SOUTHERN PERSPECTIVES on the RURAL ENERGY CRISIS

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R.S. GANAPATHY
PETER HAYES

Edited and Published By Nautilus, Inc.

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PHOTO CREDITS

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UNITS OF ENERGY

The two units of energy used in this paper are the kcal (one thousand calories; one calorie is the amount of energy required to raise the temperature of one cubic centimetre of pure water at standard temperature and pressure by one degree Centigrade) and the MJ (one million joules; a joule is the work of one newton-meter, also equal to 0.239 calories). One barrel of oil has about 6 billion joules. One kilogram of wood dryweight might have about 13 MJ, although this figure varies across the woods. One kilowatt-thermal [kW(t)] is a measure of power —one thousand joules/second. A conversion efficiency (ratio of electrical output to primary energy input) is required to measure the conversion of thermal energy to electrical energy [kW(e)]. A crude rule of thumb would be 30 to 40 percent. A power of one kw(e) applied for one hour produces energy of one kwh(e)-one kilowatt-hour (electrical). Similarly for thermal units.

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African village and overgrazing

About Nautilus:

Nautilus Inc. is a public-interest research and education group focussed on the interrelationship of energy, environment, and development. Our particular objective is to analyze and evaluate the development impacts of U.S. governmental and commercial policies on third world countries, especially in Asia-Pacific (and to determine impacts of these policies on the U.S.).

A key area of our concern is the export of U.S. nuclear technology to Asia. In 1979, *Pacific Research* published our study of a U.S.-Westinghouse nuclear export to the Philippines, "500 Mile Island." We are nearing completion of a book on the south Korean nuclear program—the most ambitious of any third world country—and the crucial role played by the U.S. Export-Import Bank in financing reactor-transfers (for more information, see page 48).

Nautilus frequently writes for popular magazines and journals, speaks to university students and citizen groups, and appears on radio programs.

Rice production, Philippines

Preface

Over two and a half billion people live in the villages of Asia, Africa, and Latin America. The daily struggle of these people to obtain energy is therefore an aspect of the global energy problem that affects more people than any other.

It took OPEC to bring energy to the center of global policy concerns. Belatedly for rural people in the Third World, attention is now being paid to the rural energy crisis. Villagers' vital energy statistics are being measured, their energy anatomy dissected, and their energy ills diagnosed.

In itself, information is harmless. But as the basis of the response to this crisis, information is also power. Villagers may use much of the anthropomorphic energy flows on the planet, but non-villagers—governments, international organisations, and transnational companies—clearly control most of the information about their energy plight. Villagers do not control the design of energy policies aimed at their energy problems. The gathering and interpretation of information about the energy dimension of their lives is therefore political.

It was to challenge some of the presuppositions about appropriate policy responses to the rural energy crisis—and thus some of the political ramifications of international policies aimed at redressing the crisis—that Nautilus decided to publish these essays. The essays are unabashedly provocative, and are designed to stimulate debate. They ask hard questions about the origins of the rural energy crisis, and while careful to supply pointers as to what might be done, the authors do not present easy solutions or short-cuts through the power-structure. Perhaps the most important point made by all the authors is that much of what is being done in the name of serving rural energy needs will actually make the situation worse for many of those most in need.

Most of what is being written on this problem emanates from international aid or development agencies, academic institutions, and consulting firms. The authors of these essays come from other quarters. Amulya Reddy's work with the Cell for the Application of Science and Technology to Rural Areas in central India is widely known for being a model of self-reliant work of the highest calibre. R.S. Ganapathy's work springs from an active interest in increasing citizen participation in international energy policies, especially at the UN. Peter Hayes, now a researcher with Nautilus, established the international network of *Soft Energy Notes*, aimed at transferring information—and sometimes warnings—about what is coming down the international energy pipeline to the third world.

Nautilus offers this publication in a spirit of debate, and we hope it will elicit dialogue. The authors' addresses appear at the beginning of each essay. Nautilus also solicits your comments and criticisms of this publication, and suggestions as to how it might be better next time.* The authors are responsible, of course, for the content of each essay.

Peter Hayes

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I. Energy Options for the Third World

*Amulya Reddy**

1. INTRODUCTION

Third world countries differ from each other in many ways, but the most important difference which has been stresed since 1973 is that between oil-*exporting* and oil-*importing* developing countries. The former are considered to be "the blessed," and the latter, "the unfortunates." This is because most oil-exporting developing countries have the resource base of conventional energy to repeat the evolution of the energy consumption patterns of the industrialized countries; and therefore, their discussions on energy options can be restricted to considerations of various *paths* to western goals. It is not so with the oil-importing third world countries. In their case, energy options must imply choices with regard to *goals*, as well as *paths* to chosen goals. In this sense, their constraints (with respect to conventional energy sources) compel them to exercise an extra dimension of freedom—the freedom to choose what magnitude and structure of energy targets their societies shall strive for.

It follows that an essential part of any discussion of energy options for third world oil-importing countries must be directed towards the main options with regard to the magnitude and structure of energy targets.

2. THE MAGNITUDE AND STRUCTURE OF ENERGY TARGETS

The *magnitude* of a society's energy requirements depends, first, on its population—obviously, the larger the population, the greater will be its energy requirements, and second, on its per capita energy consumption—the larger the direct and indirect per capita energy consumption in a society, the greater will be the energy requirements of a society. It is important, however, to realize that these two factors of population and per capita energy consumption are not unrelated—invariably, the lower the per capita energy consumption, the greater is its need for muscle power, and therefore, the larger is its rate of population growth likely to be.

The choice of an energy goal hinges, therefore, on targets for population and for per capita energy consumption. Population planning is outside the scope of this paper, so attention will be restricted to per capita energy consumption, which in turn depends upon several factors.

The first factor is the degree of "affluence" of the society, usually expressed as the per capita GNP —the more the goods and services produced, distributed and consumed per person, the greater will be the per capita energy consumption, according to the well-known per capita energy consumption vs per capita GNP "correlation." The use of this "correlation" to define energy targets for developing countries involves two assumptions: (1) that these countries should follow the patterns of industrialization and energy utilization adopted by the developed countries, even though these patterns were historically determined by the low oil prices of the pre-1973 era, and (2) that the goal of third world countries should be the growth of GNP. Both these assumptions are questionable— the first may not be realizable, and the second may not be acceptable.

The second factor determining the per capita energy consumption is the "lifestyle" of the society as revealed by the composition of the GNP. This lifestyle comes into the energy picture because different products and services are associated with different energy consumption values. For example, a lifestyle based on individual transportation by automobiles requires more energy than one based on mass transportation

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by buses.

The third factor is the degree of centralization of production. The point is that the greater the average distance between the centers of production and of consumption, the larger becomes the energy which must be spent on processing, packaging, storage, transport and distribution. Centralized production for distant markets invariably requires more energy than decentralized production for local consumption.

The last factor which determines the per capita energy consumption concerns the technologies chosen for the production, distribution and consumption of goods and services. Here, the point is that different ways of producing, distributing and consuming goods and services are associated with different energies. For instance, most production technologies of the developed countries are energy-intensive, because these technologies were generated in countries which were able to obtain oil at low prices from the oil-exporting countries. Green revolution agriculture is a prime example of such an energy-intensive production technology. For perhaps similar reasons, a bias towards energy-intensive distribution or transport technologies can be observed in the industrialized countries, for example, goods transport by rail has given way to the energetically more expensive truck transport. Consumption technologies, too, are important because some ways of consuming goods and services consume more energies than others, for example, space heating by electricity costs more energy than the use of waste heat.

In addition to the magnitude of the energy target, the *structure* of the target is also important. There are four aspects to this structure. First, there is the distribution of the total energy requirements over different energy-consuming sectors, e.g., industry, agriculture, transportation, etc. Actually, it is much better to seek the task-wise distribution over various energy-consuming tasks, viz., low-, medium- and high-temperature heating, lighting, stationary and mobile motive power, electronic controls and communication, etc. Such a distribution indicates the category of energy-consuming tasks, and the magnitude of energy required for each category. This way of looking at the energy target is important because different categories of energy-consuming tasks are best satisfied by different energy forms—as will be elaborated later. The second aspect is the spatial distribution of energy requirements, in particular, the urban-rural distribution. The third aspect, and the one invariably neglected in energy discussions, concerns the distribution of energy in societies characterized by marked income disparities. The fourth aspect relates to the mix of energy sources —in most third world countries, the sources of energy used differ among the different income groups, mainly because different energy sources are usually associated with differing costs.

Thus, a definition of options with regard to energy targets for third world countries must be based on answers to a number of key questions:

Magnitude of the energy target

(i) What is the population corresponding to the target?

(ii) What per capita energy consumption will be attempted? i.e.,

(a) what extent of affluence, or per capita GNP?

(b) what type of lifestyle, or composition of GNP?

(c) what degree of centralization of production?

(d) what technologies of production, distribution and consumption?

Structure of the energy target

(i) What will be the break-up of the energy target according to sectors and categories of energy-consuming tasks?

(ii) What will be the spatial distribution of energy, e.g., between urban and rural areas?

(iii) What will be the energy distribution between various income groups in the stratified society?

(iv) What will be the mix of energy sources?

3. THE GROWTH OR KEEPING-UP-WITH-THE-JONESES OPTION

There are two distinctly different approaches to these questions and, therefore, to the definition of energy goals.

The first is a *more-of-the-same* approach based on a continuation of current trends of energy consumption, and hence, the assumptions and value-judgments underlying these trends. This approach leads to what may be called the *growth or keeping-up-with-the-Joneses option.*

In this context, one must not fail to note that most third world countries are in fact dual societies, with small, affluent, largely urban-based elites (10-20% of the population) and large masses of poverty-stricken people, most of whom live in rural areas. Further, the elites are heavily influenced by the life-styles of the developed countries and practice an outlook best described thus: "all that is rural is bad, all that is urban is better and all that is western is best!" This dual nature of society is clearly reflected in the energy consumption patterns.

The per capita energy consumption targets aimed at by decision-making elites are those based on attempting "to catch up with the west." This attempt is manifested as:

(a) the striving for continuously increasing values of per capita energy consumption, which are unquestioningly assumed to be the basis of per capita GNP, the growth of which has been the crucial socio-economic objective of most industrialized countries;

(b) the economic aim of emulating the composition of the GNP characteristic of the industrialized countries, and therefore generating the energy required to produce a similar bundle of goods and services;

(c) the belief that developing countries must necessarily follow the path of industrialization of the developed countries, in which centralized production for remote markets resulted in large energy expenditures on distribution, even though production for local consumption is traditional to the third world countries;

(d) the view that, in industrializing their economies, third world countries have no option except to adopt the package of production, distribution and consumption technologies adopted in the developed countries, even though these technologies were evolved to suit their specific historical circumstances of capital abundance, labor shortage and cheap energy.

In fact, these assumptions may not be tenable at all. Untempered pursuit of GNP *per se* only aggravates the inequalities of a dual society, and must, therefore, be abandoned as a socio-economic objective, and with it, the so-called "correlation" between per capita GNP and the per capita energy consumption. The composition of the GNP can be far more important than the magnitude of GNP in determining the quality of life, particularly for those below the poverty line—skyscraper office buildings (and the energy that goes into them) must be counted in the GNP (and the per capita energy consumption), even though they cannot easily substitute for low income housing. The switch from traditional decentralized production for local consumption to centralized production for distant markets invariably increases the energy bill due to energy costs for processing, storage, transport, and marketting, and at the same time prices the goods and services beyond the means of the poorest sections. Finally, the energy- and capital-intensity of the production, distribution and consumption technologies of the developed countries, along with their labor-saving character, make them intrinsically inappropriate for oil-importing developing countries, most of which are grappling with continuously increasing unemployment and desperate shortages of energy and capital.

Apart from all these considerations, it is fairly certain that if the entire populations of developing countries were to have the same per capita energy consumption as the developed countries, say the USA, then the energy demand would become too high to be sustained with the present pattern of usage of energy resources. For instance, on the basis of US per capita energy consumption figures, India alone would require about three times the total energy now consumed by the USA—a requirement which is 150 times the present production of commercial energy in India. Thus, energy resource limitations may make it impossible for third world countries to achieve the growth or "keeping-up-with-the-Joneses" option—the Joneses can use so much energy only because the Singhs use so much less. The more-of-the-same option for energy targets is just not feasible if the per capita energy consumption levels of the developed countries are used as norms.

The outlook is not any brighter with the structure of energy targets.

The sectoral distribution of commercial energy in many developing countries seems to be based on an emulation of the industrialized countries, even though third world countries are primarily agricultural, e.g., the comparison between USA and India.

TABLE 1. SECTORAL DISTRIBUTION OF COMMERCIAL ENERGY

Sector	Energy consumption India	(percentage) USA
Industry	39.1	30.3
Transport	32.3	25.2
Domestic	18.0	14.0
Agriculture	4.6	4.0
Miscellaneous	6.0	26.5

The spatial distribution of energy in developing countries is even more alarming (Table 2)—the urban-rural disparities in energy consumption show that commercial energy production hardly flows to rural areas, even though the bulk of the population lives there. The existence of these urban islands of energy affluence amidst vast oceans of rural energy deprivation is another characteristic of dual societies. They result from the energy supply system responding only to energy demands and ignoring energy needs which cannot be backed up with purchasing power.

TABLE 2. URBAN-RURAL DISTRIBUTION OF COMMERCIAL ENERGY IN THIRD WORLD INDUSTRIES

	Asia	Africa	Latin America
Rural share of commercial energy	23%	4%	23%
Rural poopulation	75%	91%	50%

Finally, there is a highly skewed distribution of energy between different strata in dual societies—a reflection of the skewing of incomes. The inequalities in energy consumption are not merely in the magnitude of energy consumption, but also in the forms of energy used. The point is that various types of energy—electricity, oil, coal, non-commercial energy (firewood, animal dung and agricultural wastes)—have differing costs, and the poorer the section of society, the cheaper the energy source it uses. And the poorest sections of third world countries survive on non-commercial energy. This non-commercial energy can be gathered at "zero" private cost, but there are very high-social environmental costs in the form of environmental degredation (deforestation, soil erosion and desertification) and lost social opportunities of diverting the labor now spent on gathering non-commercial fuels to socially productive activities. No wonder that developing countries rely to a great extent on non-commercial energy, which for example accounts for 50% and 90% of the total energy consumption in India and East Africa respectively.

Thus, energy targets based on the growth or keeping-up-with-the-Joneses option will only preserve and accentuate:

(a) the energy-deprivation of the agricultural sector,

(b) the urban-rural disparities in energy consumption,

(c) the highly skewed distribution of energy over the different income groups,

(d) the dependence of rural areas and the poorest sections on non-commercial energy.

These unwelcome features of current patterns of energy consumption in third world countries are an essential part of their dual societies. In this sense, the growth or keeping-up-with-the-Joneses option is an offspring of dual societies, and only serves to consolidate and acerbate the inequalities and injustices of such societies—it inhibits the development of third world countries.

4. THE DEVELOPMENT OPTION

An alternative approach to energy goals can be based on the development option, in which the energy sector is used as a mechanism for promoting development. The magnitude and structure of energy targets must therefore be chosen with this perspective.

Of course, much will depend upon the definition of development. In this context, the recent UN definition constitutes an excellent basis. According to this definition, development is viewed as a process which is primarily directed towards:

(a) the satisfaction of basic human needs (material and non-material), starting with the needs of the neediest, in order to achieve a reduction of inequalities between and within countries;

(b) endogenous self-reliance through social participation and control; and

(c) harmony with the environment.

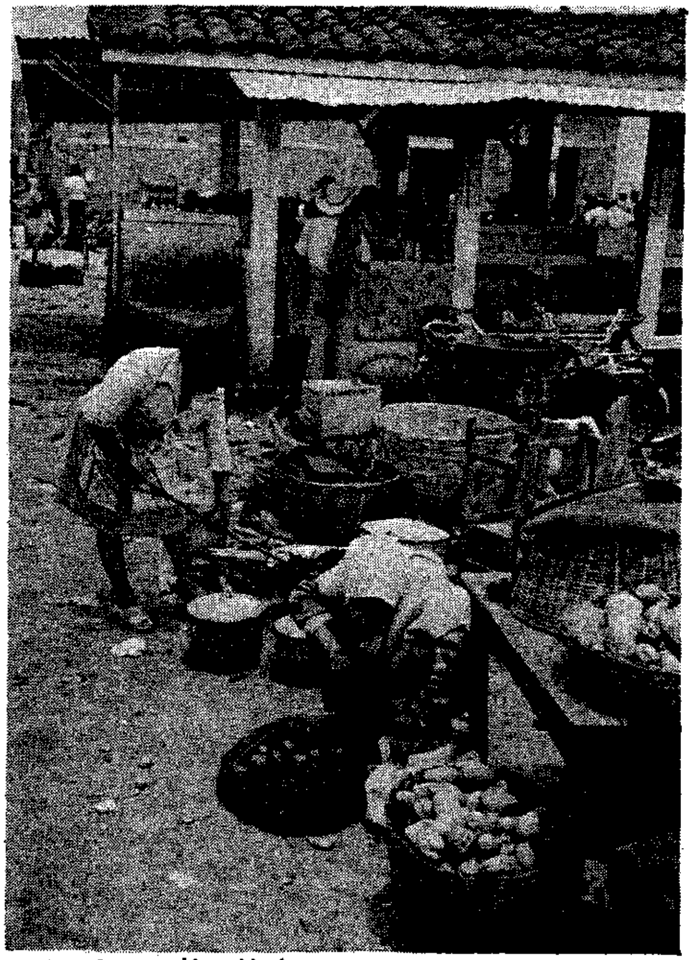
The commitment to development, rather than to growth *per se*, as a socio-economic objective has major implications with regard to energy targets for third world countries.

First, the viewpoint that growth of GNP should be a by-product, rather than basis of, development results in a liberation from a dependence on the "correlation" (between per capita energy consumption and per capita GNP) as a source of energy targets. Instead, per capita energy targets must be derived from development objectives, and in particular from the objective of satisfaction of basic human needs.

Second, the emphasis on development requires that the composition of the GNP, i.e., the product-mix, of third world countries be radically different from that in the developed countries. In particular, the basic needs of the neediest may have to be satisfied by simple life-styles. This requirement of simplicity *may* involve natural rather than energy-intensive synthetic fibers, renewable rather than depletable materials which have to be extracted at considerable energy expenditures, shared communal facilities (e.g., mass transportation systems) rather than energy-intensive luxuries for individual use (e.g., private automobiles).

Third, many cases of highly centralized production for massive markets have evolved at high energy costs only to satisfy the profit-seeking motives of large corporations, even though decentralized production for local consumption may be adequate for the satisfaction of basic needs. Industrialized food systems are an example. The change-over from production for small, local markets to production for nation-wide, or even world-wide markets, is inevitably associated with increasing off-the-farm energy expenditures on food processing, packaging, transport, distribution and storage. Today, this off-the-farm energy expenditure accounts for about 75% of the total energy consumption of the industrial food system of the USA. This energy price will have to be paid if third world countries "westernize" their agricultural sectors.

Fourth, a decision to avoid imitating the historically-conditioned path of industrialization of the developed countries means that the choice of technologies need not be restricted to their package of technologies. This widening of the choice has dramatic implications for the energy question. The point is that every technology is generated in response to certain ranges of factor prices, including the price of energy, and therefore, most technologies of the developed countries are very much the product of the



Market-place cooking, Mexico

pre-1973 low oil prices. Had the current oil prices prevailed over the past fifty years, it is almost certain that a radically different pattern of energy-saving technologies would have emerged in the industrialized countries. Today, the developed countries may not be able to dismantle their energy-intensive technologies, but the third world countries, precisely because they are in the very early stages of industrialization, can opt for available or generatable alternative energy-saving technologies. This would be a far wiser policy than importing and establishing western-type energy-intensive technologies and inevitably landing in a serious energy crisis from which they will have to extricate themselves painfully. The argument can be particularly well illustrated by the green revolution agriculture which is well-known to be a major sink for energy, rather than a source of energy, which is what one would expect from the phenomenon of photosynthesis.

All this means that the development approach to norms for per capita consumption is totally different from that based on keeping-up-with-the-Joneses. Unfortunately, hardly any research has been done in this new direction.

A significant step, however, was taken by Hafner (1979) who estimated the minimum per capita energy requirements for a North American to have a satisfactory life (Table 3). This minimum is about one-third the current US per capita energy consumption. But even this minimum is a high figure and can be reduced substantially. For instance, one can deduct the space heating component, which is about 10% of the 31,000 kcals per capita per day, because most third world countries are fortunately located in sun-drenched tropics. Thus, the per capita energy consumption figure gets reduced to 28,000 kcals per capita per day. But, still further reductions are possible by adopting (a) needs-oriented product-mixes, (b) where sensible and feasible, decentralized production for local consumption, and (c) alternative energy-saving technologies for production, distribution and consumption. The magnitudes of these reductions can only emerge from detailed research, but they may result in substantial reductions, perhaps even 50% to yield a per capita consumption figure of about 14,000 kcal per capita per day.

TABLE 3. MINIMUM ENERGY BUDGET FOR A SATISFACTORY LIFE IN USA

Basic Need	Energy requirement	percentage
Food	6,200 kcal/day	20
Housing	6,200 kcal/day	20
Clothing	2,065 kcal/day	6.7
Transportation	4,130 kcal/day	13.3
Leisure	12,400 kcal/day	40
Total	30,955 kcal/day	100

Source: Hafner, 1979.

Some such drastically reduced figure multiplied by the projected population will yield the energy target corresponding to the period for which the population projection has been made. Thereafter, it is a question of ensuring that the energy targets keep pace with the population growth. An important point to note with regard to the magnitude of development-based energy targets is that they are very much lower, and therefore more accessible and feasible, than the growth-oriented targets based on attempts to keep-up-with-the-Jonses.

In addition, the adoption of a development-oriented approach to energy targets has major implications with regard to the structure of these targets.

First, they demand substantial inter-sectoral shifts towards agriculture and agro-industries. The argument for such a shift is simple. In the context of growing unemployment, an employment-oriented strategy of development is unavoidable, and the sector which can generate the most employment in the predominantly agricultural third world countries is the agricultural and agro-related sector, particularly the processing, storage and marketting of agricultural produce and wastes. To ensure that the capital-output ratios in such agro-industries are sufficiently low, adequate inputs of inanimate energy may be essential—hence, more energy must flow to this sector.

Second, since the bulk of the third world population lives in rural areas, that is where the real energy needs of society are and that is where most of the energy must flow. Hence, the urban-rural disparities in energy consumption must be reduced drastically. This reduction is related to the whole question of energy supplies for third world *villages*, which therefore become the main focus of the development-based energy option.

Third, the inequalities in per capita energy consumption must also be reduced because the energy aspect of development objectives must mean satisfaction of basic energy needs, starting with the energy needs of the most energy-deprived. This means that the poorest sections in villages must be made the target population in development-oriented energy programs.

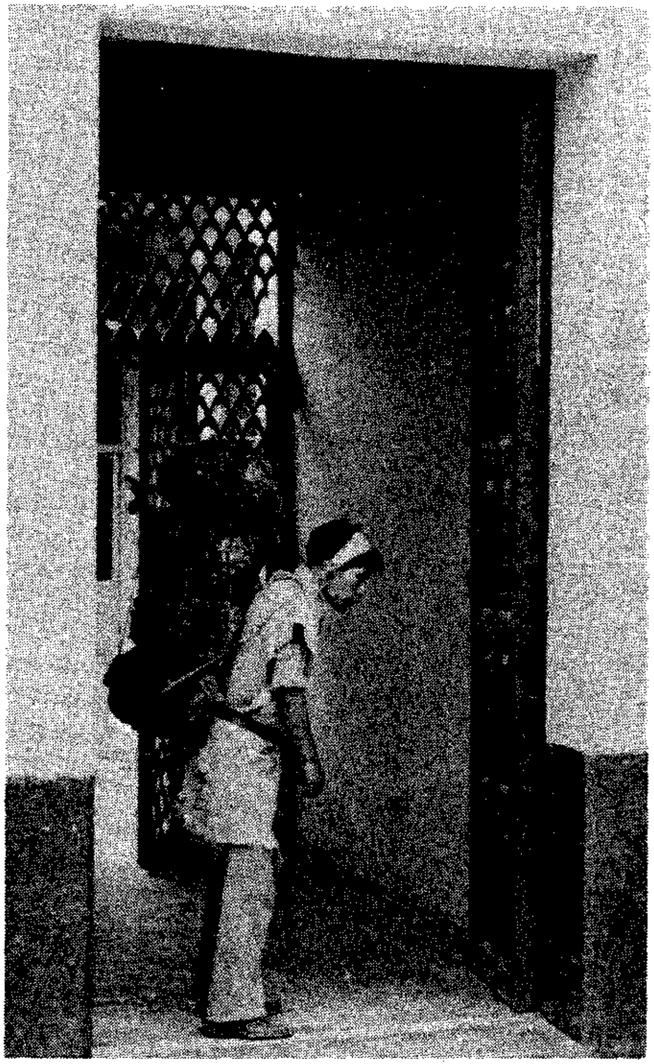
Fourth, the mix of energy sources for meeting rural energy needs must be altered to avoid the serious ecological consequences of the almost exclusive dependence of villages on non-commercial fuels.*

To summarize, the development option requires the following changes in the structure of energy targets: a biased energy flow towards the agricultural and agro-related sector, the villages in rural areas and the poorest sections in villages, and a shift away from environmentally unsound uses of non-commercial energy sources. These are major changes. In fact, they are in some senses more fundamental than a mere quantitative increase in the magnitude of the energy target, because the development option is incompatible with the continued existence of dual societies, whereas the growth option is a natural expression of dual societies. The beneficiaries of the two options are also different: whereas it is mainly the elites of developing countries who benefit from the growth option, it is the people, and in particular the poorest sections, who stand to gain by the development-oriented option. Further, there is a difference in the socio-economic implications of the two energy options: the growth option for energy is incompatible with socio-economic development, but the development option for energy is not inconsistent with economic growth. Notwithstanding all this, the development option raises a crucial question: what options are there for satisfying the energy needs of third world villages?

5. ENERGY NEEDS OF VILLAGES

The first step in answering this question is to define the magnitude and structure of energy needs of villages, but it is precisely this very step that poses problems. The difficulty is that a third world village is, in many senses, "an area of darkness" (to use the title of a well-known novel on India): literally, because there is a serious inadequacy of light which is a clear indication of the pitifully low levels of commercial-energy use, and metaphorically, because detailed information on energy consumption patterns in villages is lacking. However, empirical studies of the energy budgets of villages and of families below the poverty line are well underway, and the next year or two should witness the emergence of a clearer picture. Until then, the only choice is to fall back on "guesstimates" which, however, seem to tally with qualitative observations.

An idea of energy flows in villages can be obtained from an energy input-output matrix which reckons with all the energy sources as inputs and all the energy-consuming activities as outputs. Of course, such matrices may vary from village to village, province to province, country to country, and continent to continent. Thus, the energy input-output matrix shown in Table 4 for a typical Indian



Wood delivery, Mexico

*See Professor Reddy's treatment of these targets in Reddy (1981) also reported in *Soft Energy Notes, 4,* 1, pp. 13-15 (available from 124 Spear St., San Francisco, Ca. 94105, U.S.A.). [editor's note]

TABLE 4. ENERGY INPUT-OUTPUT MATRIX* FOR TYPICAL INDIAN VILLAGE (POPULATION $\leqslant$ 500)

Energy-consuming Activities (Outputs) x (10^3 kcals/day-capita^{-1})

Energy sources (Inputs)	Agriculture	Domestic Activities	Lighting	Transport	Manufacturing	Total
Human Labor	183.7	124.5	—	24.9	3.1	336.2
Bullock Power	420.8	—	—	80.9	—	501.7
Non-commercial energy	—	2110.7	—	—	233.5	2344.2
Oil	24.9	—	130.8	—	—	155.7
Coal	—	43.6	—	—	—	43.6
Electricity	46.7	—	18.7	—	—	65.4
Total	676.1	2278.8	149.5	—	236.6	3446.8

village with a population of 500* is presented only to underline the following essential features of the situation.**

(1) The main categories of energy sources are human labor, bullock power, non-commercial energy (firewood, dung and agricultural wastes) and commercial energy (oil, coal and electricity). The contribution of these energy sources is shown in Table 5.

TABLE 5. CONTRIBUTION OF VARIOUS ENERGY SOURCES TO VILLAGE ENERGY BUDGET

Energy Source	Percentage
Human labor	10
Bullock power	15
Non-commercial energy (firewood, dung, agro-wastes)	68
Oil	4
Coal	1
Electricity	2

The broad categories of energy-consuming activities are agriculture, domestic activities (livestock grazing and maintenance, fetching water, gathering non-comercial fuel, cooking, washing, carrying cooked food to farm workers, and other household tasks), lighting, pottery, brickmaking and metal work, and transportation and other activities. The division of the total energy input into these various energy-consuming activities is presented in Table 6.

TABLE 6. DISTRIBUTION OF VILLAGE ENERGY CONSUMPTION OVER VARIOUS ACTIVITIES

Activity	Percentage consumption
Domestic	66
Agriculture	20
Lighting	4
Transport	3
Manufacturing	7

(2) Human labor and bullock power must be included in the energy matrix; otherwise, the magnitude of energy used for agriculture will be highly misleading—55% and 84% of all human and bullock energy used in the village goes for agriculture, and these two *animate* sources of energy account for about 90% of the total energy used in agriculture. Even this 90% is only an average figure for India; in a large number of villages, particularly in backward areas, agriculture may not use any commercial energy at all.

(3) The dependence on non-commercial energy is striking—it accounts for about 70% of the total energy used in the village, but the figure goes up to 90% if only *in*animate sources are considered. Further, the bulk of this is used as non-commercial fuel for domestic cooking. Other domestic activities such as water heating and space heating (in some parts of India) and non-domestic uses in brick-making, etc., account for the remaining non-commercial energy.

(4) The magnitude of the per capita energy consumption is extremely low, about 750 kcals per capita per day, if only commercial energy is taken into account, but is quite high, about 7000 kcals per capita per day, if both non-commercial and animate sources are considered. Even if animate sources are ignored, the daily per capita energy consumption is around 5250 kcals, which is about one-third of the ultimate per capita energy consumption that third world countries should aim for, according to the development option (see Section 4).

(5) The magnitude of current per capita energy consumption levels in villages may not be too discouraging, but the productivity of this energy is another matter. The efficiencies of many of the devices which use animate and non-commercial energy are

*60% of India's 567,000 villages have a population of 500 and under.

**See Professor Reddy and coworkers' detailed empirical investigation of energy flows in Pura Village (Ravindranath *et al.*, 1978, and Reddy, 1978) reported in *Soft Energy Notes 2*, July 1979, pp. 53-54. [editor's note] extremely low. For instance, the traditional Indian cooking stove has an efficiency of only about 10%, and therefore results in a serious wastage of the non-commercial fuels used for cooking.

(6) Similarly, approximately 40% of the total human labor is spent on domestic activities and actually consists of child-hours and woman-hours. *At least* 10 hours per day have to be spent by each household, particularly the poorest ones, to carry out the major activities of cooking, fetching water, gathering firewood and grazing the livestock—traditionally the first two activities are women's occupations, and the latter two are often carried out by males. The poorest families cannot hire labor; hence, the simplest way for them to cope with the domestic workload is for the mother (who does the cooking) to be assisted by a daughter (who fetches drinking water) and by one or two sons, who graze livestock, gather firewood, and carry the father's food to the fields.

(7) In the absence of labor-saving devices and/or hired labor, these household energy needs become work schedules and time budgets for the members of the family, and these schedules and budgets can be achieved only when there are at least two or three children to help the parents. Thus, a family below the poverty line can survive in the face of demanding domestic energy needs only by having two or three children whose first cost in these income strata is "zero." Such energy consideration are unfortunately completely ignored by population planners.

(8) The vital role of children as an energy source has an impact on education too. Since the contribution of children is essential for the balancing of a poor family's energy budget, it follows that such families cannot forego these crucial energy contributions in return for a questionable type of education in a village school. In other words, a landless laborer's intuitive grasp of cost-benefit analysis and of the opportunity cost of a child's labor is vastly superior to that of educational policy-makers.

(9) In the case of agriculture, the energy needs are now being met primarily by human and bullock energy. The human contribution in the typical village energy budget corresponds to about 160 males each working for 1800 hours per year (180 ten-hour days), and about 35 females each working for about 1000 hours per year (125 eight-hour days). The bullock contribution to the village agriculture corresponds to about 56 bullocks each working for about 1200 hours per year. The annual input into the village agricultural activity is as shown in Table 7. This input is wholly directed towards (a) water lifting and pumping, (b) traction and (c) miscellaneous other uses of mechanical energy such as sowing, etc. (Of course, the human beings also play roles of decision-making and guidance.)

TABLE 7. CONTRIBUTION OF ANIMATE ENERGY SOURCES TO AGRICULTURE IN TYPICAL 500-POPULATION VILLAGE

Source	Number	Hours/Year	Annual total
Male labour	160	1800	288,000 man hours
Female labour	35	1000	35,000 woman hours
Bullock power	56	1200	67,200 bullock hours

(10) Finally, the matrix permits the definition of some overall targets. For instance, the total energy consumed in all the activities is of the order of 3.5 million kcals per day, or 4000 kWht per day, which corresponds at the usual 60% load factor to a supply of 280 kW of power. Further, the break-up of energy consumption according to end-uses is as shown in Table 8. It can be seen that the most demanding end-use of energy is cooking which is based on medium-temperature heating, followed by stationary and mobile mechanical power for water lifting and pumping, traction, etc.

TABLE 8. APPROXIMATE ENERGY CONSUMPTION ACCORDING TO END-USE

End-use	Percentage
Heating (cooking, water heating, brick-making, metal-work, etc.	70
Stationary Mechanical work (including ploughing, etc.)	27
Transport	3

Having described the main features of an indicative energy input-output matrix for a typical village, a fundamental question arises: does such a matrix facilitate the achievement of development objectives? Several aspects of the village energy budget must be considered in order to derive an answer.

First, the predominance of non-commercial energy, and of animal and human labor implies that there are few ways of increasing the production of energy. Increases in the human population will only lead—as has happened—to increases in energy needs; in fact, the gap between needs and supplies will only grow. Larger bullock populations will result in greater need for fodder, and for pasture land at the expense of crop land. An increase in non-commercial energy, particularly firewood, cannot be achieved by leaving forests to natural forces, which is largely the case at present.

Second, energy supply systems in villages neither satisfy basic human needs nor correspond to a reduction of inequalities between rural and urban areas and between various income groups within the villages. The extremely low inputs of *in*animate energy into the agricultural systems impede the increase of production of food. At the same time, the limitations on land availability and the lack of energy to create new industrial activities imply a saturation in the growth of employment. These two factors —low agricultural productivity and restricted growth of employment opportunities—coupled with an increasing population result in less food to buy and less work to earn the money to buy this food, i.e., decreasing satisfaction of the basic need for food. The basic need of shelter is not adequately fulfilled, particularly with respect to services such as the supply of water and cooking fuel. Community health is threatened by polluted water and the absence of sanitation—90% of the rural population in India is said to suffer from intestinal parasites, which are estimated to consume about 15% of the already low per capita daily intake of 2000 calories of food. Attempts to solve the water and sanitation problems require further inputs of energy. As long as the poorest families have to depend on the labor inputs of children, their basic need for education cannot be satisfied. The generation of employment is very much dependent on the increased supply of energy to new agro-industrial activities, but the difficulty of increasing energy supplies within the framework of the current energy supply patterns constitutes a major obstacle. Above all, village life in third world countries may seem idyllic to city dwellers, but the real picture is different: the manual work constituting the human energy input is dull, back-breaking, often degrading, and erodes the quality of life whch gets progressively worse, particularly for the poorest families. This is mainly because what little commercial energy flows into the village can be bought only by those with purchasing power—hence, the richer sections utilize commercial energy to become richer and therefore inequalities are increased.

Third, the self-reliance of villages becomes increasingly undermined as the inability to increase energy supplies inhibits the satisfaction of basic needs. As the village becomes more and more dependent on imports of essential commodities (including food in many cases), its ability to control its destiny is diminished, and the debilitating dependence on the metropolis increases.

Finally, the virtually exclusive reliance on non-commercial energy implies the absolute necessity of ecologically sound practices with regard to the vegetative energy resource base. But what is taking place in most third world countries is a devastation of the very forests which supply the bulk of village energy needs. Hence, the current energy supply system in villages will progressively deteriorate because it is inherently un-sustainable in the face of rising populations.

The conclusion is clear—*the energy budgets of villages in third world countries are inconsistent with development*, and radical changes in the magnitudes and structures, both on the supply and demand side, are essential to meet development objectives.

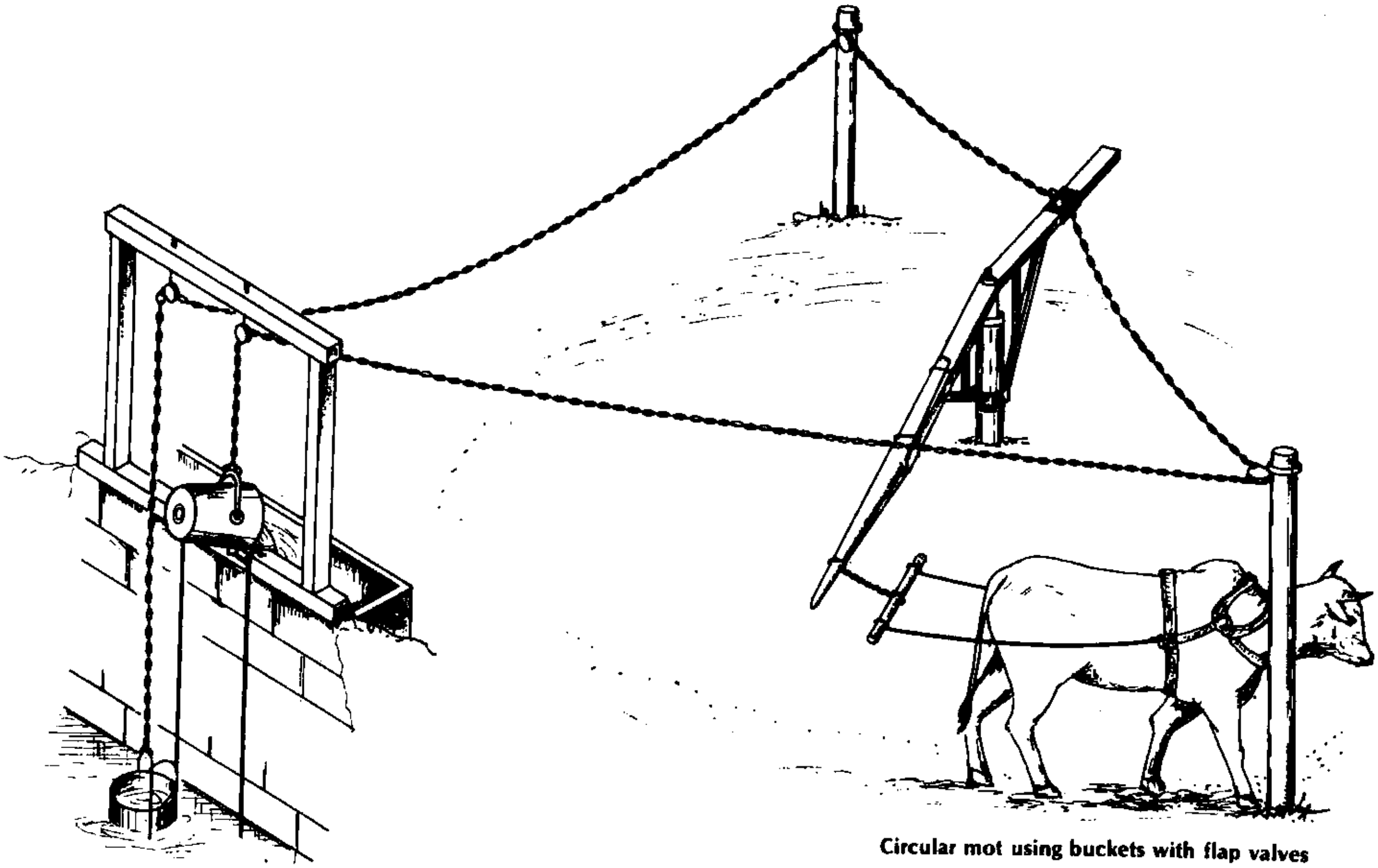
6. MEETING VILLAGE ENERGY NEEDS

The response of most third world countries to the challenge of meeting village energy needs has been based on an energy-analogue of the "trickle-down" theory of GNP growth. Just as the pursuit of GNP has been sought to be justified with the argument that the benefit of growth will gradually "trickle down" to the poor, there is an implicit view that the erection of large-scale, centralized power stations will result in their energy "trickling down" to the villages. But, the energy of such plants which does reach the villages is indeed a mere trickle of less than 20%.

There are many reasons for this reluctance of centrally-produced energy flow to villages. An obvious reason is that the decision-making elites in most third world countries are mainly urban-based, and quite naturally, they make first claims on centrally-generated power. But an oft-quoted reason is that villages cannot generate sufficient demand backed up by purchasing power—however, this is only another way of stating the obvious truth that there is only a small percentage of rich persons in villages. In any case, the weak demand leads to very low load (utilization) factors ranging 1 to 14%, which render the energy supply uneconomical. Another important economic obstacles to energy supplies to rural centers is the high cost of conveying energy from centralized plants to distant villages. The costs of transmission lines (about $150 per kW for $850 per km) are a great deterrent to connecting villages to grids. In addition, there are transmission losses (as much as about 20%) which aggravate the problem.

The result of all this is that rural electrification from centralized sources in the third world is rarely a success story. In India, for example, only 11% of the 350,000 villages with an under-500 population have been electrified—and will be electrified in the next decade or so—even though 25% of India's 600 millions live there. And even when they are electrified, they are only supplied with about 100 kWhe per day, which is equivalent to about 400-500 kWht per day, i.e., about 10% of current energy consumption. In fact, this 10% is consumed by the rich who constitute approximately 10% of the rural population.

Above all, rural electrification from centralized power stations comes nowhere near satisfying the largest and most important energy need in villages, viz., energy for cooking. In fact, it is this need which must be the touchstone of any scheme for energizing villages. The crucial question is: does the proposed



Circular mot using buckets with flap valves

scheme meet the energy needs for cooking in the villages?

Thus, what may be called the *centralized option* for meeting the energy needs of villages must be pronounced a failure. In fact, even when the touchstone of cooking energy needs is ignored—as is the practice in most third world countries—the centralized option has not been successful. Seen in this perspective, arguments in favor of particular technologies of centralized energy production, e.g., nuclear power stations, are irrelevant to the basic issue of providing power to villages, because the failure under discussion originates from the very approach of centralization, and not from the particular technologies for centralization. The depletable nature of fuels used in central power stations (other than hydroelectric), as well as the environmental impact of energy production in such stations, are of course important additional issues which have been treated elsewhere.

Inevitably, therefore, attention must be turned to another path to the achievement of energy targets. This is what may be termed the *decentralized, renewable sources option*, i.e., the use of renewable sources for the village-scale* decentralized production of energy to meet most village needs.

It is obviously an advantage to attempt a smooth, continuous, so-called "reversible" transition from current energy production and consumption patterns in villages to a future pattern of decentralized energy production based on renewable energy sources. Otherwise, the possibility of irreversible damage done to the fabric of village life may distort development objectives and lead to the rejection of the option. In other words, the energy path (or means) is just as important as the energy goal (or end). Hence, abrupt changes and major perturbations in energy production and consumption patterns are sought to be avoided by designing a time evolution of the energy input-output matrix from its present form to a future form. For this reason, large-scale imports of fossil fuels, e.g., diesel, for the local generation of electricity are not considered.

The starting point, therefore, must be the fact that human beings, cattle and non-commercial fuels supply the bulk of the energy needs of villages in third world countries. An energy program, such as the uncritical mechanization of agriculture, which leads to wholesale redundancy of human labor, may benefit the proprietors of the machines, but will only increase farm unemployment and mass migration to the cities, unless there is a simultaneous generation of employment opportunities in the village. Similarly, the sudden displacement of bullock power from the village scene may prove to be disadvantageous for several reasons. First, bullock power does not depend on depletable fossil fuel sources. Second, cows and bulls play an intricate role in an agrarian

*The term "village-scale" is meant to include the scale of a cluster of, say ten, villages.

economy by serving in several economic categories—(1) consumer goods (they can be eaten as beef), (2) machines for producing consumer goods (milk), (3) equipment yielding intermediate goods (dung which yields biogas energy and fertilizer) and services (traction), and (4) "mother machines" (cattle reproduce cattle). Cattle are therefore a crucial part of agricultural ecosystems entering in many ways into the flows of matter and energy. Besides, the monetary investment in bullocks is too large, viz., about $3.8 billion in India, to warrant a rapid phasing out. Finally, however ecologically unwelcome the dependence of non-commercial energy may be, the fact is that the "zero-cost" end-use appliances, viz., mud and cooking stoves, have been evolved to use this fuel. Hence, alternative fuels will bypass the poorest families unless these fuels can be used with appliances which are within their means.

Nevertheless, major improvements can be effected in the productivity of human and animal labor and in the efficiency with which non-commercial energy is used.

Continued reliance on human labor would be putting back the clock of history only if the arduousness, drudgery and low productivity of labor are preserved in their traditional and pristine form. It is possible, however, to turn the critical and creative attention of modern science and engineering on every one of the productive activities involving human effort, and thus achieve the twin objectives of lightening the burden while increasing per capita productivity. The *modus operandi* for attaining this target has to be based on exploiting the mechanical advantage of what are known in physics as simple machines—levers, pulleys, wheels, cranks, gears, etc.—which do not require inputs of harnessed energy. The research, design and development work could well be inspired by the spirit and physics underlying the well-known statement of Archimedes: "Give me a long enough lever, and I will lift the earth!"

One has only to observe the effort by a teen-age village girl in rope-drawing or hand-pumping water from a deep well to realize that there is tremendous scope in simple inexpensive designs for alleviating human burdens while enhancing efficiency. A similar challenge arises with a large number of agricultural operations—weeding, sowing, planting, harvesting—which are today being carried out with human labor, but are strenuous, tedious, literally back-breaking, and above all, characterized by low productivity.

One of the most important possibilities in this mission of finding better* ways of using human energy is *pedal power*** involving the principles and parts of bicycles and bicycle mechanisms, e.g., pedals, sprockets, chains, axles, wheels, etc. There are two main categories of pedal power possibilities:

(1) *stationary* applications, e.g., water-pumps, winches, electrical generators, refrigerators, winnowers, corn grinders, mechanical power take-offs, hydraulic pumps, etc., and

(2) *transport* applications, e.g., bicycle-drawn trailers, cycle rickshaws for passenger transport, pedal rovers for unprepared terrains, wheelbarrows, etc.

Above all, an extensive rise of pedal power will significantly augment the effectiveness of a massive source of energy in the rural energy scheme, viz., human energy, *without* demanding large inputs of harnessed commercial and non-commercial energy.

Similarly, the productivity of bullock power can also be enhanced by creative engineering on the devices which transform this animate energy source into desired end-uses.

With regard to cooking with non-commercial fuels, simple designs for mud cooking stoves permit a doubling or trebling of the efficiency with which the heat produced by the combustion of these fuels is utilized for the chemical changes involved in cooking. This means that the same quantity of non-commercial fuel used in the village can satisfy double or treble the current cooking energy needs, or that the current energy needs can be satisfied with a half or third of the current fuel consumption.

All this pertains to more efficient utilization of currently used energy sources—they come under the category of "conservation measures." But the real thrust of the decentralized, renewable-sources option for meeting village energy needs is the emphasis on energy production technologies which have not been hitherto exploited in villages:

(1) biogas energy produced by the anaerobic fermentation of cattle, poultry, human and agricultural wastes;

(2) "energy forests" in which fast-growing trees are specifically grown as sources of firewood and/or charcoal;

(3) solar energy;

(4) wind energy; and

(5) micro-hydroelectric plants.

The temptation will be to carry over urban thinking and attempt to convert all these sources into electricity and thus integrate them into all-electric systems with transmission lines and electrical end-use equipment. The temptation is increased because an all-electric system is well established in the developed countries and most of the technologies and end-use

*Better from the point of view of the particular human being who is laboring as well as from the point of view of his society.

**Pedal power is environmentally very sound—it is non-polluting, not based on continuous use of depletable energy resources, and can be "cycled and recycled."

equipment are either available off-the-shelf or are almost there. But there are also serious disadvantages: the capital costs of end-use equipment are almost certain to exclude families below the poverty line (compare electric cookers with mud stoves). In addition, totally different domestic life-styles are suddenly demanded by an all-electric system.

Further, the system can suffer from substantial efficiency losses which occur in two ways. First, there are the losses whch are associated with energy conversions from one form to another. For example, going from biogas to electricity may only yield 25% conversion of energy, so that direct use of biogas for cooking may be far more efficient than converting biogas to electricity which is then used for cooking. Second, energy comes in various grades; electricity and mechanical motion correspond to the highest grade of energy, in contrast to waste heat which is the lowest grade; and fossil fuels (coal and oil) are of intermediate grade. (Solar energy is very special because its grade depends upon how much it is concentrated—unconcentrated it is very low grade, but it becomes very high grade when concentrated.) The grading of energy sources leads to a simple thumb-rule: "Don't use a higher grade energy source than the task deserves." For example, it is unwise to use high-grade electricity for medium-temperature heating which is what is required in cooking.

All this means that so-called all-electric rural energy centers are not such a good idea, however "modern" they may sound. Nevertheless, it is very likely that no single alternative energy technology, neither biogas nor "energy forests" nor wind nor sun, can meet all the energy needs of villages. There will have to be a *mix* or combination of energy sources without conversion into a single form, e.g., electricity. It is here that the compactness of villages may be turned into an advantage because it lowers distribution costs. Energy sources can be matched, through appropriate devices, to energy-consuming tasks, and separate supplies can be considered, e.g., for cooking, pipeline distribution of biogas, or fuel from an energy forest, and for lighting, low-tension electric lines. Some indication of possible appropriate devices is presented in Table 9.

It is important not to exclude the use of electricity and electrical appliances and equipment from villages. In some situations, e.g., lighting, communication, water pumping, their advantages are too obvious to cite. Where the electricity will come from is another matter. It may prove convenient to generate it in the village itself. It is also possible for a cluster of villages to have a tower-top focussing solar collectors driving an electricity generator, or a run-of-the-

TABLE 9. MATCHING SOURCES AND DEVICES TO TASKS

Energy-consuming task	Possible appropriate devices/equipment
Cooking	Stoves for non-commercial fuels, Biogas stoves, solar cookers
Water lifting and pumping	Windmills, biogas-based Humphrey pumps, solar-powered pumps, animal- and pedal-powered pumps, handpumps, electric pumps
Water purification	Solar distillation, filters
Water heating	Waste heat from cooking stoves, solar water-heaters
Drying of agricultural produce	Solar dryers
Space heating/cooling	Solar airconditioning (Skytherm process)
Refrigeration	Pedal-powered refrigerators, "dry ice" (solid carbon dioxide from biogas)
Grinders, mills, winnowers and crushers	Windmills, animal- and pedal-powered devices, electric mills
Heating in small-scale chemical and metallurgical industries	Equipment based on combusion of non-commercial fuels or biogas, and solar heating devices
Lighting	Electricity, windmills and biogas generators, solar collectors (when they become sufficiently inexpensive)
Mechanical power	Windmills, biogas engines, animal- and pedal-power, electric motors
Mobile power	Biogas engines, pedal-power, animal-power

river micro-hydroelectric plant. Or it may prove economical for villages near electric grids to obtain more than a "trickle" of electrical energy. The point is that electricity may have to form an essential part of the mix of energy sources, and the "trickle" of energy from centralized power stations must neither be vetoed nor ignored.

A detailed scenario for the decentralized, renewable-source option for meeting village energy needs is neither possible nor advisable, because the details would vary too much with the precise nature and structure of the energy needs and the availability of energy sources. Further, the time-variation of the changes in energy supplies and needs will vary from village to village. The scenario will also vary with developments in technology. Finally, even for the micro-world of third world villages, all the techniques of energy planning have not yet been fashioned. This then is the real challenge—to envisage their energy futures and to implement these visions. One point is clear—if third world villages are to be the peripherals to growth, their futures, as well as those of the people in them, are bleak, but if they are made the core of development, their futures are bright.

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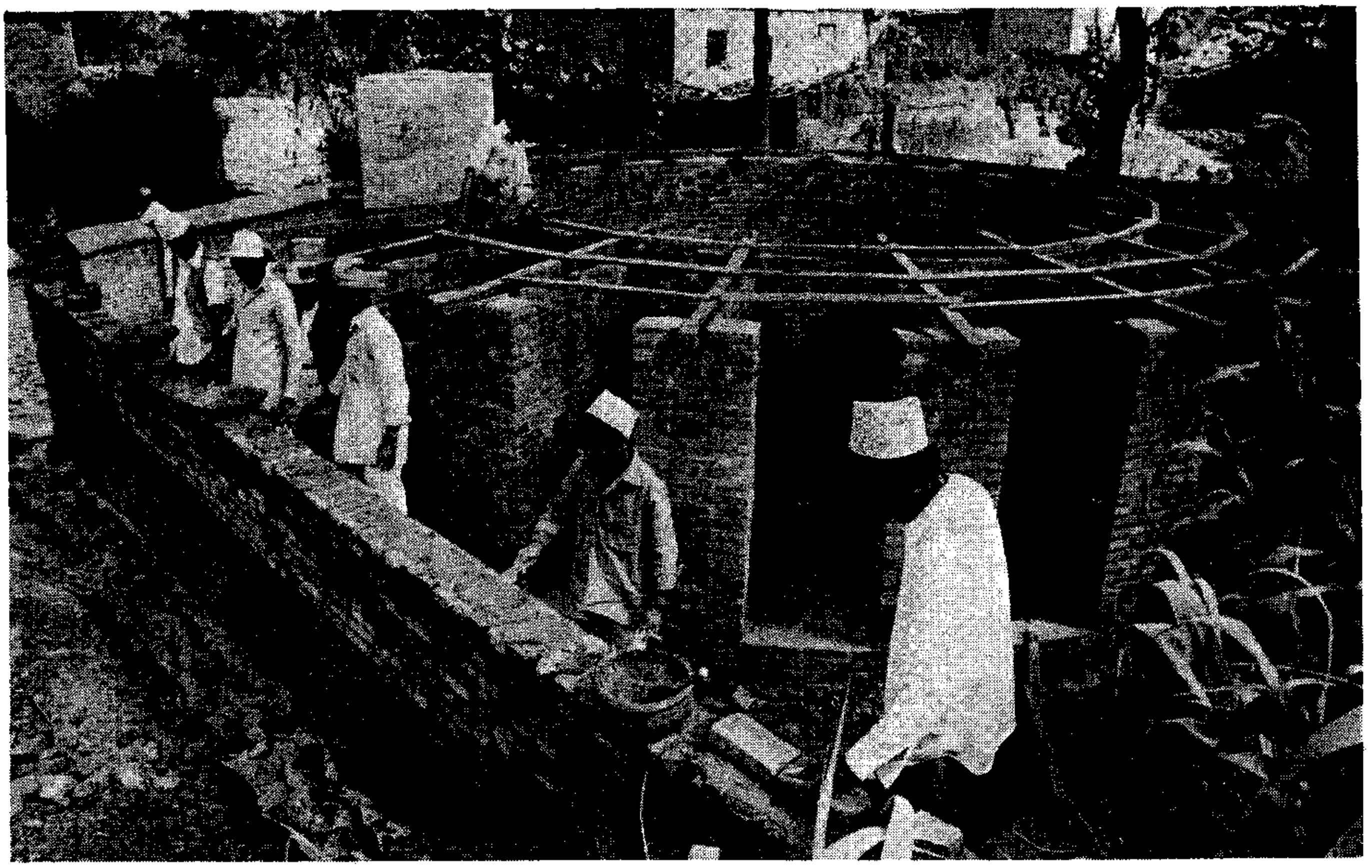

Biogas, Nepal