Vol XXXII
No. 4

ISSN 0019-5014

OCTOBER-
DECEMBER
1977

# INDIAN JOURNAL OF AGRICULTURAL ECONOMICS

INDIAN SOCIETY OF
AGRICULTURAL ECONOMICS,
BOMBAY

# ENERGY IN RURAL INDIA: NATIONAL POLICY FROM THE VILLAGE PERSPECTIVE

John Adams and Wallace E. Tyner*

Ever since the expansion of the coal industry in Great Britain during the industrial revolution, energy has been recognized as a prime motive force in economic growth. The multiplication of inanimate energy inputs has characterized agricultural as well as industrial development in the more advanced countries. In sharp contrast, industrial and agricultural growth is being retarded in the less developed world by the slowness with which energy use is being stepped up. In a time of mounting strains on global energy resources, the poorer third world countries are under especially severe pressures to rationalise their energy policies. Lacking foreign exchange, they are unable to purchase adequate energy supplies; lacking sufficient flexibility in their economic structures, they have difficulty in shifting domestic resources towards exchange-earning export industries; lacking capital, manpower, and sometimes planning foresight, they face great challenges in attempting to exploit domestic energy resources. Deepening their quandary is the fact that the technology of the rich countries is geared to patterns of energy use that appear to be unsuitable—perhaps unattainable—and their ability to borrow techniques from the advanced economies is limited commensurately.

As has so often been true in the post-War period, a fundamental problem of development is thrown into clear relief in India. India has large, if not lavish, supplies of the principal energy sources: coal, hydropower, and with further development, oil and natural gas. India's atomic energy research and application are far advanced and she has made progress in two exotic areas: solar energy and bio-gas. Yet at present, the salient feature of India's pattern of energy consumption is that about half of the total energy used is non-commercial. Firewood, cow dung, and crop residues remain major sources of energy. In the rural sector, an even higher percentage of energy consumption is non-commercial, as shown in Table I. Total energy con-

TABLE I—ENERGY CONSUMPTION IN RURAL INDIA

| Energy sources | Annual amount (trillion kilocalories) | Percentage of total |
|---|---|---|
| Non-commercial | | |
| Firewood and charcoal | 460 | 52.7 |
| Dried dung | 186 | 21.3 |
| Crop residues | 107 | 12.3 |
| Total non-commercial | 753 | 86.3 |
| Commercial | | |
| Oil and natural gas | 85 | 9.7 |
| Coal (soft coke) | 14 | 1.6 |
| Electricity | 21 | 2.4 |
| Total commercial | 120 | 13.7 |
| Total energy consumption | 873 | 100.0 |

*Source:* These values were calculated from data contained in Roger Revelle, "Energy Use in Rural India," *Science*, Vol. 192, June 4, 1976, p. 973.

* Associate Professor, Department of Economics, University of Maryland, College Park, Maryland and Professor, Department of Agricultural Economics, Purdue University, W. Lafayette, Indiana, U.S.A., respectively.

sumption for agricultural and domestic activities in rural India is estimated to be about 873 trillion kilocalories per year, of which about 753 trillion kilocalories, or 86 per cent, is non-commercial. The commercial energy sources supplying the remaining 14 per cent of rural India's energy are coal in the form of soft coke, electricity, and natural gas and oil (mainly diesel oil and kerosene).

India is still a rural country: four-fifths of its people live in villages and a little less than half of its gross national product originates in the rural sector. Growing more food has been a key priority for three decades and John Mellor and others have recently argued for an agriculturally-led employment-oriented strategy of development.[1] It thus appears constructive at this juncture to undertake an evaluation of India's energy resources and policy from the rural or village perspective. We will, therefore, briefly examine the main non-commercial and commercial energy sources and solar energy with respect to supply, technology, and government policy. In concluding, we will discuss the general directions in which rural energy policy is likely to move.

## NON-COMMERCIAL ENERGY SOURCES

More than four-fifths of total energy consumption in rural India is from non-commercial sources: firewood and charcoal, cow dung, and crop residues. By contrast, non-commercial energy comprises less than one per cent of total energy consumed in the United States, where oil and natural gas account for about 75 per cent of total energy consumption. Hence, non-commercial energy in rural India is as important, proportionately, as fossil fuel energy is in the United States. There are two primary types of non-commercial energy sources in India, the forest products (firewood and charcoal) and the by-products of agriculture (cow dung and crop residues). These are all renewable energy resources and, historically, through roughly the end of the 19th century there was a rough equilibrium between their availability and the demand of village populations. But India's forest areas have been substantially reduced over the last two millenia as village colonisation has occurred, usually at the expense of tribal peoples with more extensive settlement and use habits. And, in the British period, improvements of infrastructure, the rural commercial revolution, and mounting population expansion pushed village economic and ecological systems beyond the bounds of self-sufficiency.[2] Today, the desire to increase village land and labour productivity mandates both better use of existing sources of rural energy and provision of modern energy supplies. Ample energy flows can no longer be generated within the village using existing technology; village power must be supplemented increasingly by outside energy sources or new technology. The scant evidence we have from village studies only suggests the nature of some

1. John W. Mellor: The New Economics of Growth: A Strategy for India and the Developing World, Cornell University Press, Ithaca, 1976, p. 123.

2. These developments are discussed on a wider canvas in Elizabeth Whitcombe: Agrarian Conditions in Northern India, Volume One: The United Provinces under British Rule, University of California Press, Berkeley, 1972, see pp. xi-xii, Chapter 2 (especially pp. 75-77, 82-85), and pp. 275-276.

of the relationships between energy systems and economic and social practices; but, there is evidence that fuel and fodder have become progressively less abundant and more difficult to obtain.[3]

*Firewood and Charcoal*

India has some 75 million hectares of forest land of which about 60 million hectares are considered of potential use. Almost all of this forest land is owned and regulated by the State Governments. In 1969-70, the recorded fuelwood harvest from the State forests amounted to 9 million tons out of the 130 million tons of estimated annual consumption. Recorded production was thus only about 7 per cent of estimated consumption. The remainder of the consumption must have come from one or more of the following sources: production from forest land not owned by the States, unrecorded production from State forest land, and production from village lands or roadsides not officially designated as forest lands.[4]

Village studies conducted by anthropologists and others give some insight into the manner in which villagers obtain badly needed and increasingly scarce firewood.[5] Children and the elderly often spend much time foraging for twigs and branches. Trees are mined for wood, and leafy branches are cut down with a knife or saw on the end of a long pole and fed to goats. There is a fine art in taking everything one can from a tree without killing it. Where public forest lands are within a day's walk, villagers poach wood at some risk. Guards are notorious for taking bribes, or for catching culprits and extorting rupees, clothes, or other favours.[6] There is some evidence that timber contractors are permitted to engage in over-cutting, especially in the tribal areas.

These various pressures lift current consumption beyond the maximum sustainable yield of India's forest lands, even allowing for the reforestation taking place under the development plans. In association with over-grazing, which stems from similar pressures, the rapid depletion of India's forest reserves may cause adverse environmental consequences. Erosion is already widespread and climatic effects, such as warmer temperatures, reduced rainfall, and gradual desiccation of farm lands, are possibilities.[7] Recently, the rate of consumption of firewood has increased because of shortages and high prices of kerosene, a major substitute. Higher kerosene prices and the growing firewood scarcity cause more diversion of cattle dung from composting to

3. Uses of forest products are described in some detail in Gerald Berreman: Hindus of the Himalayas, Second Edition, University of California Press, Berkeley, 1972, Chapters 1 and 2; and F. G. Bailey: Caste and the Economic Frontier, Manchester University Press, Manchester, 1957; Murray Leaf has a discussion of the ecology of a village in Chapter III of Information and Behaviour in a Sikh Village, University of California Press, Berkeley, 1972.

4. P. D. Henderson: India: The Energy Sector, The World Bank, Washington, D. C., 1975, p. 30.

5. For an illustration, see Alan Beals: Gopalpur, A South Indian Village, Holt, Rinehart and Winston, New York, 1962, pp. 9-10.

6. *ibid.*

7. Henderson: *op. cit.*, pp. 166-167.

fuel. The breakdown of traditional energy cycles involving renewable resources thus places severe stress upon the rural environment and economy. Some suggest exhorting or forcing villagers to do things differently, but such measures are unrealistic unless there is a perceptible change in the availability and cost of alternative energy sources. Misuse of India's forest resources and grazing will continue until cheap substitute fuels and fodder become available. In addition, in so far as the nation's forests are concerned, reforestation and careful management are needed to provide for other uses such as paper pulp (critically short in India), construction, and wildlife conservation parks (tourist attractions and earners of foreign exchange).

Some specific policy measures should be considered to conserve India's forest resources:

1. A key step is to provide cheap alternative energy sources. If petroleum supplies were not already under severe strain for urban-industrial and transport use, and needed as inputs into fertilizer plants, lower priced kerosene would be an obvious option. Recent off-shore discoveries may help India reach oil self-sufficiency in the 1980s and cheaper fossil fuels for rural areas could become a reality. A major practical difficulty is that to villagers most forest products are "free", in that they do not entail any cash outflow. They are obtained only by labour, usually the labour of under-employed members of the family. Nonetheless, the cost to the nation of these individual economic actions is high in environmental terms, and a socially desirable policy might be to shift some of India's scarce petroleum to kerosene production.

Solar energy and bio-gas are other alternatives for cooking that may ease the strain on firewood and charcoal. Technical improvements in bio-gas generation from dung and crop by-products are being made and a number of units may be placed in villages with government subsidies in the next few years. It remains to be seen whether these facilities will be able to provide methane, or possibly electricity, in sufficient amounts to all village families to supplant traditional fuels.[8]

3. Without the development of alternative energy sources an increase in penalties on abuse of public forests and roadside trees is not likely to be successful. Villagers will not be deterred by fines, rather the rangers or police will simply be given more margin for bribes and extortion. Commercial abuse should be halted, however, and excessive use of timber as an industrial fuel and for charcoal should be curtailed. In these cases, too, alternatives must be provided.

4. A few private farmers, interested in obtaining some return from their lands without expending much effort, already grow fast maturing trees.

8. Henderson: *op. cit.*, pp. 165-167 and Government of India: Report of the Fuel Policy Committee, Government of India Press, Simla, 1974, pp. 31-33.

Research on high-yielding species should, given India's climatic conditions, pay off in varieties that provide fuel, pulp, and other products. Co-operative village woodlots have been suggested as one means of providing adequate fuelwood supplies.[9] This recommendation has two drawbacks, although it might be pursued experimentally. First, poorer villagers needing wood will still be inclined to poach, and richer more powerful persons may find it easy to allocate public timber to their own uses. Secondly, where timber is scarce, as in the Gangetic plains, land is being fully used for crop production. Land can be shifted to timber only if breakthroughs in crop yields are realised.

*Cow Dung and Crop Residues*

The other two non-commercial energy sources are cattle dung and crop residues. In the villages dung is used for composting and fertilizer, as dried saucer-shaped cakes for cooking, and as a cleaning and purifying agent for stoves and kitchens. It is a versatile and valuable substance of economic, ecological, and ritual importance. Sugarcane waste is normally used as a fuel under the hugh iron kettles in which sap is boiled down to jaggery, as semi-refined sugar often used in coffee or tea. Other crop by-products are used for cooking, bedding, thatching, and for livestock feed. In the latter use, residues are an input for traction power in agriculture and for manure. In practice, livestock that grazes on waste—or even on someone else's crops—becomes a travelling converter shifting energy from places and forms where it is not useful to a farmer to fields, crops, and foods where it is.

Cow dung and crop residues are renewable resources in the sense that so long as draft animals are employed in production and crops are produced, these energy resources will be produced as by-products. It has been proposed that these resources be used as raw materials for generating bio-gas at the village or farm level to provide for more efficient energy conversion of resources than at present. The essential advantage of controlled fermentation of dung and crop waste slurry in bio-gas units is that there are three useful products: methane gas, carbon dioxide, and fertilizer. Methane is a clean, flexible fuel and the nitrogen-rich fertilizer sludge is relatively easy to apply to fields.[10] It has even been suggested that the carbon dioxide could be transformed into dry ice but this process is less likely to be efficient. Since the traditional use of dung for fuel destroys its fertilizer value (and vice versa) the bio-gas process promises a considerable increment in the efficiency of energy conversion in the village. The most important use of methane would probably be as a cooking fuel. But it might also be used in combustion engines that could drive pumps, farm implements, or a craftsman's tools. Another

9. Arjun Makhijani, "Energy Policy for Rural India," *Economic and Political Weekly*, Vol. XII, Nos. 33 and 34, Special Number, August, 1977, pp. 1459-1460.

10. In a study of bio-gas units in Gujarat, Moulik and Srivastava found some resistance to using gas produced with human nightsoil in cooking. Thus, at least to some, bio-gas is not perceived as a "clean" source of energy. T. K. Moulik and U.K. Srivastava: Bio-Gas Plants at the Village Level: Problems and Prospects in Gujarat, Indian Institute of Management, Ahmedabad, 1976, p. 44.

possibility is that electricity could be generated and used for lighting and to power machinery.

The economic desirability of family-owned and village bio-gas plants has been subject to considerable debate. The results are highly sensitive to the assumptions made about the reliability and life-span of the units, their size and efficiency, and the kinds of uses to which the gas and fertilizer are put. Variables such as temperature, the mixture of water and waste, and peak load demand also affect the outcome.[11] The consensus of the several studies is that bio-gas units are likely to prove economically desirable under a fairly wide range of circumstances, especially when relatively large community-owned installations are employed and when gas is used for cooking. The case for using the gas to power pumpsets or small electrical generators is less strong, but not without merit. There are many technical, economic, and social administrative, complexities that must be dealt with in implementing a national bio-gas policy. The Fifth Plan's goal of placing 100,000 units in the rural areas floundered badly, in large part because these various problems had not been anticipated and resolved.

Some proponents notably Prasad, Prasad and Reddy, Sathianathan, and Makhijani, have argued that bio-gas plants are profitable and publicly desirable under a broad range of conditions; Parikh has reached somewhat similar but more conservative conclusions.[12] In contrast, Ramesh Bhatia has used a social benefit-cost framework to show that under most conditions private bio-gas units are not desirable.[13] He did not, however, examine village-scale units in detail. Moulik and Srivastava found that downward adjustment of theoretical values to take field experience into account reduced private and social returns, but that bio-gas plants were feasible. Returns to larger units were greater, but community ownership raises major distributional and pricing questions. They observed that credit, maintenance, and administration were apt to prove problems. They also pointed out the extremely important fact that Gujarati villagers use cotton husks for fuel, at virtually zero cost. So using the kerosene price as the opportunity value of bio-gas must over-state benefits.[14]

In his representative study, Parikh showed that even with relatively conservative yield and conversion assumptions, the energy yield from bio-gas

11. The Moulik and Srivastava study cited above is unique in basing its evaluation of bio-gas on a careful field study. Most of these factors and variables are discussed in their work. Their discussions of scale effects and actual operational problems in field installations are unusually strong. (See pp. 38-52, 74-84.)

12. Kirit S. Parikh: Second India Studies: Energy, Macmillan Company of India Ltd., Delhi, 1976; Arjun Makhijani and Alan Poole: Energy and Agriculture in the Third World, Balinger Publishing Co., Cambridge, for the Ford Foundation, 1975; C. R. Prasad, K. Krishna Prasad and A. K. Reddy, "Bio-Gas Plants: Prospects, Problems and Tasks," *Economic and Political Weekly*, Vol. IX, Nos. 32, 33 and 34, Special Number, August, 1974, pp. 1347-1364; M. A. Sathianathan: Bio-Gas Achievement and Challenges, Universal Book Co., New Delhi, 1975.

13. Ramesh Bhatia, "Economic Appraisal of Bio-Gas Units in India: Framework for Social Benefit Cost Analysis," *Economic and Political Weekly*, Special Number, August, 1977, pp 1503-1518.

14. Moulik and Srivastava: *op.cit.*, Chapter VI.

is greater than that energy obtained from burning the dung. The yield from burning a given amount of cow dung would be 3,930 kilocalories a day as contrasted to the 5,170 kilocalories per day realisable from burning bio-gas from the same quantity of dung.[15] Not only does the bio-gas yield 25 per cent more cooking energy, but the fertilizer value of the manure is conserved. The bio-gas process thus has the additional value of reducing the need for energy intensive commercial fertilizers and would save foreign exchange.

Since there are economies of scale in bio-gas installations, and since village-oriented units are in line with established community development programmes, the government is placing the greatest stress on the larger plants. Cost estimates for the village units have not always considered the total costs of distribution, pressurisation, metering and storage.[16] There are some organizational and management problems that need to be resolved, too, before widespread village installations are likely to measure up to hopes.

With a village unit, dung would be collected and brought to a central facility run by a quasi-official manager. Because the process is more or less continuous, dung can be added while gas and fertilizer are removed. An incentive system would have to be devised to encourage villagers to supply cow dung for bio-gas generation. A system of payments and fuel and dung credits could be envisaged that would motivate persons to collect dung from streets and fields and bring their stable cleanings to the plant. Those who use gas for heating, cooking, lighting, or as a fuel for pumpsets would have to employ their credits or money to pay for their consumption. Fertilizer would also have to be priced. It is obvious that such a system would require substantial changes in the current handling of animal and plant wastes in the villages. Its implementation also presumes honest, attentive local management and the existence of a reliable maintenance network.

Some have attempted to justify the bio-gas process as a means of decentralised rural electrification.[17] Rather than serving as a fuel, bio-gas would be converted into electricity for light, heat, and other needs in the village. We have previously examined and compared the costs per unit of electricity of local bio-gas and centralised power generation.[18] In our judgement, earlier cost estimates have been substantially biased toward local units. On average, centralised power production and distribution has an appreciable cost advantage over local bio-gas electricity generation. The major shortcomings of bio-gas electricity generation lies in the mechanical transformation of bio-gas into electricity. Small electric generators are not efficient converters and even the expensive process of rural electrification generally appears to be a preferred option. On the other hand, a major cost component of centralised

15. Parikh: *op. cit.*, pp. 93-98.
16. Bhatia, *op. cit.*, p. 1513.
17. Makhijani and Poole: *op. cit.* and Prasad, Prasad and Reddy, *op. cit.*
18. Wallace E. Tyner and John Adams, "Rural Electrification in India: Bio-Gas versus Large Scale Power," *Asian Survey*, August, 1977, pp. 724-735.

power generation is distribution. Hence, where villages are remote from transmission lines small bio-gas units may yield a cost savings. There may be numerous locations—perhaps 50 to 100 thousand villages—in rural India where bio-gas facilities would be advantageous at least as a transitional source of electrical power.

The chief matter for the government to consider is that the costs of bio-gas as opposed to those of centralised generation vary from case to case. Not only are power distribution costs variable, but the economics of bio-gas generation vary from setting to setting. The amounts of manure and other inputs available depend upon the size of the village herd, the quantity of fodder, and other factors. Also, villages that are, in the south Indian phrase, "full of politics" may not be suited to an endeavour that presumes a degree of co-operation. It ought to be possible to establish a set of criteria that could be used to determine whether or not the location and circumstances of a particular village are suited for a bio-gas unit. With such a worksheet even a surveyor with a minimal technical background could make an informed judgement about the merits of a particular case.

Before an effort is made to put bio-gas into those villages where it is deemed advantageous (either for direct use as a fuel or for bio-gas electricity generation), steps will need to be taken to provide an administrative network to support field operations. A new programme of this type will have to draw together bureaucrats, engineers, and economists to co-ordinate its various aspects. Financial resources will have to be found and the degree to which villages will be held responsible for repaying capital costs to the government determined. At some point, too, the opportunity costs of this large amount of capital need to be considered before going ahead with the programme in a big way. Moulik and Srivastava point out that even their fairly high estimates of private returns to bio-gas investment would prove unattractive to farmers, since most have better uses to which credit could be put. This may also prove true of village level investments. Production and operation problems will surface once numerous facilities are installed under different site conditions. Maintenance is likely to be a headache, and previous back up performance with village radio and television and other decentralised programme does not inspire full confidence. As with everything else, State and local political factors are likely to impinge on selection decisions in locating the available units.

It would be hopelessly naive to install bio-gas units in Indian villages without expecting their use and effectiveness to be substantially affected by rural social, power, and economic relationships. One should not disturb the existing flows of energy resources through the village and inject new resources of important value without anticipating the reactions of and consequences for the villagers. Currently, dung is used for fuel and compost and there are established arrangements for collection, drying, and distribution of dried dung cakes. Where cattle are stalled in the family dwelling or compound, the farmer or his workers routinely cart manure and urine-soaked straw to compost pits. Generally, rich and poor seem to get adequate cooking fuel, although this is clearly a bigger problem for the latter. Ownership rights to dung found outside a farmer's sheds or compound are usually vested on a first-come, first-serve basis, although not all castes or families would undertake the collection task. A major lacuna in the literature about village India is that no one has ever carefully traced in a village the exact production, distribution, and use patterns of dung, fodder, and other energy resources. Without such knowledge it is difficult to anticipate the consequences—although we know there will be some—from installing a bio-gas plant to serve a village or several neighbourhoods.

When a bio-gas plant is built, dung must be collected and handled differently. Dung will acquire a market value and an incentive will be created for owners of cattle to claim latent property rights, both for income and for the acquisition through credits of the doubled benefits of the bio-gas process: fuel (or electricity) and fertilizer. The losers will be those who do not own cattle and who have depended upon dung collection to satisfy their needs. Some equitable and enforceable method must be found to govern flows of gas or electricity and fertilizer in the villages. A pre-requisite for taking the bio-gas system into village India is a set of locally intelligible property rights and payments that does not do excessive violence to existing economic relationships. At a minimum, some serious thought must be given to determining the effect the new technology will have on village institutions and how the villagers will respond. Without this care there is a presumptive case for a more uneven internal distribution of energy resources and incomes.

If these many problems can be resolved, bio-gas generation holds promise as a means of increasing the conversion efficiency of energy used in rural India.

## SOLAR ENERGY

The average annual intensity of solar radiation in India is about 600 calories per square centimetre.[19] By contrast, the highest regional average intensity in the United States (in the western south-central region) is about 430 calories per square centimetre.[20] In winter many parts of India receive 500 or more calories per square centimetre, which is about twice the January average for the south-western United States. As solar energy becomes marginally economic for applications in a range of regions in the United States, it is probable that it will be even more feasible in many parts of India. Solar energy can be utilized for home and hot water heating, crop drying, wood seasoning, and for other purposes in the rural areas. One important research prospect is the development of a solar powered water pump for irrigation.

19. Parikh: *op. cit.*, p. 42.
20. Federal Energy Administration: Project Independence Blueprint Final Task Force Report—Solar Energy, Washington, D.C., 1974, p. A-1-9.

The on-going research in this area needs to be expanded to perfect the pump design. Solar powered water pumps would be very beneficial in spreading the benefits of irrigation without utilizing non-renewable energy resources.

## COMMERCIAL ENERGY SOURCES

The recent history of progress in agricultural development may be described as raising yields per person and per hectare by increasing the quantity and efficiency of energy utilization in agriculture. Whether agricultural development has occurred in countries with high (United States) or low (Japan) land-labour ratios, increases in yields have required large increases in fuel energy inputs from fossil fuel sources such as coal, oil, and natural gas. Increasing usage of irrigation, fertilizer, pesticides, and mechanical energy requires complementary increases in the use of fossil fuel energy.[21] Although all commercial energy forms (fossil fuels plus nuclear and hydropower) amount to only 14 per cent of total energy consumption in rural India, the percentage is increasing and commercial energy will be a determining factor in the development of rural India. We will thus examine the resource positions of oil and natural gas, coal, and electricity and comment upon policy options dealing with these three major commercial energy sources.

### *Oil and Natural Gas*

The current proved reserves of oil in India are estimated at about 400 million tons (3 billion barrels). About 70 per cent of this has been discovered since 1974. In addition, India has potential oil reserves of about 5,900 million tons (45 billion barrels) as estimated by a team of Soviet and Indian geologists.[22] A programme of exploration and development could relieve the foreign exchange burden of oil imports and help alleviate energy shortages in the rural areas. To develop these resources at a rapid rate, India will need to continue leasing offshore areas to foreign firms for oil exploration and development. Indonesia has been quite successful in using production sharing leasing arrangements similar to those of India. The foreign companies are required to fund all exploration and development activities in exchange for a portion of the oil if resources are discovered. Even when no oil is found and the lease is terminated (as has happened with some of the early leases), India receives all the exploration data from the foreign companies at no cost.[23] It is valuable to know where there is no oil just as it is valuable to find reserves. Dry holes in some regions can help direct future drilling to more productive areas.

21. Kenneth D. Frederick, "Energy Use in Agricultural Production in Developing Areas," in Ronald G. Ridker (Ed.): Changing Resource Problems of the Fourth World, Johns Hopkins University Press, Baltimore, for Resources for the Future, 1976, p. 101.
22. Larry Auldridge, "India Steps up Exploration, Development," *Oil and Gas Journal*, August 23, 1976, p. 52.
23. For a more detailed discussion of India's offshore leasing system, see Wallace E. Tyner: Energy Resources and Economic Development in India, Martinus-Nijhoff, Leiden, Holland, 1977 (forthcoming).

Some leased areas have been relinquished by foreign exploration firms because early drilling results were discouraging. The treatment of drilling costs and royalty payments to foreign governments under United States tax law is also a major factor affecting American firms' willingness to remain active. After the Indian leases were signed, United States tax authorities issued a ruling that disallowed tax write-offs against American tax liabilities for taxes paid to the host governments under the Indian and Indonesian production sharing contracts. This ruling has dimmed, at least temporarily, the prospects for profitable development by American companies. Since large international transfers could be involved, the Indonesian government is working for a modification of this decision. Persumably India has joined in this effort, or will shortly.

India now imports about two-thrids of its oil and spends 40 per cent of all foreign exchange earnings for oil imports. Heavy taxes on petrol and kerosene make their consumption in the rural areas very expensive. To ease the strain on foreign exchange earnings and increase petroleum availability in both the urban and rural areas, India will need to develop its potential petroleum reserves as rapidly as possible.

*Coal*

India has sufficient coal resources to meet consumption for at least 80 years. The situation with respect to coking coal, which is used in the rural areas for heat generation, is less secure. It is estimated that coking coal reserves are adequate for no more than 40 years.[24] Although soft coke consumption in the rural areas is a very small fraction of total coke consumption in India, it may be desirable to develop alternative energy sources such as bio-gas. Because of the high cost of petroleum-based fertilizer inputs, the Government of India is launching a programme to produce fertilizer from coal.

*Electric Power*

Electric power is generated in India from coal, hydropower, and nuclear power (plus a small amount of diesel generation). India is richly endowed with hydropower resources, having a capacity of at least 41 million kilowatts, of which only 17.5 per cent has been developed or is under development.[25] Despite these rich hydropower resources and adequate coal supplies, development of power generation capacity has lagged behind schedule during the Five-Year Plans. In the Fourth Plan period only 50 per cent of the planned additions to installed capacity were achieved.[26] Power generation is below the level that could be productively absorbed by the industrial and agricul-

24. Parikh: *op. cit.* p. 38.
25. Government of India: Report of the Fuel Policy Committee, *op. cit.*, p. 28.
26. Government of India: Draft Fifth Five Year Plan, 1974-79, Planning Commission, Government of India Press, New Delhi, 1974, p. 118.

tural sectors of the Indian economy. P. M. Agerwala has observed : "Power shortages seem to have added a new dimension to the ideological differences over granting priorities to industry and agriculture. In one State, power supplies were stopped specifically for providing interim relief either to industry or agriculture at the cost of the other."[27] During 1974-75, power cuts ranged from 25 per cent in Maharashtra to 60 per cent in Tamil Nadu, Punjab, Haryana, and Delhi.[28] Power shortages have forced cutbacks in crop irrigation and limited the success of rural electrification. Furthermore, uncertainty regarding power availability adds to the risks farmers face and inhibits innovations that depend on the reliability of expected returns. The green revolution varieties are energy intensive and require greater quantities of both fertilizer and water. Power shortages have impeded progress in expanding food production.

As of 1970-71, only 16 per cent of the villages in India had been electrified.[29] In the Fifth Plan, rural electrification was included in the "minimum needs programme" reflecting the importance attached to it by the Government. The goal is to energise 1.5 million pumpsets and to electrify 110,000 villages.[30] Advances in rural electrification are necessary to make full use of India's extensive groundwater supplies. Both the pace of rural electrification and the rate of additions to generating capacity need to be expanded significantly for accelerated development of rural areas.

## ENERGY POLICY AND AGRICULTURE

Recently, rural development has experienced a revival in the economic development literature. In his work on an employment-oriented strategy of development focusing on increased agricultural production, John Mellor calls for a higher rate of growth of power than in previous years.[31] Electric power is needed not only for irrigation, but also for small industry and domestic consumption in the rural areas. Other energy dependent inputs needed are fertilizer, pesticides, and mechanical energy. Increased availability of these forms of energy would lead to increased agricultural output. Many do not recognize, however, that increasing agricultural production requires increasing the efficiency of energy utilization. Three times as much energy is used per ton of rice produced in India as in the United States or Japan. Nineteen million BTUs of energy are required to produce a ton of rice in India whereas only 6.3 and 6.2 million BTUs are needed in the United States and Japan respectively.[32] Greater amounts of commercial energy (irrigation, fertilizer, pesticides, and mechanical energy) are used in these countries.

27. *The Economic Times*, January 31, 1975, quoted in Mellor: *op. cit.*, p. 123.
28. Sham Lal (Ed.): The Times of India Directory and Yearbook Including Who's Who, The Times of India Press, Bombay, 1976, p. 609.
29. Government of India: Report of the Fuel Policy Committee, *op. cit.*, p. 86.
30. Government of India: Draft Fifth Five Year Plan, *op. cit.*, p. 125.
31. Mellor: *op. cit.*, p. 123.
32. Makhijani and Poole: *op. cit.*, pp. 16-18.

Conversion of these commercial energy forms into agricultural output is more efficient than is conversion of non-commercial energy in India. Draft animals used for cultivation in India are particularly poor energy converters and there is an average of one draft animal for every hectare of cultivated land in India.[33]

Successful development of agriculture involves reducing the proportion of inefficient energy inputs in favour of energy forms such as fertilizer and irrigation that yield greater output per unit of energy input. So while total energy utilization per unit of food produced must be lowered, utilization of efficient energy inputs such as irrigation, fertilizer, and mechanical power must be raised.

## CONCLUSION

To increase consumption of efficient energy inputs, production will need to rise in all commercial energy sectors. Increased expenditures need to be allocated to the energy sector as a whole in order to increase productivity in the rural areas of India. A number of specific policy directions emerge from this study of the individual energy sectors.

For oil and natural gas development, India will find it in her interest to pursue an active policy of leasing offshore potential petroleum-bearing areas to foreign concerns in order rapidly to accelerate domestic petroleum production. India can do this without expending any scarce foreign exchange and at the same time reduce the pressure on foreign exchange from oil import costs.

A substantial increase in investment for generation and distribution in the electric power sector is needed. In the short-term, increases in thermal (coal) power generation are planned, but in the long-run a greater emphasis on utilizing India's renewable resource, hydropower, is called for. India is approaching the point of having a unified national grid so that hydropower generated in the north-eastern areas can be transmitted to other parts of the country. Hydropower projects also generally produce substantial irrigation benefits.

Although bio-gas generation appears not be economic for the purpose of rural electrification in most instances, it does appear to be feasible in many cases for direct generation of fuel and fertilizer. Use of cow manure and crop residues to generate bio-gas would increase the efficiency of agricultural production and productivity in the rural sector. Bio-gas has excellent potential as a cooking fuel and some prospects for powering machinery, lighting and electricity generation.

33. Makhijani and Poole: *op. cit.*

Solar energy is particularly attractive in the Indian setting especially if solar irrigation pumps can be perfected. Vigorous research and development in this area within India is important because the technology cannot be imported at this time.

We believe that India has reached the crossroads in her economic development and in her approach to energy uses and policy in the rural areas. The nation is now on the threshold of shifting dramatically from traditional to modern energy sources and technologies. Decisions made now are fraught with consequences for the lives of almost a billion people through the early decades of the next century. In the years ahead it will be necessary for India to provide substantially more energy to her rural and urban sectors if growth is to attain anything like the 5 to 6 per cent rate needed to offset population increases and improve living conditions. In the rural areas, the efficiency of energy use must be enhanced: this is a pre-requisite for agricultural growth and for providing power for small-scale industrial employment that will occupy a growing labour force. As others have pointed out, increases in energy supplies are needed in both cities and villages, but per capita consumption must be increased much more in the villages.[34] Like people elsewhere, Indians must come to rely less upon their brawn (and the strength of their beloved bullocks) and more upon machines that ease toil. As long as Indian farmers use little energy, and that ineffectively, they will remain poor. A reasonable, long-sighted, and coherent energy policy can make living in rural India a pleasant experience and need not place undue strains on the nation's stock of potential energy sources. It is both desirable and likely that over the next several years the Indian government will find itself drawn inexorably deeper into energy policy choices and the evaluation of their impact on rural areas.

34. Amulya Kumar N. Reddy and K. Krishna Prasad, "Technological Alternatives and the Indian Energy Crisis," *Economic and Political Weekly*, Special Number, August, 1977, pp. 1466-1467.