institutes in the Asian region.

Two of TERI's publications are invaluable sources: TIDE (the TERI Information Digest on Energy), which carries technical papers, relevant digests from international journals and a comprehensive list of energy-related developments and activities in the Asian region and abroad; and TEDDY (the TERI Energy Data Directory and Yearbook), which contains comprehensive statistical tables of sector-wise, state-wise and aggregate energy consumption, patterns and trends in India, including both conventional and non-conventional sources. (Additional data along these lines is available in the Statistical Outline of India, published by Tata Economic Consultancy Services). Another good publication is TISGLOW (the TERI Information Service on Global Warming).

[60] Ibid., p. 24.

[61] Ibid., p. 33.

Invention is 1% inspiration and 99% perspiration. - T. Edison

Part IV. Completion

The totality of material gathered thus far demonstrates fundamental interrelationships which may govern the future of many countries. While mere demonstration does not in itself furnish convincing proof, it does at least motivate the search for more compelling evidence, by indicating not only where to look, but also how to look, and why the search matters. Although one might not agree with all of my conclusions, no believer in rational progress could, after living in the developing world, think unimportant the issues related here.

The first step.

The central purpose of this report is to encourage the exchange of ideas and expertise among the professionals of India and the West. In particular, I have tried to stress the value of actually going to India, to find the (often painful) reality of economic development in context. Physical travel and visitation in person is by no means the only kind of exchange which makes a difference, but in some ways it is the most permanent. In my opinion it is the most valuable, especially for defining and clarifying the majority of issues that are little discussed and less understood.

Notwithstanding my initial remarks about the lack of information on Indian energy development, there is a large and growing body of indigenous literature on the subject which is becoming increasingly available, although still largely confined to specialized journals. While this literature lacks somewhat in coming from the same small pool of upper-class (often expatriate) academics, seldom representing the experience of the rural majority, it is generally accurate within limitations self-imposed by strict utilitarianism. In addition, the studies of India by foreigners are increasing in number and quality. Finally, there are a large number of NGOs and other organizations which conduct all kinds of activity (some useful, some less so) in India and the developing world, much of which pertains to energy development, especially in its social and environmental aspects. Many of these organizations can be found through electronic media.

In the absence of further efforts to better understand and know India, in spite of the avenues opened by this report (and by others' works), my stated purpose will have failed. The Western understanding of the developmental aspect of our neighbors (and ourselves) will stagnate, reverting to effectlessness as yet another abstract field of study, neither touching nor being touched by the vast majority of human existence. Lest we, the privileged, come to prefer comfortable isolation in the place of sharp contact that upsets, recasts and enlarges the world, I can only offer my word that India is neither as distant, nor as strange, as it might appear. From here to there, from the comfortably known to the unknown, requires relatively few steps, only the first of which is difficult.

A note on India.

It would probably be better to say nothing at all, than to attempt further to describe this country. Nevertheless, I must say a few things for the benefit of you who will, I hope, soon be venturing for the first time into the Two-Thirds World (as one Indian writer has put it). It is important to realize that, whatever may be your impressions and judgements of life in the developing world, that world is undeniably one in which the large majority of humankind now lives. Entering that world does feel like passing into a disparate reality. However, the boundary between worlds is neither clearly defined, nor located along political borders.

The city of Bombay, for example, is intricately gerrymanderable into small islands of extreme modernity and wealth, and large irregular areas of extreme backwardness and poverty, with every inconceivable variation in between. You must not suppose these regions are clearly separate, although they are superficially distinguished by language, class, religion, race and other externalities; all such distinctions interpenetrate, no matter the criteria of separation. Bastions of the ultramodern are shot through with innumerable atavisms, throwbacks to ages of incomparable inequity, while no few residents of chawls (nominal slums) watch television, ride to white-collar jobs on motorcycles and prepare their children to become engineers and marketing agents. Although vastly different worlds may be said to exist, side by side, the boundary between them is not only fluid, but even fractal. About every aspect of finite existence slips a manifold of infinite surface, separating the strange from the familiar, the mysterious from the understood: a surface infinitely crenelated, recursive, ever-changing, the structure of the whole reduplicated in its parts at every level of detail, to the limit of human perception. At this limit, all boundaries dissolve.

Although you may never shake the sensation of sliding among juxtaposed worlds and realities (even, at times, a disconcerting sense of fractal boundaries crazing your own being), you will find that it doesn't really matter what world you happen to occupy, where the boundaries happen to fall. You will find the people you meet to be as similar to you, in every particular, as they are different. However, you must suspend the certainty of everything you think you know, if you wish to be happy outside of your familiar spaces. (If you wish, on the other hand, only to be right, you had better never leave home at all). In suspension you will find it quite easy to understand what other people are getting at, even without comprehending a word of the language, and they will welcome you almost as family.

Perhaps I should not speak as though issuing guarantees, since no individual is likely to have precisely the same experience that I did; yet I cannot think it simply luck, or personal charisma, that not one of the hundreds of people I met (most especially those in the chawls) ever treated me with less than respect and kindness. If anything, I received a deference which was often embarrassing and always unwanted. Never once was I permitted to reimburse the expense of hospitality, which was a far greater burden on my hosts than it would have been on me; I came to understand that, in privileging me as a guest, my hosts chose certain obligations that I could not challenge without serious offense. A relationship of mutual privilege was the rule, not the exception, of personal interactions. It may be (as some have asserted to me) that I was seen as the inheritor of old imperial rights, that I merely usurped a respect for the power of white skin which fifty years of independence have not completely dispelled; but I doubt this was the case. Power may inspire fear and, out of this, a kind of bitter respect, but it cannot command the kind of trust and spontaneous hospitality with which I was invariably received.

Many travelers to India bring back impressions of intolerable living conditions, aggressive and rude Indians, a menagerie of pickpockets and swindlers, dysentery from the smallest bite of doubtful food and in general a nightmarish ordeal, occasionally tempered by a misperception of romantic exoticism (or an appreciation for cheap hashish). Such travelers seldom, if ever, go beyond the well-trampled domain of touts whose business it is to prey upon tourists. There is a kind of pathetic humor in the incongruity of the European tourist, wearing tattered and revealing clothes and often dreadlocked and unbathed for days (if not weeks), passing blithely among the clean, reserved, educated, even sophisticated citizens of India. Ordinary Indians want nothing to do with either oblivious tourists or the poor unfortunates who prey on them. It is prudent to adopt the local attitude in this respect, as with many things. Fortunately, it is rather easy to distance yourself from both tourist and tout, distinguishing yourself as a visitor. I seldom saw the ugly world of the tourists, and even then in a far kinder light than they: rest assured that their unfortunate world comprises only the tiniest fraction of the life of India. Where any truth about India is concerned, you must take all second-hand accounts with a grain of salt,[62] although some may turn out to be accurate in your own context.

There remains to clarify just one further point, on which I am unashamedly biased. I do not think that any person could go to India and believe for very long that he was helping the less fortunate, unless he was blinded by arrogance. While I do not criticize the desire to help those in need (which I believe is a fundamental human trait), I must condemn the presumption that an outsider could understand the supposed problems of the supposedly less fortunate well enough to solve them. Many things which we would call problematic simply are not, to those who live them. Many of those we would call less fortunate might well choose not to lead our life over theirs, even if they had the choice. Moreover, most Indians are too proud to accept charity, especially when they need it. They are rightly suspicious of the kind of pitying altruism that stamped many well-intentioned bigots who administered the British Empire.

Each new day that I lived in India only confirmed my opinions on this point, in spite of my own naive and idealistic hopes to the contrary. Many of the experts with whom I consulted were, although very helpful and open to my ideas, frankly skeptical of my ability to contribute much of substance to their work, much less promote international research collaboration -- and skeptical they should have been, since I had so little knowledge of practical energy development, not to mention being unfamiliar with the milieu of India. One of my contacts (who eventually consented to being included in part III) put it quite bluntly. He said, "What would be the purpose of such collaboration as you propose? Do you really think you Americans have expertise which we need? How then would you help us? We have no need for it." His point was quite sharp, but accurate in its own light -- leading me to clarify to him (and to myself) that, although I did hope for a mutual gain, I really expected the West to benefit from Indian experience, much more than the other way around. I still believe this is the correct way to view things, at least for the collaboration I am promoting. Even though I cannot insist that you adopt exactly my own receptive attitude, I must say that this attitude took me a very long ways down a cryptic and delicate path, in a land long accustomed to compulsion from above.

A visitor to India must intend not to teach, but to learn; you must expect not to help, but to be helped. You will find endless opportunities to learn and discover, if only you seek them. I am

[62]I do not except my own account from critical skepticism, even though I have done my best to maintain accuracy at all levels of interpretation.

not advocating any sort of existential opportunism, of merely traveling for the thrill of novelty. Rather, I maintain that your attitude -- in a way, your very self and being -- will determine what you find in India, or in any vastly different environment.[j] I do not know what you will find, but if you are open, any place will open to you, revealing a world sometimes terrible, sometimes wonderful, but always a world in which you belong.

Acknowledgements.

I am indebted to more people than I can easily name -- not least, the nameless selectors of the Fulbright committee who believed in the potential of my thoroughly untested ideas. To begin with, thanks are due to Prof. Urjit Yagnik (Physics), who put me in touch with both the HSS Department at IITB, and the Rural Science Extension Centre at Vedchhi, contacts which enabled me to strengthen my proposal before its submission to the Fulbright board.

Honors are due to USEFI, the agency that administers the Fulbright grant in India, for its tireless professional and personal activity on behalf of all the Indian Fulbrighters. The orientation and conference were invaluable opportunities to meet fellow grantees and contacts in education and government. I must especially thank Mr. Subhash Chawla, a constant guide and confidant; he is the epitome of the instant-family hospitality which I met in India, first at USEFI, then everywhere else. I owe apologies to Subhash for my periodic ill-planned, peripatetic excursions on less-traveled roads, which caused him endless (but ultimately, unnecessary) worry.

I am grateful to the Department of Humanities and Social Sciences on many accounts. Firstly, the department head, Prof. Amitabha Gupta, was willing to host me for study, sight unseen, long before I had any definite plans. Upon arrival and throughout my stay, HSS students and faculty of gave freely of their time, companionship and critical analysis. Many bureaucratic obstacles would have been insurmountable without the help of Prof. Gupta: he gained me institutional access wherever there was no precedent for a student of my status (as was frequently the case), arranged comfortable lodging for me and otherwise handled the logistics of my stay at the IIT. Our amiable afternoon discussions gave much-needed direction to my studies.

I will never forget Mr. Vimal of the NAPM, who welcomed me to the December conference in Delhi with a smile and a warm samosa from his breakfast. The conference was a source of numerous contacts and a good introduction to power-sector policy issues. Indirectly, this conference resulted in an unexpected sojourn through old Delhi and a memorable cross-country bus trip through Rajasthan and Gujarat to Bombay, the first of many happy accidents which brought me closer to serendipity in the everyday.

Mr. Vasant Vadawale is responsible for most of my contacts in Gujarat, including those in Vedchhi and at ICNEER, as well as the Redstone farm in Panchgani. I had a most enjoyable stay with him and his brother's family in Baroda. Without his enthusiasm I would never have discovered, much less appreciated the importance of, the range of innovative education in India. Suren, Uma and Krishnamurthi at SKV, and Shirin and Deepak at ICNEER, gave me an immediate sense of the practicalities of responsible development. Of equal importance, they introduced me to the small but significant circles of activism that still flourish among the inheritors of Gandhiji's ideals. My trip to Gujarat was in every sense a journey of discovery, which set the tone for later field visits and awakened me to the suburban chawls surrounding the IIT in Bombay.

A fortuitous connection at SKV took me to Kerala, where Sahadevan, Radakrishnan and the rest of the gang at Ampere afforded me an inspiring view of prospects for their state. Thanks especially to Vishwanathan and his friends and relatives in Kanayi, who brought me into their lives for three days, fixing forever my impressions of Kerala as a unique and enlightened place. I must also thank Prof. Matthews and the officers of the Vizhingam wave energy project, a forward-thinking endeavor which signifies the promise of the oceans: the infinite natural and human spaces yet to be explored.

The staff and officers of the MEDA office in Pune welcomed me on several occasions. I owe thanks especially to Dr. Torane, who invited me to visit the Chalkiwadi wind farm; to Dr. Salunke, who made sure I actually got there after a minor snafu; and to the MEDA people at Satara and Chalkiwadi, where circumstances conspired to bring an unexpected meeting with the district commissioner and an evening of traditional Maharastrian entertainment. Thanks also to Sucheta Joshi, a chance meeting with whom (at Mood Indigo in Bombay) was later to enable my visit to CWPRS, at the invitation of her father, a research officer there: thanks to Vilas and his colleagues who received me at the station.

Special thanks to Rajive, who from the very beginning encouraged and inspired me to explore and follow my intuitions. He proved time and again what surprising things may come from a fusion of radically different points of view.

Finally, I am grateful to Mona, Peter and Oovi Patrao at the Redstone farm, who received me so warmly on my first visit in May and subsequently in August after the inception of the school. I would never have thought to try my hand at teaching, without their encouragement. The students were (as ever so, in the proper setting) more adept at learning than their elders, infinitely forgiving of my sometimes uncertain starts, and honest enough to show occasional boredom. Their own enthusiasm made up for my shortcomings as a teacher, igniting an amazing synergy which could pack into mere hours the inquiry of ages. Three weeks at the school convinced me of the extraordinary possibilities inherent in a dual open/focused approach, while the students themselves let me see that the effort of teaching was, indeed, worth their while and mine.

My thanks go again to all those mentioned above, plus many unmentioned, for their unstinting hospitality, comraderie and countless invitations for chai and dinner. My work in India was made possible not in spite of, but rather entirely through, the "distraction" of chance encounters leading to close friends, in whose company I became a thoroughgoing insider. Nishant, Chandrashekar, Nikhil, Heeral, Srinivas, Urvi and many others kept me with balance and perspective in the midst of uncertain turmoil.

I reserve a special place for my first and perhaps closest friends, the children of the Bansode family -- especially Surendra, who found me hapless in the middle of a Novaratri dundiya dance, just days after my arrival in Bombay, and made sure (as only children can) that I was welcomed and provided with sticks. His family became the first of many to adopt me as honorary cousin-brother, abolishing boundaries of country and class and opening the door to an intimate world of everyday miracle, unfettered hope and scrumptious cuisine. I could never have felt at home in the chawls, nor perceived the ambiguous layers between the extremes of wealth and poverty in Bombay, without the unassuming companionship of Surendra and others like him. The children of India were my primary guides: they are able to accept things as given, quick to ignore unimportant differences and forget gauche blunders, unconscious of trivial discomforts, willing to make the best

of people and circumstances, eager to expand their horizons and always the most effective language teachers. To them I owe whatever insight and inspiration may be found in these pages.

Part V. Appendices

A. Other development-related contacts.

The following list includes a number of organizations which I visited or otherwise encountered as contacts. These organizations have no stated commitment regarding assistance to visitors, although I found them generally helpful and willing to discuss their work. Comments, if any, are to be found below the address. Entries are arranged alphabetically by last name or organization name (not acronym) in the following categories: solar energy, biomass gasification, other energy-related organizations; education, development studies, governmental agencies, grassroots organizations and internet contacts. Entries are listed by organization and/or principal contact(s), with the organization's address indented.

Solar Energy

Auroville
Chaman L. Gupta, Professor of Applied Sciences, Solar Energy Unit
Mr. Tency Baetens
    Sri Aurobindo Ashram
    Pondichery 605 002
    INDIA
    email: solagni@auroville.org.in

EG-SOLAR: Foreign Aid Group of the State Technical College, Altoetting e. V.
    EG-Solar
    Neuoettingerstr. 64c
    D 84503 Altoetting
    GERMANY
    tel: 0049-8671-969937
    email: EG-Solar@t-online.de

Indian Institute of Technology, Bombay (IITB)
Dr. Milind V. Rane, Assistant Professor
    Department of Mechanical Engineering
    IIT Powai
    Mumbai 400 076
    INDIA
    tel: 22-576 7514, 7393 (lab)
    email: ranemv@me.iitb.ernet.in

Sardar Patel Renewable Energy Research Institute (SPRERI)
Dr. T. K. Chaudhuri, Chief Scientific Officer, Solar Energy
    SPRERI

Vallabh Vidyanagar 388 120
Gujarat, INDIA
tel: 2962-31332, 30538

Wolfgang Scheffler, Diplom Physiker
Solare Bruecke
Berghof 112
D-83734 Hausham
GERMANY
tel: 0049-8025-7192
email: SOLAREBRUEKE@t-online.de
(Mr. Scheffler is the inventor of the Scheffler flexible-parabolic community cooker.)

ULOG Group
Gruppe ULOG
Morgartenring 18
CH-4054 Basel
SWITZERLAND
tel: 0041-61-3016622
(ULOG provides small-scale solar energy equipment, training and consulting and has distributed Scheffler cookers extensively in Africa and India.)

<u>Biomass gasification</u>

Indian Institute of Technology, Bombay (IITB)
Dr. P. P. Parikh, Professor
Department of Mechanical Engineering
IIT Powai
Mumbai 400 076
INDIA
tel: 22-576 7548

<u>Other energy-related organizations</u>

Environmental Management Consultants
Dr. Prasad Modak
Environmental Management Consultants
c/o ILFS
Mahindra Towers, 4th floor
Dr. G. M. Bhosale Marg, Worli
Mumbai 400 018
INDIA
tel: 22-416 8217

Prayas
Mr. Girish Sant
Amrita Clinic
Athawale Corner near Sambhaji Bridge
Karve Road
Pune 411 004
INDIA
tel: 212-230337
email: energy@prayas.ernet.in
(This organization has been active on the Enron controversy, in policy issues and other "initiatives in health, energy, learning and parenthood".)

International Energy Initiative (IEI)
Dr. A. K. N. Reddy, Director
IEI c/o Energy for Sustainable Development
25/5 Borebank Road
Benson Town
Bangalore 560 046
INDIA
tel: 80-554 3563
(IEI was founded by A. K. N. Reddy, a noted professor of energy studies and former director of ASTRA at IISc-Bangalore.)

IBPL Urja Research Foundation
T. Gopinath, General Manager
701-C, Poonam Chambers
Dr. Annie Besant Road, Worli
Mumbai 400 018
tel: 22-492 6629, 495 2810
(A subsidiary of Industrial Boiler Products, Limited, this foundation promotes energy efficiency through various activities and the publication Energy Scenario).

Tata Energy Research Institute (TERI)
Dr. B. D. Sharma, Fellow (Renewable Energy Technology)
TERI
Darbari Seth Block
Habitat Place
Lodhi Road
New Delhi 110 003
INDIA
tel: 11-462 2246 / 460 1550 x2138
email: bdsharma@teri.res.in

Education

Homi Bhabha Center for Science Education (HBCSE)
TIFR
V. N. Purav Marg (next to Anushaktinagar Bus Terminus)
Mankhurd
Mumbai 400 088
INDIA
tel: 22-556 7711, 555 4712, 555 5252
email: hbcadm@hbcse.tifr.res.in

Moral Rearmament Academy
MRA - Asia Plateau
Panchgani
Dist. Satara 412 805
Maharastra, INDIA
(The MRA is based on an idea of Bertrand Russell and runs camps and workshops on "moral rearmament" and social justice.)

Redstone Farm School
Peter and Mona Patrao
Redstone Farm
Village Bhose
Panchgani
Dist. Satara 412 805
Maharastra, INDIA
tel: 2168-40566

Rural Science Extension Centre, Vedcchi
Smt. Kokilaben Vyas, Secretary
Gandhi Vidyapith, Vedchhi
Dist. Surat 394 641
Gujarat, INDIA
(The RSEC was, until recently, coordinated by Mr. Vasant Vadawale. He now works with schools in the Baroda district.)

Vasant Vadawale
768, Sharad Nagar
Tarsali
Vadodara 390 009
Gujarat, INDIA

Development studies

Center for Development Studies and Activities (CDSA), Pune
Christopher Berninger or Anita Gokile
Postal address:
P. B. No. 843
Deccan Gymkhana,
Pune 411 004
INDIA
Campus:
Survey no. 58 & 49/4
Bavdhan Khurd, Off NDA Circle
Paud Road
Pune 411 021
INDIA
tel: 212-338918, 336436
email: cdsa.sdp@gems.vsnl.net.in
(CDSA is a center within the School of Development Planning, University of Pune, offering a two-year Master's degree course.)

Indian Institute for Advanced Studies
Rashtrapati Niwas
Shimla 171 005
tel: 177-231390
(IIAS is a premier institution for studies in the humanities and social sciences. Direct inquiries to the Public Relations Officer at the above address.)

Indira Gandhi Institute of Development Research (IGIDR)
Dr. Kirit S. Parikh, Director
Dr. R. Ramnathan, Energy studies
IGIDR
Gen. Vaidya Marg, Goregaon (E)
Mumbai 400 065
INDIA
tel: 22-840 0919, 0920, 0921
email: postmaster@igidr.ac.in

Unit for Media and Communications, TISS
Dr. Anjali Monteiro, Reader and Head
Dr. K. P. Jayasankar, Senior Producer
Tata Institute of Social Sciences
Deonar
Bombay 400 088

INDIA
tel: 22-556 3289 to 3296
(Drs. Monteiro and Jayasankar have produced a number of documentary films about development in India.)

Governmental and nodal agencies

Agency for Non-conventional Energy and Rural Technology (ANERT)
Director
ANERT, Government of Kerala
Post Box No. 442
Thycaude
Thiruvananthapuram 695 014
INDIA
tel: 471-449854, 440122, 440124

Gujarat Energy Development Agency (GEDA), Government of Gujarat
Mr. R. N. Pandya, Senior Technical Executive
2nd floor, Suraj plaza-II
Sayajiganj
Vadodara 390 005
Gujarat, INDIA
tel: 265-363123, 362058, 361409

Maharastra Energy Development Agency (MEDA), Government of Maharastra
Dr. S. Kumar, Solid Waste Management
Dr. J. V. Torane, Wind Power
Shri V. V. Mahulkar
S. No. 191, A, Phase - I
2nd floor, MHADA Commercial Complex
(opposite Tridal Nagar)
Yerawada, Pune 411 006
INDIA
tel: 212-683633, 683634

Ministry of Non-conventional Energy Sources (MNES),
Government of India
Ajit K. Gupta, Adviser & Head (Power group)
MNES
Block No. 14
CGO Complex, Lodhi Road
New Delhi 110 003
tel: 11-436 1152

Grassroots organizations and NGOs

All-India Women's Conference (AIWC)
Mrs. Lalita Balakrishnan, Chairperson (Rural Energy Department)
AIWC
6 Bhagawan Dass Road
New Delhi 110 001
INDIA
tel: 11-338 9680

Center for Holistic Studies
(see entry under Agriculture)

Goa DESC
No. 11 Liberty Apartments
Feira Alta, Mapusa
Goa 403507
INDIA

National Association of People's Movements (NAPM):

in Gujarat:
Medha Patkar
B-13 Shivam Flats, Ellora Park
Baroda 390 007
Gujarat, INDIA

in Delhi:
Mr. Vimal
tel: 11-642 6783

Redstone Farm
(see entry under Education)

Social Work Research Center
Mr. Sharma
Tilonia
Madanganj 305 816
Rajasthan, INDIA
(The SWRC is engaged in rural development, employment generation among agricultural workers and education and literacy, especially for women. Tilonia is located about 40 km from Ajmer.)

Vidnyan Ashram
PO Koloshi
Ratnagiri district
Maharastra, INDIA

Agriculture

Center for Holistic Studies
Dr. Winine Pereira
79 Carter Road
Bandra
Mumbai
INDIA

International Crop Research Institute for Semi-Arid Tropics (ICRISAT)
ICRISAT HQ
Patancheru 502 324
Andhra Pradesh, INDIA
tel: 040-506161
email: icrisat@cgnet.com
web: http://www.cgiar.org/icrisat

International Federation of Organic Agriculture Movements (IFOAM)
IFOAM Head Office
c/o Oekozentrum Imsbach
D-66636 Tholey-Theley
GERMANY
tel: (49) 6853-5190
email: IFOAM@t-online.de
web: http://www.ecoweb.dk/ifoam/index.html

M. S. Swaminathan Research Foundation (MSSRF)
MSSRF
3rd cross street, Institutional Area
Taramani
Chennai 600 113
INDIA
tel: 44-235 1229, 1698
email: msswami@mssrf.org
web: http://www.mssrf.org

Internet

The following sites are good places to start for links to energy and development in India and worldwide.

Akhil Bharatiya Vidyarthi Parishad (ABVP)
  http://www.abvp.org
(An Indian national student activist organization working for social and political change through agitations and education.)

Center for Renewable Energy and Sustainable Technology (CREST):
Global Energy Marketplace
  http://gem.crest.org/index.html
Solstice on-line information service
  http://solstice.crest.org/index.shtml
(A comprehensive database of renewable energy information.)

International Institute for Sustainable Development (IISD):
IISDNet
  http://iisd1.iisd.ca/contents.htm
(The on-line network of a Canadian development organization.)

International Network for Sustainable Energy (INFORSE)
  http://www.inforse.dk/
(A European network established at a recent UN conference.)

Leadership in Education And Development (LEAD):
LEAD India
  http://www.lead.org/india/lead/abcreed.htm

Renewing India
  http://www.renewingindia.org/index.html
(A site affiliated with Winrock, CREST and other organizations.)

Signposts to Asia and the Pacific: Contacts: India
  http://138.25.138.94/signposts/contacts/India/index.html
(A journalistic information resource. The Indian contacts page lists of number of relevant NGOs not found elsewhere on the Internet.)

U. S. Agency for International Development (USAID):
Development Links
  http://www.info.usaid.gov/resources/

Winrock International:

http://www.winrock.org/
Development Links
http://www.winrock.org/intdevel.htm
(Winrock is a large U. S.-based international agricultural development agency.)

B. Summary of MNES activities.

This summary outlines the activities of the Ministry of Non-Conventional Energy Sources as they are glossed in the MNES Annual Report 1996-97, to which all citations refer.

Rural Energy. This area of activity is comprised of National Programs for development in each of the following seven areas: biogas (based on dung, night soil and leaf manure), improved chulhas, biomass production (tree farming) and biomass gasification (for captive power generation, drying of gluten and tea leaves, village electrification and diesel fuel replacement), animal energy, integrated rural energy, urjagrams (model villages in which most energy needs are met from renewable sources) and special area demonstrations (for promotion and publicity in far-flung areas difficult to supply with conventional sources). Many of these programs are implemented through such grassroots NGOs as the AIWC; biogas plants and chulhas, for instance, are in practice built, used and maintained by women. The programs are not entirely distinct, but overlap to an extent, in particular with the Integrated Rural Energy Program (IREP), which is closely coordinated with the Urjagram Program. In a nutshell, IREP "consists of the two major components, namely, i) provision of energy for meeting the basic needs of cooking, heating and lighting, specially for the weaker sections by utilising locally available energy resources to the extent possible and ii) provision of energy as the critical input in the economic development of rural areas which would result in the creation of employment, increase in productivity and income, besides accelerating the process of decentralised development."[63] These seven programs are accomplished with the help of technical back-up units, which provide technical support at the district level, and national and regional training institutes, which undertake performance evaluation and impact assessment as well as training.

Solar Energy. This area includes programs in solar thermal energy (water heating, cooking, other thermal applications and solar passive architecture), solar photovoltaics (research & development, demonstration and utilization, industrial activity and solar water pumping) and a Solar Energy Center (SEC) in Gurgaon, on the outskirts of Delhi. The Solar Energy Center is responsible for testing and standardization of technology, dissemination of information, thermodynamic studies of solar power generation (through IIT-Delhi) and international communications. "The Centre coordinates the cooperation in the field of solar energy among the group of 15 (G-15) developing countries and participates in other international activities... [In addition,] the SEC executed a Memorandum of Understanding with the National Renewable Energy Laboratory (NREL), USA, in 1994 for the exchange of technical expertise, samples, data, etc."[64]

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[63] Page 29.

[64] Pages 45, 48.

Power from Renewables. Programs in this area include wind power (assessment, mapping, demonstration and commercial promotion), small hydro power, solar power, biomass power generation (bagasse co-generation and biomass gasification). These programs include various demonstration, subsidy and commercialization schemes. The World Bank, through IREDA, has extended lines of credit to finance projects to develop small-hydro power (US$70 million), solar photovoltaic power ($30 million) and biomass power ($100 million), among other areas. Power projects range in scale and type from the 110 kW SPV installation at Walwhan Dam, Lonavla district (near Bombay), commissioned by the Tata Electric Company, to the planned 140 MW Integrated Solar Combined Cycle Power Plant[65] at Mathania (Jodhpur), Rajasthan, which will involve a 35 MW solar power component and a 105 MW conventional power component.

Energy from Urban and Industrial Wastes. MNES has a national pilot program on recovery of energy from wastes. A number of projects are underway investigating the technical, environmental and social aspects of generation of power from incineration of dry waste and biomethanation of liquid refuse. The aim is to combine ongoing efforts to safely dispose of various industrial effluents (e. g. from leather and paper factory processes) with research in energy production. UNDP/GEF has provided a US$5.5 million grant for the development of high-rate biomethanation for the reduction of greenhouse gas emissions while recovering energy from municipal and industrial wastes.

New Technologies. The Ministry supports the development and commercialization of new energy technologies in the following areas: fuel cells (phosphoric acid, polymer electrolyte, solid oxide and molten carbonate types), hydrogen energy (production, storage/transportation and utilization as fuel for vehicles, heat pumps and power generation), geothermal energy, alternate fuels for surface transportation (methanol, natural gas, batteries) and ocean energy. Fuel cells and hydrogen sources are of particular interest in the prospect of developing modular, flexible and distributable generation of power.

Research and Development. MNES sponsors R&D programs in each of the energy sectors under its purview. "As a result of the opening up of the economy from 1991 onwards, it was decided to adopt a market-driven approach for renewable energy. The R&D activities were to be made more applied and related to industry with focus on technology development and commercialisation."[66] Research topics include amorphous and polycrystalline silicon films, aquaculture for biomass cultivation, feasibility of production of hydrogen using off-peak grid power, technology for ultra-low head small-hydro development, biochemical energy conversion routes, and the expected topics in areas already outlined above (rural energy, solar energy, etc.).

Indian Renewable Energy Development Agency. "IREDA was established in March, 1987 as a Public Sector Enterprise under the administrative control of the Ministry of Non-Conventional Energy Sources with the main objective of administering a revolving fund to promote, develop and finance NRSE technologies."[67] IREDA's stated thrust areas for the year

[65]Page 66.

[66]Page 89.

[67]Page 93.

were solar photovoltaics, cogeneration, small hydro and wind energy. Disbursements for these areas were (Rs. in crore) 65, 40, 48 and 408, respectively, out of Rs. 626 crore total, showing that wind energy accounts for the majority (65%) of loans. In the same year, IREDA sanctioned an additional Rs. 1336 crore of loans, distributed (corresponding respectively as above, Rs. in crore) as 166, 51, 346 and 659.[68] With the exception of small hydro, the share of which grew from 8% (disbursed) to 25% (sanctioned), reducing the share of other areas, the distribution is about the same as for disbursements. In accordance with Government of India guidelines, on the basis of its profit, IREDA paid a dividend of 2.41% for the year 1995-96.

International Relations. "India participates in a broad range of international cooperative activities in the field of renewable energy. The activities are conducted both on a bilateral basis as well as with multilateral organisations. The international programmes are aimed at sharing our experience and expertise with other countries, promoting scientific and research cooperation in the technologies of interest to the country and mobilising financial resources for various programmes."[69] In addition to receiving aforementioned UNDP and World Bank loans and various other multilateral financial and technical assistance, India participated in the World Solar Summit at Harare, Zimbabwe (1996). Bilateral activities include Indo-Russian conferences held in Moscow (1996 and 1997), a joint project with NREL for SPV installation in the Sundarbans area (West Bengal) and initial discussions with Australia, Canada, Denmark, Japan and the USA for "Activities Implemented Jointly" under the UN Framework Convention on Climate Change.

C. Chronology of visits.

The following is a log (not all-inclusive) of the author's energy-related visits (*), academic activities and cultural events attended. Major trips are italicized. The question mark (?) denotes uncertainty in a date. Formal visits are glossed in the format * *Organization (Location): Principal contact, Expertise* or * *Individual (Location), Expertise*; if omitted, name of principal contact was unavailable or not applicable. Location may be omitted where preceded by italicized trip headings, or on second occurrences. Some of the organizations below may be found in appendix A.

September	
26	Arrival in New Delhi
28 - 30	Orientation at Fulbright House, Delhi
October	
1	* MNES (Delhi): Mr. Ajit Gupta, Power section
2	Observance of Gandhi Jayanta at Raj Ghat, Delhi
3	Arrival at IIT, Bombay
4	5th night of Novaratri dundiya dancing at Paspoli village, Powai, Bombay
8	* Prof. P. P. Parikh (IITB), Biomass gasification

[68]The data are from Table 9.1, page 93.

[69]Page 101.

9 HSS Department ceremony to honor Saraswati
Masquerade night at Novaratri dundiya, Paspoli
10 Final night of Novaratri dundiya, Paspoli
11 Observance of Dusshera with Bansode family, Paspoli
18? Performance of Joe Zawinul Syndicate with Zakir Hussain at Rang Bhavan, Bombay
25? Trip to Bhaskar Save farm at Umbergaon, Gujarat, organized by Group for Rural Activities.
? TISS social/environmental exposition, Bombay
29 Joint HSS/Mech. Engg. meeting on alternative energy & development at IITB
30 Observance of Diwali

November

5 - 6 Seminar on industrial ecology by Robert Socolow, CEES (Princeton) at IITB
12 Observance of death anniversary of grandfather of Bansode family, Paspoli
? * CTARA (IITB): Prof. N. Shah, Rural energy development
18 * Center for Holistic Studies (Bombay): Winine Pereira, Environmental science
21 Fair/garba at Paspoli
22 Observance of death of Sufi saint at Paspoli; qawwali performance
24 Lecture by Dr. James Watson at Bhaba auditorium, TIFR, Bombay
25 "Integrity" seminar at Lala Lajpatrai College, Bombay
31 - Dec. 4 *Trip to Delhi*

December

1 - 2 Conference on Power-Sector Policy Reform (organized by NAPM and Prayas) at Indian Social Institute, New Delhi.
5 - 7 Bus journey from Delhi to Bombay
12 - 23 Field visits in Gujarat
13 - 15 * ICNEER (Valsad): Shirin & Deepak Gadhia, Solar energy and rural development
16 * Rural Science Extension Centre (Vedchhi): Mr. Vasant Vadawale, Science education
18 * GEDA (Baroda): Mr. R. N. Pandya, Renewable energy
* SPRERI (Vallabh Vidyanagar): Dr. T. K. Chaudhuri, Solar energy
19 - 22 * Sampoorna Kranti Vidyalaya (Vedcchi): Suren & Uma Gadekar, Social impact of development
20 * Gandhian ashrams (Vedcchi)
24 Midnight mass at Powai parish church
26 - 30 Mood Indigo at IITB

January

5 Presentation to Group for Rural Activities, IITB
13 Lecture by Dr. Prasad Modak on Agenda 21 at the Center for Environmental Sciences and Engineering, IITB
14 * Environmental Management Consultants (Bombay): Dr. Prasad Modak, Environmental engineering

* Dr. Shireesh Kedare (Bombay), Renewable energy and rural development
20 Presentation at USEFI, Bombay
22 Mid-term presentation for HSS Department, IITB

February

1 - 4 Fulbright Mid-Year Review Conference in Panjim, Goa
5 * Department of Philosophy, Goa University: Prof. A. V. Afonso, Philosophy and social change
11 * Goa DESC (Panjim): Mr. Louis D'Souza, Impact of tourism
15 - 18 1st trip to Pune, Maharastra
16 * MEDA: Dr. S. Kumar, Solid waste/urban energy; Dr. J. V. Torane, Wind energy
17 * Prayas: Mr. Girish Sant, Public policy in energy and health
College art/drama competitions at Bharat Natya Mandir
18 - 22 Conference on the History and Philosophy of Science (organized by HSS department), IITB
22 Classical recital with Ustad Zakir Hussain, Thane
24 Customs negotiations at Sahar Airport, Bombay
Performance of "The Taming of the Shrew" at Sophia College
25 Visit with Prof. A. W. Date (IITB), founder of CTARA
26 * TISS (Bombay): Dr. Anjali Monteiro and Dr. K. P. Jayashankar, Media production and social science

March

9 - 12 2nd trip to Pune, Maharastra
11 * Center for Development Studies and Activities
* BAIF: Dr. A. L. Joshi, Rural development
12 * School of Energy Studies, Pune University: Prof. M. G. Takwale, Solar energy
13 Observance of Holi
14 - 27 Trip to Kerala
16 * Society for Eco-Friendly Development (Payyanur): Mr. K. Sahadevan, Rural development/social activism
17 Microhydel site at Pathanpara
18 - 20 Kanayi village
21 * Kerala State Planning Commission (Kalyasheri, Kannur)
23 * Wave Energy Pilot Project (Vizhingam): Prof. P. T. Matthews, Ocean energy
24 Presentation to Workshop on Press, Ethics and Law (organized by Indian Society of Interdisciplinary Studies), at Trivandrum Press Club

April

4 Visit with Mr. Sheldon Austin, USIS, Bombay
8 Visits to Mahakali caves, Aarey Milk Factory, Chhota Kashmir (Bombay)
22 * IGIDR (Bombay): Dr. R. Ramnathan, Energy and the environment
30 Nighttime harbor excursion, Bombay

May

2 Performance of "Art" at Sophia College, Bombay

9	* IBPL Urja Research Foundation (Bombay): Mr. T. Gopinath, Energy efficiency
13	Visit to Russian Cultural Center, Bombay
14?	Underground nuclear tests at Pokhran, Rajasthan
17	* Mr. Vivek Monteiro (Bombay), Social/environmental action and education
18 - 23	*3rd trip to Pune, Maharastra*
20	* Chalkiwadi wind farm (Satara): Dr. J. V. Torane, Dr. P. S. Salunkhe
21	* Redstone organic farm (Panchgani): Peter and Mona Patrao, social/environmental issues and education
30	Performance of "Love Letters" at Prithvi Theatre, Bombay
June	
1 - 24	*Travels through northern India*
2 - 3	Jaipur
4 - 6	Pushkar
7	Ajmer
8	Agra, Delhi
9	Delhi
10 - 15	Shimla
13	Visit to Indian Institute for Advanced Studies, Rashtrapati Niwas (Shimla)
14	Visit to H. P. University (Shimla)
17 - 22	Dharmsala
19	Trek to Triund
23 - 24	Delhi
28 - 30	*4th trip to Pune, Maharastra*
29	* CWPRS: Dr. Mone, Energy research; Dr. A. Kale, Ocean engineering
July	
2	* TIFR (Bombay): Dr. P. R. Apte, Solid-state materials
11	Trek to peak of Kul-subai, Maharastra
28	Presentation to Indian students on graduate studies in the U. S., at USEFI, Bombay
31	* Dr. Shireesh Kedare
August	
2	Sarod recital by Arnab Charabarty at TIFR, Bombay
5 - 26	*Teaching-in-residence at Redstone farm school, Panchgani*
12	Visit to Asia Plateau / Moral Rearmament Academy
30	Observance of Ganesha Chathurti
September	
10	Final presentation to HSS Department, IITB
13 - 16	Participation in orientation of 1998 Fulbright grantees in New Delhi
21	Departure from Bombay

D. Acronyms, abbreviations and glossary.

AIWC	All-India Women's Conference

ANERT	Agency for Non-conventional Energy and Rural Technology
BAIF	Bharatiya Agro Industries Foundation (now BAIF Development Research Foundation), Pune
BHEL	Bharat Heavy Electricals, Limited
CDSA	Center for Development Studies and Activities, Pune
CEES	Center for Energy and Environmental Studies, Princeton
CPI	Communist Party of India
CPI(M)	Communist Party of India (Marxist)
GEDA	Gujarat Energy Development Agency
GEF	Global Environmental Fund
GIDC	Gujarat Industrial Development Corporation
GIS	Global Information System
GOI	Government of India
HBCSE	Homi Bhabha Center for Science Education, Bombay
HSS	Humanities and Social Sciences (Department of IITB)
ICNEER	International Center for Environment, Education and Re-integration, Valsad
IEI	International Energy Initiative
IGIDR	Indira Gandhi Institute of Development Research, Bombay
IISc	Indian Institute of Science, Bangalore
IITB	Indian Institute of Technology, Bombay (Mumbai)
IITM	Indian Institute of Technology, Madras (Chennai)
IREDA	Indian Renewable Energy Development Agency
IREP	Integrated Rural Energy Program
ISI	Indian Social Institute, Delhi
ISIS	Indian Society of Interdisciplinary Studies
KSEB	Kerala State Electricity Board
KSSP	[Kerala State Planning Commission]
KVIC	Khadi and Village Industries Commission
MDMTC	Dr. Manibhai Desai Management Training Center, Pune
MEDA	Maharastra Energy Development Agency
MIDC	Maharastra Industrial Development Corporation
MNES	Ministry of Non-Conventional Energy Sources
MSEB	Maharastra State Electricity Board
MSSRF	M. S. Swaminathan Research Foundation, Chennai
NAPM	National Association of People's Movements
NIOT	National Institute of Ocean Technology, IITM
NREL	National Renewable Energy Laboratory, Golden (Colorado)
SARMET	Society for Advancement of Renewable Materials & Energy Technology
SEB	State Electricity Board
SKV	Sampoorna Kranti Vidyala [Institute of Total Revolution], Vedchhi
SPRERI	Sardar Patel Renewable Energy Research Institute, Baroda
TERI	Tata Energy Research Institute, Delhi
TIFR	Tata Institute of Fundamental Research, Bombay

TISS	Tata Institute of Social Sciences, Bombay
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
USEFI	United States Educational Foundation in India
USIS	United States Information Service

A. P.	Andhra Pradesh
H. P.	Himachal Pradesh
M. P.	Madhya Pradesh
U. P.	Uttar Pradesh

FWHM	full width at half-maximum height
kW	kilowatt
kWh	kilowatt-hour
m/s	meters per second
MCFC	molten carbonate fuel cell
MNC	multinational corporation (or company)
MW	megawatt
NGO	non-governmental organization
NRSE	new and renewable sources of energy
OWC	oscillating water column
rpm	revolutions (rotations) per minute
Rs	Indian rupees
SPV	solar photovoltaic
VAR	vapor absorption refrigerator

(Note: non-English words below are italicized.)

anumukti - a word of Sanskrit roots meaning "freedom from atomic energy"

approtech - appropriate technology, or technology supposedly suitable for the needs of a developing country

bagasse - the pulp left over from processing sugar cane

bioenergy - *see* biomass energy

biogas - methane or carbon monoxide gas produced by anaerobic bacterial digestion (decomposition) of organic matter

biomass energy - energy derived from any organic source

biomass gasification - chemical conversion, by heating, of organic matter (wood, leaves, chaff) into producer gas of low to medium energy content: usually a mixture of nitrogen, carbon monoxide and carbon dioxide

biomethanation - production of methane gas from anaerobic bacterial digestion of organic matter

chikoo - a sweet pulpy fruit common in the warm regions of India

chawl - technically, a slum of brick, tin and concrete houses; in urban areas, chawls are home to low- and middle-income Indians and may merge with conventional apartment high-rise areas

chulha - a traditional wood-fired oven of clay, brick or stone with round holes in the top for cooking, as on a range

crore - 100 lakhs, or 10 million; a common unit in Indian literature

energy gain ratio - the quantity of energy gathered over the lifetime of a renewable-energy device, divided by the quantity of non-renewable energy required to manufacture the device

fuel cell - a device in which fuel (e. g., hydrogen or methane) is efficiently oxidized via a catalyst, producing electricity and exhaust vapor

full width at half-maximum - a standard measure for characterizing the shape of a wave or wavelike peak: the full width of a wave, taken at half its maximum amplitude

gasifier - any device for gasification of biomass; generally a metal tank in vertical orientation with a burner, infeed and outlet for gas

genset - portable diesel-powered set for generating electricity

gobar gas - literally, "garbage" gas or biogas produced from cow dung and/or vegetable compost

heat pump - a device which moves heat from one place to another, e. g. a refrigerator, using an input of work (energy)

high-intensity farming - conventional mechanized farming requiring large inputs of water, fertilizer and pesticides

hydraulic energy - energy in the motion of fluid, e. g. the energy of moving water waves

insolation - amount of sunlight received by a given area

khadi - homespun cloth, of the kind that became a symbol of Indian resistance to British rule *lakh* - 100,000; a common unit in Indian literature

microhydel - micro-hydroelectric power or energy; denotes small-scale production of energy, i. e. on the order of kilowatts rather than megawatts

nacelle - the rigid shell covering the turbine-generator apparatus of a propeller-type wind generator

nodal agency - the state-level branches of a national organization; for example, MEDA and GEDA are nodal agencies of MNES

pneumatic energy - the energy of moving air

prime mover - a device which extracts work (energy) from a flow of heat; the functional opposite of a heat pump

producer gas - the gas released in the heating of volatile organic compounds in wood or other organic matter; *see* biomass gasification

pumpset - a diesel-powered or electric pump for crop irrigation

Rankine cycle - in thermodynamics, the cyclic process which drives most thermal power turbines; characterized by non-isothermal transfers of heat, necessitating less-than-ideal conversion of heat into work

samosa - a kind of fried dumpling stuffed with curried potato

sericulture - the cultivation of worms for silk

solar photovoltaic - denotes a device which converts solar (or other) radiation directly into electricity

Stirling cycle - in thermodynamics, a cyclic process which is characterized by isothermal and adiabatic exchanges of heat, resulting in highly efficient conversion of heat into work

Stirling engine - a prime mover (engine) utilizing the Stirling cycle

synchronous speed - the speed at which an AC electric motor (or generator) turns in phase with the supply current

tetrapod - a concrete structure with four symmetric legs inscribing the vertices of a regular tetrahedron; used to reclaim land from the ocean or in the construction of breakwaters *urjagram* - a word of Sanskrit roots (literally "energy village"): a village supplied mostly with renewable sources of energy (SPV power, biogas, etc.), to demonstrate and popularize renewable energy; part of a program initiated by MNES

vapor absorption refrigerator - a type of heat pump which operates by means of a large mass of high-absorbent material which maintains a low vapor pressure above a reservoir of fluid, allowing the fluid to boil at ambient temperature

vermiculture - cultivation of earthworms for agricultural use

vidyalaya - Sanskrit word for school or institution

wave caisson - a hollow structure partially submerged in the ocean, with an opening to transmit wave oscillation to a volume of air

yatra - travel, or a march or tour to publicize a political issue; for example, Gandhi's march to the sea was a yatra

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Endnotes

a. Although I have heard arguments to the effect that commercialization of such technology will put it out of the reach of the poor who really need it, commercial enterprises are inarguably more effective and efficient in diffusing technology than government. At any rate, not commercializing the technology will not place it any more quickly in the hands of the needy. Whether it is better to spend limited resources to commercialize, or to support non-profit self-sufficiency programs, remains to be seen.

b. More than one researcher whom I spoke with on this issue suggested that the Stirling cycle replace the Rankine cycle in low-temperature steam engines, to improve conversion efficiencies. MNES did at one point introduce Stirling engines to be used with biomass gasifiers, but their use as yet is not widespread.

c. For instance, if a 100 MW wind-generating station has sufficient wind for generation 20% of the time, then the availability of the station can be no better than 20%. Assuming the probability of wind presence to be essentially independent from station to station (plausible for stations distant from each other, but not for proximate ones), then at least five 100 MW stations would be required to give 100 MW of assured capacity (i. e. 100 megawatts' power available 100% of the time). That is, the capacity required to be installed equals the assured capacity needed divided by the availability factor. Compare this with conventional power stations, whose availability factors lie in the range of roughly 60% - 80%, requiring installation of only 1.6 to 1.2 times the assured capacity needed, rather than 5 times as required for wind (in this example).

d. With the caveat that the rise of fuel cost is neither inevitable, nor necessarily attributable to scarcity. Despite being a graceless stretch of analogy, it is accurate to state that foreign exchange is far scarcer in India's economy than oil is in the world economy. In other words, the world's supply of fossil fuel may (with the advancement of extraction technology almost guaranteed by heavy investment in relevant R&D) be essentially unlimited, to those who can afford it; whereas India's foreign exchange reserves, even with limited influx, are hard pressed to afford fossil imports at any price. Regardless of supply parameters, oil will always be scarce to India, until it can better afford the cost of foreign exchange. As economist Amartya Sen pointed out, in his classic analysis of famine, the effective availability of a commodity has less to do with its absolute supply, than the consumer's command of, or ability to buy, the commodity.

e. The impact of energy choices on human ecology may be more important than economy in the long run, but the former is much harder to assess with any accuracy.

f. This is equivalent to adding a large number N of values fluctuating at random, but according to the same probability distribution P, to obtain an aggregate with a much narrower fluctuation about a mean of $N * mean(P)$. Of course, some wave energy concepts avoid the variability problem entirely.

g. If the so-called biodynamic method of farming actually works, I will bet Herr Steiner's reputation that it has nothing to do with intangible cosmic shapes and forces.

h. Disadvantage in this sense does not mean only poor, uneducated or backwards. Consider the predicament of Russia's nuclear establishment, a body of highly-trained scientists and bureaucrats whose institution has crumbled around them. Their immediate problem of finding a means to survive on worthless (and often absent) paychecks could rather directly translate into a more serious international security problem, should their services be retained by a regime hostile to the global *status quo*. Of perhaps greater concern are the hundreds of tons of enriched uranium and plutonium which, thanks to the widespread breakdown of the state control infrastructure, lie largely unguarded and unaccounted in numberless sites across formerly Soviet territory -- not to mention hundreds of missiles and dozens of decrepit nuclear power plants of the Chernobyl type.

i. It is interesting to note that the founder of CTARA, professor Anil Date of the Department of Mechanical Engineering, was a student of E. F. Schumacher, who encouraged Date's ideas for a practical means to alleviate poverty in India.

j. Actually, the statement holds true for all environments, not only the unfamiliar; but its truth is much less evident when you are immersed in the habits and preconceptions of familiarity. To put it another way, after a long enough stay in a very different or upsetting place, home is no longer as comfortable or familiar as you would remember: while the present strange becomes familiar, the past familiar becomes strange.