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APPROPRIATE TECHNOLOGY FOR RURAL ENERGY

PLANNING OF RURAL ENERGY SYSTEMS: ISSUES AND PERSPECTIVE,

~~Background Paper~~,

PLANNING OF RURAL ENERGY SYSTEMS: ISSUES AND PERSPECTIVE

by

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UNIDO consultant

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1. INTRODUCTION

Rural energy planning has only recently received attention as up-till now due to the low purchasing power and subssistence level economic activities in the rural reas, the rural energy supply consisted of gathered fuels, wood and waste, which were supposed to be locally available renewable resources. However, in the recent years, it is realised that this supply is no longer renewable, if the population pressure is beyond the capacity of environment, in particular land, to provide these fuels. Moreover, the realisation that the rural development affects more than 70% of the population in the developing countries and is an essential element for the national development is gradually entering into the planning process. If the efforts for rural development are intensified, rural economic activities would be different than they have been in the past and that would call for a different energy consumption pattern, where the inefficient forms of traditional energy supply would no longer suffice. The energy forms would have to be efficient as well as available on a sustainable basis.

The scope of the present paper in brief is as follows:

- Identifies difficulties in the present pa ttern of rural energy consumption which is largely based on non-commercial fuels, supply of which is unplanned and sufficient only for the subsistance level activities.

- Reflects on future energy demand till 2000 AD under the high rural development scenerio showing that increase in non-agricultural activities should be foreseen and that intensification of agriculture will also require increased energy inputs. Moreover, the requirements of the household transport and industries would grow not only quantitatively but qualititatively as well and more efficient energy would be required.
- Discusses techno-economic considerations for rural energy supply options and in particular those based on concepts of decentralized systems, although they are not advocated if found to be more expensive then centralized systems. It discusses supply alternatives for fuel (heat) and power separately and identifies technical parameters necessary for the success of the supply schemes.
- Emphasizes and illustrates the need for looking into issues concerning technology management, since technological solutions per se are quite simple. The need for looking into problems of technology transfer in the rural environment, establishing organizational framework for construction and maintenance and standardization procedures are emphasized.

While dealing with these issues developing countries of Africa, Far East and Latin America are kept in view. The world-regions are taken as defined by the World Energy Supplies (1978) and exclude South Africa and Japan. In some cases, however, individual countries are also discussed but in that case only countries having population more than 5 millions in 1973 are considered.

In this short paper, only world regional considerations are given against which individual countries could approximately

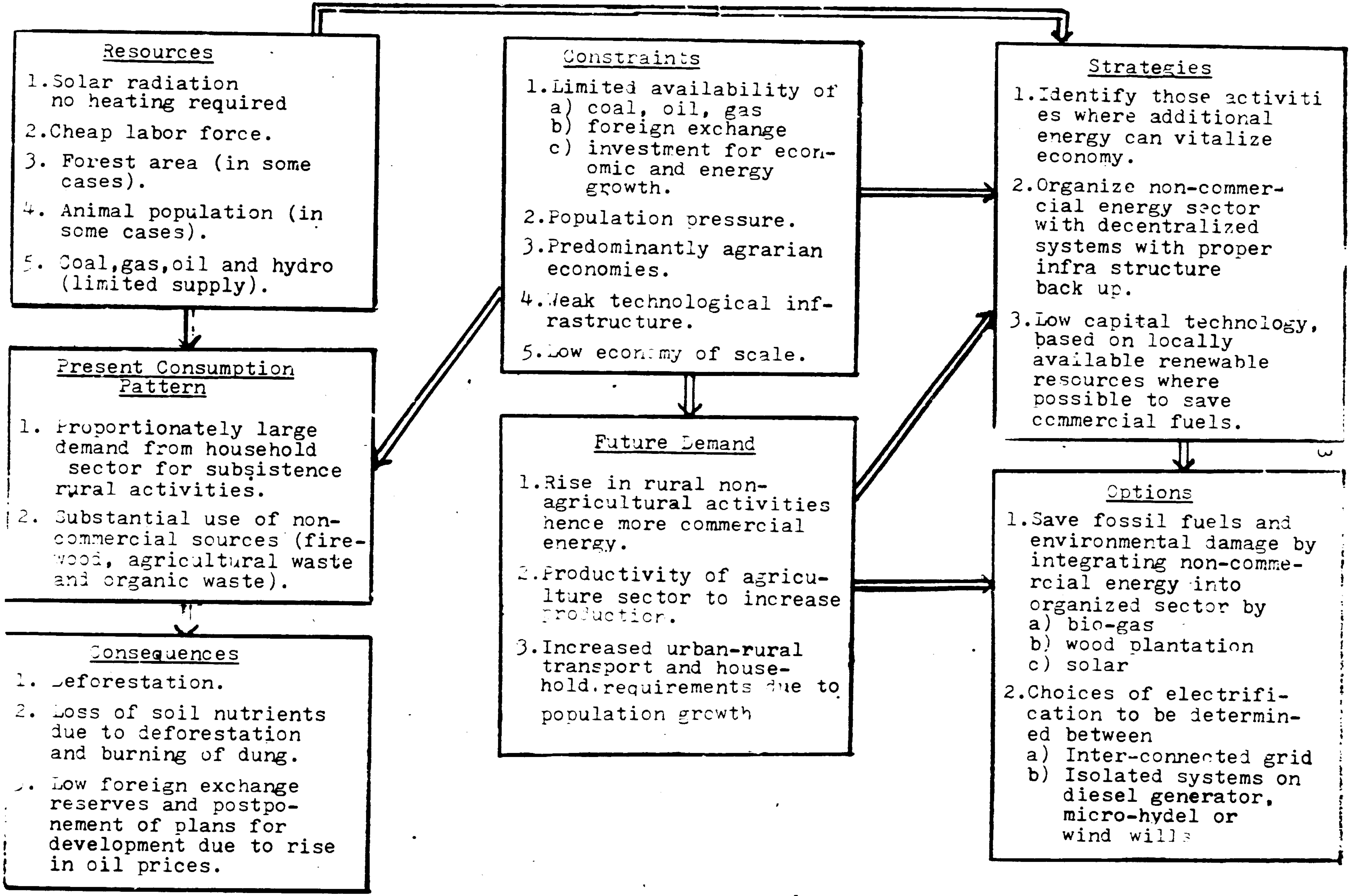

Fig: 1 Rural energy systems for the developing countries.

assess their own situation knowing their own present position with respect to the regional averages.

The time horizon kept in view is upto 2000 as it takes 5 to 10 years for planning and constructing energy facilities and another 10 to 15 years till new technology or solution can pentrate into energy technology market sufficiently and contribute significantly to the extent of 2% to 10% to the energy supply. The perspective of the rural energy systems on which this paper is based is illustrated in Fig. 1.

2. PRESENT ENERGY CONSUMPTION PATTERN:

A summary of the present energy consumption in the developing regions as of 1973 can be seen in Fig. 2. The overall percentage of commercial energy consumption is 32%, 50% and 60% for Africa, Far East and Latin America. This amounts to per capita commercial energy consumption of 0.19, 0.23, and 1.0 tons of coal equivalent (tce) for these regions respectively as opposed to 11 tce in the USA for the same year. However only 5 to 10% of the commercial energy consumption of these regions is in the rural areas and that of electrical energy can be as low as only 0.5 to 3% of the average regional figures. World Bank report on rural electrification (1975) indicates that only 4%, 15% and 23% of the rural population of Africa, Far East and Latin America was served with electricity in 1971.

Figure 2 : Energy consumption in millions of tons of coal equivalent mtce (1973).

Region	Commercial Energy a)	Fuelwood b)	Agricultural Waste b)	Total
Africa	66 32.3%	116 56.8%	22 10.9%	204
Far East+	247 50.4%	143 29.2%	100 20.4%	490
Latin America	304 60.5%	98 30.2%	31 9.3%	433
Sum of the 3 regions	617	357	153	112.7

excluding South Africa

\+ excluding Japan

a) United Nations, "World Energy Supplies" (1975)

b) Parikh J. (1978), World Bank IIASA Study on "Energy Systems and Development"

What does this low level of energy consumption imply in terms of economic activities that could be sustained with it? How much of this energy consumption goes towards subsistence level activities and what is the energy consumption in the economically productive activities?

In order to assess the energy required for subsistence, the data for energy consumption in the rural households are shown in Fig. 3. The energy consumption in the household sector, comprising mainly of cooking and lighting, ranges from 0.25 to 0.40 tce per capita. Let us assume a figure of 0.325 tce per capita to be the total energy required for cooking, lighting and minimal energy for subsistence family and minor transport. We call it energy required for subsistence. This is less than that required for basic needs as the energy required for shelter, cooking, health, education etc. is not included. The energy threshold for development would be considered that which is found in the countries having per capita GNP of $ 2000 in 1973 i.e. approximately 2.5 tce per capita, slightly higher than the world average in 1973.

Having determined the two energy thresholds(levels), we now examine the levels of energy consumption of various countries with respect to these thresholds. In Fig. 4, the per capita commercial energy consumption is plotted against the per capita commercial energy production on a logarithmic scale. The line of self reliance is where both of them are equal. The area before the energy threshold for subsistence is the triangle of struggling existence. It can be seen that most of the developing countries are below the (level) threshold for subsistence if one considers only the commercial

Figure 1.3. Household requirements of energy in various countries:

Country	Units reported	Other remarks	per person requirements in kgce/year*
India[a]	Average of a variety of fuels ranging from dung to kerosene	Household survey of 21,000 rural households	300
Kenya[b]	324 kgce/year	Wood, charcoal and kerosene use taken together	325
Tanzania[b]	400 kgce/year	"	400
Ivory Coast[c]	1.5 kg of wood/day		352
Thailand[d]	6 to 7m^3/family	Heavy use of charcoal means more losses	450-500
Nepal[e]	0.6 to 1 m^3 wood/year/person	Nepal requires heating of different measure in different parts	260-435
China[f]	1800 kg/family/year	Chinese coal of low quality; range depends on quality assumptions	250-400

*All units converted to UN coal 7000 kcal/kg

a) National Sample Survey 17. Govt. of India (1964), New Delhi
b) Inquiries made for a monthly consumption in a few households (6 to 10) and averaged over a year, J.Parikh (1978)
c) Development Forum, March 1978.
d) FAO report to the Govt. of Thailand No. 3156 (1972) Rome
e) D.Earl (1975)
f) El Hinnawi (1977). The size of the family taken is 5 persons/family.

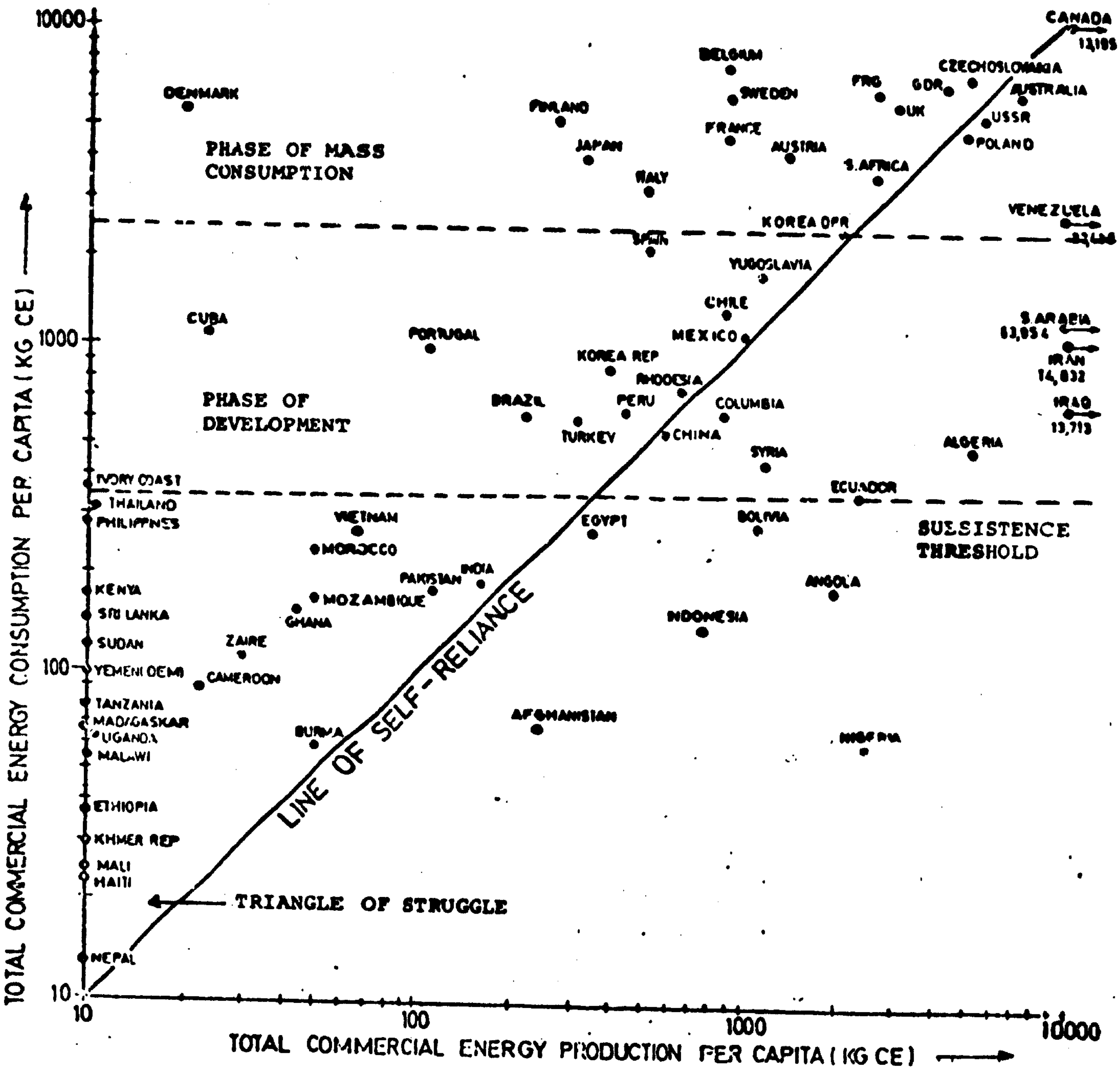

Figure 4. The position of countries with respect to thresholds and phases of subsistence development and mass consumption

energy consumption. Severely constrained and dependent on non-commercial energy sources are those with consumption below 100 kgce/person. In fact, some of the oil exporting developing countries are also using non-commercial energy to considerable extent, specifically in the rural areas. Those developing countries who are close to the boderline of subsistence may also have some industrial growth. However, this may be due to inequitable distribution of energy and at the cost of those millions who do not get enough to cook their inadequate meals.

Role of Non-Commercial Fuels

It is only when the substantial use of non-commercial fuels in the rural areas is included that the nations below the subsistence threshold in Fig.4 come at the subsistence level. However, can such heavy use of non-commercial fuels be relied upon for even a decade for which neither the investment nor any planned efforts are put in? Only recently attention has been drawn to wide scale deforestation and accompanied soil erosion (Eckholm, 1975). How significantly these environmental effects are linked to the process of desertification has been highlighted in the U.N. Conference on desertification in Nairobi (1977) and is briefly summarised by J. Parikh (1978a). Moreover, the scarcity of supply of non-commercial fuel is increasing each day and the distance which has to be travelled and the time which has to be spent to collect it.

Thus the present mode of rural energy supply not only causes environmental damage but cannot be taken for granted to support present population even at its present level for a long time.

The brief statements made above covering present situation lead us to the two main issues with which the future energy policy should concern itself:

(i) The present rural energy system is largely based on non-commercial energy supply of which cannot be taken for granted in view of increase in population and rural development. How to restructure it and how these energy supply could be ensured to be available on a sustainable basis in the rural areas ?

(ii) How to obtain additional energy required for rural development and to rise above the subsistence level activities. Apart from changing the present pattern, the qualitative and quantitative changes in the future demand are to be expected which are discussed in the following section.

3. ASSESSMENT OF RURAL ENERGY DEMAND AND EXPECTED STRUCTURAL CHANGES

The purpose of this section is not only to assess the magnitude of the energy problem ahead of the developing regions but also to anticipate structural and qualititative changes, if the efforts for rural development are put in. Quantitative work in this area has been done by J. Parikh (1978a) where energy demand for the developing regions have been worked out for low and high rural development scenarios for different demographic structures and income distributions. In another paper (J.Parikh 1978b) some implications for the expected sectoral changes are

... also worked out where the discussions on growth rates of energy requirements of agriculture, transport and household sectors are given. Therefore, this section summarises these two works and highlights those issues which directly concern policy decisions. These figures are only reference figures and more work should be done at the level of individual countries. We seperate the two issues. namely, magnitude of the demand and structural changes.

3.1 Assessment of Rural Energy Demand Till 2000:

In the literature there has been little distinction between rural and agricultural population, because the percentage of rural non-agricultural population is very small at present. In future, however, under the high rural development scenario, (HRD) rural non agriculture sector should grow considerably, rationale for which is as follows. The share of agricultural GNP in the total GNP decline as the GNP per capita increases as shown in Fig. 5. Note that 65% of agricultural population produces 33% of GNP in the Far East as opposed to 5% agricultural population producing 4% GNP in the USA. Thus it is assumed that under the HRD scenario, the proportion (and not the magnitude) of the rural agricultural population will decline at the same rate as the decline in the share of agricultural GNP in total GNP. In the low rural development scenario, (LRD) the proportion of agricultural population in the rural population remains the same in 2000 as it was in 1973.

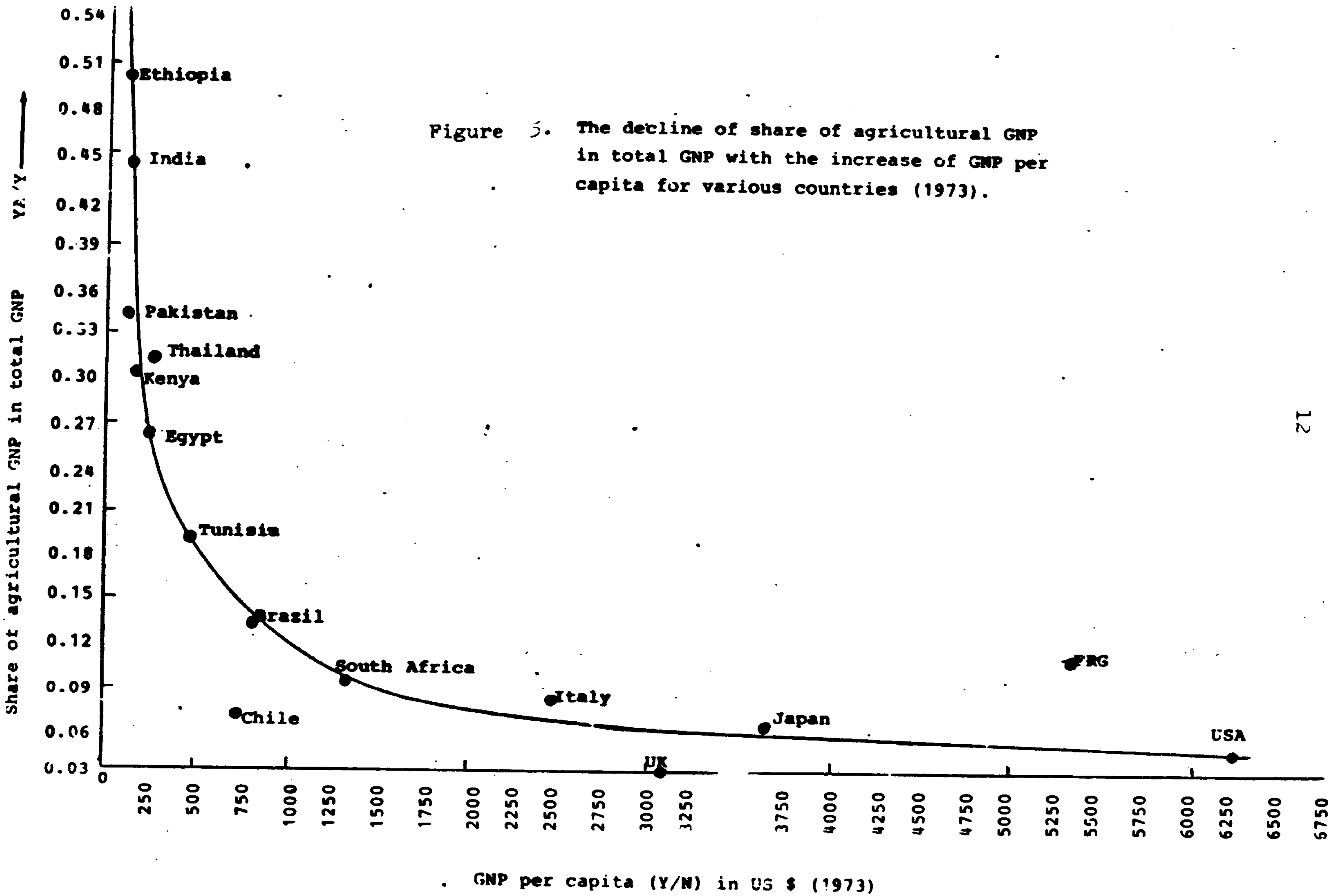

Figure 5. The decline of share of agricultural GNP in total GNP with the increase of GNP per capita for various countries (1973).

The detailed discussions on income and population distributions are omitted here (J.Parikh, 1978a). The highlights of the results are given in Figure 6 for the three world regions only for the high rural development scenario and could be summarised in words as follows:

i) Due to already poor conditions at present the rural energy growth rates are higher than the average regional growth rates but yet the disparity with the average scene remains, although less compared to 1973.

ii) There is considerable increase in the commercial energy component in the rural energy demand. Thus, although improvement in total (including non-commercial) energy consumption is less, there is a qualitative improvement due to increase of commercial energy which is more efficient.

The regional highlights are as follows:

In Africa, 62% of the rural population in 2000 requires 35% and 17% of the total commercial energy of Africa under the high and low rural development scenarios, respectively. The total per capita consumption is 0.7 tce. Thus, there is little increase from present in absolute terms, but the increase is due to the increased component of the more efficient commercial energy. In the Far East under the HRD the rural energy consumption is 0.36 tce in 2000 out of which 0.12 tce is commercial energy.

Under the HRD, in Latin America the rural energy requirement increases rapidly but its proportion in the total commercial energy

Figure: 6. Rural Demographic, economic changes under the high rural development scenario and corresponding energy demand a)

Variable (Units)	Africa		Far East		Latin America	
	1973	2000	1973	2000	1973	2000
Population (10^6) b)						
Total	335	763	1070	2134	300	620
Rural	260	475	857	1387	130	156
Rural non-agricultural (under HRD)	22	183	122	513	4	64
Economy (10^9 of 1973)						
GNP	89	398	156	542	249	1120
Rural GNP	34	181	79	286	35	200
% Agricultural GNP	32	21	39	29	13	7.7
Rural Energy (mtce)						
Commercial energy	8	117	14	165	30	148
Non-commercial energy	100	179	180	337	100	127
% of Commercial energy	7	40	12	33	23	54
Per capita total energy (tce)[c]	0.41	0.62	0.25	0.36	1	1.76

Source : J.Parikh (1978a) (a) Unless explicitly stated 'rural', the figures indicate average regional figures for 1973, guessed from a few countries. Figure for 2000, from the SIMCRED model, (J.Parikh 1978a).

(b) U.N. demographic projections (1975)

(c) Total energy = commercial + non-commercial energy is only 13% as the proportion of the rural population in the total population is 25%. The urban-rural differential in income decreases significantly and energy consumption is 1.76 tce in the rural areas. The share of commercial energy in the rural energy is 68%.

3.2 Structural changes in the Rural Energy Demand:

Uptill now, due to extensive use of animal and human labour and due to subsistence level economic activities, rural energy is essentially in the household sector and its supply comes from non-commercial fuels. However, what structural changes should one expect in future if the efforts for rural development are put in which means that rural non-agricultural sector expects and rural agricultural sector becomes more productive and goes beyond subsistence farming.

The sectoral energy demand considerations are very useful in anticipating energy supply mix, be it oil, electricity, fuel, wood or solar. The following sectoral changes are to be expected for the time horizon 2000:

(i) Household Sector: Due to population and economic growth, the energy required in household would approximately double and more component of commercial energy is to be expected for lighting, comforts and simply due to substitution of non-commercial fuels which would get scarcer. There is some scope of conserving energy in this sector through introduction of efficient stove which could save fuel.

(ii) Intensification of Agriculture: While discussing the question of energy in agriculture at present and as it would be required in 2000, the following points have to be kept in view:

i) With the use of the present somewhat labor-intensive technologies, would agriculture produce enough to support nearly double the present population?

ii) Since the proportion of urban populations are projected to increase from 23%, 22% and 59% in 1973 to 38%, 35% and 75% in 2000 for Africa, the Far East and Latin America, the food production system would have to generate larger surplus for the people in the urban areas than is generated today.

iii) What are the limitations of subsistence level farming, which is mainly rain-fed agriculture and often subject to significant loss due to crop diseases, and farming with minimal external inputs of fertilizers, irrigation, etc.? Is there a scope for the expansion of such farming to provide the additional food and generate the necessary surpluses? If not, what is the extent of inputs of external energy for fertilizer, for irrigation and for motive power?

The arable land which was cultivated in 1967 respresents 22, 78 and 12.6% of the potentially cultivable land in Africa, Far East and Latin America (Moira, 1976). In order to bring more land under cultivation an increasing amount of energy is likely to be required. In the Far East the choice of expanding arable land is limited and to obtain higher yield more fertilizers and irrigation would be required.

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Figure 7 shows the results of the trend projections of the energy required for fertilizers, farm machinery, irrigation and fertilizers, where along with energy required for running tractors and irrigation pumps, energy going into manufacturing them is also considered. This is carried out by the author from the basic information particularly provided by FAO (1977) and other sources.

It can be seen that, in 1972, 18% of world energy in agriculture was consumed by the developing countries. Their share will increase to 52% by 2000. This is logical even if not all the food required for the 4.6 billion people in the developing world is to be produced by them. The Far East, where 78% of arable land is already under cultivation and will have to support nearly 2 billion people from the same land, will alone require for its agriculture 18% of the total world energy into agriculture. Africa the Far East and Latin America consumed in agriculture 0.9%, 4.9% and 4.1% of the world energy in agriculture in 1972 and would require 2.3% and 18.6% and 8.9% energy by 2000. Thus the compound annual growth of energy in agriculture for the three regions respectively is 8%, 10% and 8%.

This analysis however does not include energy required for processing which can be significant as more and more food gets transported to the urban areas and subsistence level farming diminishes.

Figure : 7 Use of commercial energy for inputs to agricultural production in 1972 and projections for 1985 and 2000 in mtce

Region	Fertilizers			Farm Machinery			Irrigation			Pesticides			Total		
	1972	1985	2000	1972	1985	2000	1972	1985	2000	1972	1985	2000	1972	1985	2000
Total[5] Developed Countries	84.6	168.	375.	122.	157.	211.	4.9	6.0	8.1	4.45	5.08	6.35	216.	336.	601.
Developing Market Economies	20.0	68.4	286.	8.8	22.9	72.5	4.6	8.3	17.3	0.32	1.82	13.9	34.	101.	389.
Africa	1.3	3.8	13.8	1.0	2.5	7.4	.1	.2	.7	0.04	0.28	2.80	2.5	6.8	24.6
Latin America	5.2	16.7	58.2	5.0	11.9	32.9	0.4	0.9	2.4	0.18	0.47	1.49	10.9	29.3	95.0
Far East	10.5	36.6	163.7	1.0	2.8	9.4	2.0	3.4	6.2	0.05	0.79	19.78	13.6	43.6	199.
Near East	2.9	12.0	61.3	1.7	5.5	23.8	2.0	3.8	8.0	0.05	0.28	2.30	6.7	21.6	95.2
Asian Centrally Planned Economies	10.8	23.3	60.0	1.4	3.4	11.7	2.4	2.7	3.0	0.79	1.10	1.28	15.4	30.7	76.1
Total Developing Countries	30.8	91.7	345.5	10.1	26.5	84.2	7.0	11.0	20.0	1.10	2.92	15.17	49.4	132.2	465.[illegible]
World	115.4	259.8	720.8	132.6	183.4	295.3	12.	17.	29.	5.55	8.00	21.52	265.6	467.5	1066.3

Note: Figures for 1972 and projected estimates for 1985 have been taken from Chapter:4, State of Food and Agriculture, FAO, 1977. The approximate growth rate implied between them has been used to arrive at the projections for year 2000. These projections have been carried out for each of the inputs at an aggregated level but not component-wise. For details on technical inputs see J.Parikh [illegible].

iii) Required Expansion of the Transport Sector: The interdependence of urban and rural areas could be expected to increase when the percentage of urban population is projected to go up, from 23, 22 and 59% in 1973 to 38, 35 and 75% in 2000 for Africa, Far East and Latin America, respectively (UN demographic projection, 1975).

The transport sector would have to be expanded to ensure provision of at least some portion of fuels in the rural areas and food to the urban areas even to meet the basic needs. We need to consider only rural-urban transport that would be necessary for subsistence.

In addition to the requirements for maintaining subsistence level, increase transport could also be viewed as a key to development. Improved transportation network expands market for the products and the producer is no longer constrained by the demand in the local market. This brings a better price to the producer as also possibility to exploit economies of scale which provides incentive to produce more. Other benefits of urban-rural transportation could be also felt in education, health and welfare in the rural areas.

The questions examined are:

What are the constraints in expanding the transport sector? What is the contribution of unorganized activity? Is there a suppressed demand in this sector? What kind of growth rates should be expected in this sector?

In the following, we take a look at some of the facts in the transport sector.

The Contribution of Unorganized Activities

Passenger as well as freight transport would grow at a very rapid rate as there is a considerable suppressed demand in the transport sector at present where lack of vehicles and roads and of communication in general has hindered the process of development.

In the Far East, transport carried out by bullock carts, push-carts, wheel barrows, bicycles, draft animals, and simply by walking long distances carrying head-loads is significant and of comparable magnitude to the transport carried out by modern vehicles. In India, 13 million bullock carts represent an investment comparable to that in modern vehicles.

In Africa, there is not much of a tradition of transport with bullock carts and rural transport depends on animals and people, or at the other extreme on modern vehicles. Thus in Africa's case, the suppressed demand for transport is likely to be higher as the carts are not there to carry some of the burden of the transport sector. In Latin America, the use of animals for transport is only to a small extent and already the percentage of urban population is very high. Therefore, the growth rates would be due to higher income and not as much due to suppressed demand.

Expected growth of Transport Sector

Unfortunately, information regarding rural-urban transport can be only inferred from railway passenger and ton kilometers and number of commercial vehicles assuming that in principle the rural areas could also partially use these modes for urban-rural transport.

Typically the growth rates for the railway transport range from 5 to 7% for those countries where the railways are kept up. The growth rates of commercial vehicles range from 3% to 10% for those countries which have efficient railways systems and 5-17% for those where they do not. For the reasons mentioned before, in principle, the growth in future should be higher or at least the same as in the past and in the specific case of the urban-rural transport should be higher than in the past. Thus the analysis of transport by railways and commercial vehicles could provide an indication about the expected growth rates of the rural-urban transport. But in reality, in view of the price rise in oil, if even these past growth rates cannot be maintained rural development world suffer.

iv) Rural Industrial Sector: With the rise in non-agricultural population and efforts for rural development, spurt in rural industrial activities should be expected. The scope for generating rural income from a wide variety of small and medium scale of rural industries is quite significant. These industries could range from manufacturing soap, bricks, potteries, charcoal, metal products, leather and agro industrial products, all of which require inputs of energy. Of course, there are other industries which may not require energy, e.g. weaving, handicrafts, printing etc. Thus precise statements on the energy consumption in the rural industrial sector could be made only on assessing the resources, skills and demand for the products for each local environment. Estimates for individual industries are given in Appendix 1.

4. TECHNO-ECONOMIC ASPECT OF RURAL ENERGY OPTIONS FOR HEAT AND FUEL REQUIREMENTS.

It has already been pointed out that the fuel or heat requirements at present are more than 95% of the rural energy requirements. (although this may be 90% in the future) In this section, we discuss only two aspects of fuel or heat supply technologies, namely, technological potential and criteria for techno-economic assessment.

There area a number of technical reports, some of which are surveyed by T.Turner (1978) where attention is given to the detailed analysis of individual technologies and here repetition of such descriptions is avoided. Instead, the issues of technology assessment and the difficulties of embedding new technologies in the rural environment are focussed upon.

Assessment of the Potential:

The potential of a given supply option can be roughly assessed from some physical parameters and other relevant data. For example, how much energy available from bio-gas can be calculated from the waste available or firewood production from knowledge of the forest area and the productivity per unit area. These rough calculations are extremely important in assessing the importance of an option and should be a part of policy oriented activity. However, they are only a rough measure of the potential and must be followed by an exercise of assessment of institutional constraints, cost-benefit analysis and long-term sustainability to examine if the potential can be realised or is worth realising.

Techno-economic and other aspects:

It would be a mistake to do a general purpose universal, cost-benefit analysis of a technology, especially for decentralised technologies, because, by their very nature, the analysis has to depend upon the local environment. However, the issues that have to be looked into, new factors that ought to be considered, or the questions of different scales of technologies and some other relevant issues will be discussed. Examples for the specific countries are worked out and given in the Appendices 2 & 3. Acceptable ranges of technical parameters that determine the success of the technologies are given here. This is meant to assist a developing country to make their own policy after assessing the micro-level (or state or village level) conditions against these.

There are four major supply options for fuel requirements, analysis of which should give guidance in the planning or rural energy supply for fuel or heat.

4.1 Transport of fossil fuels to Rural Areas.

This has been the major mode and the only one which planners have tried so far with little or at most moderate success. When the population is high (2000 and above), the demand is high and the distance from the major centres is not much this mode may still be preferable for sometime to come inspite of the price rise in oil in 1973 and moderate increase over that price.

In fact, the decentralised options that we are about to discuss would be compared against this alternative and would be recommended only if they are superior compared to this alternative.

Potential of the fossil fuel option depends on the fossil fuel resources/reserves of the country or its ability to purchase it by earning foreign exchange by other means by exporting other primary products or skills (e.g. Japan).

4.2 Bio-Gas Generation:

Cattle population is an integral part of the rural environment. Apart from the dung available from the cattle, there is considerable organic waste available in rural areas, such as agricultural waste and constitutes a renewable resources that is locally available and can be used for fuel.

Potential of Bio-Gas Plants.

It is possible to have a rough indication of the potential of bio-gas technology by assessing the amount of waste available. Taking only the country-wise cattle population and assuming all the cattle to be in the rural areas, the number of cattle per rural person is taken to be the indicator of available waste. Since it takes 3 to 5 animals to run a bio-gas plant for a family of 5 to 6, 0.5 cattle per person should be adequate to provide energy for subsistence and fertilizers. (This figure is taken to be low since there may be other animals besides cattle.)

Fig. 8 indicates which countries could hope to achieve subsistence level requirements entirely from bio-gas plants and which countried could obtain only partial requirements. Bio-gas could also utilise waste from piggeries, chickeneries and human waste. But since cattle censuses are available and they provide more dung per animal, only cattle population is considered.

Figure 8. Histogram of the number of cattle* per rural population in the developing countries.

>0.2	>0.3	>0.4	>0.5	>0.6	>0.7	>0.8	>0.9
							Colombia
							Chile
							Brazil
							Mexico
							Cuba
Sri Lanka	Democratic Kampuchea				Ecuador		United Rep. Tanzania
Pakistan	Upper Volta	India			Bolivia		Sudan
Afghanistan	Mozambique	Burma	Nepal		Mali		Rhodesia
Tunisia	Morocco	Bangladesh	Guatemala		Kenya		Madagascar
Nigeria	United Rep. Cameroon	Iraq	Uganda	Peru	Angola		Ethiopia

Only partial rural energy requirements for subsistence could be provided. (>0.2 to >0.4) | More than subsistence level rural requirements could be provided. (>0.5 to >0.9)

* The number of cattle per rural population (If buffaloes and oxen are included, then some countries move on the other side; for example India.)

Although the absolute number of cattle in the Far East is quite large ,in per capita terms, it is larger in the countries of Africa and Latin America. In Latin America, the percentage of the rural population is only 40% as compared to 80% in the other two. Therefore, the number of cattle per rural person is high.

Recently, bio-digestibility of water hyacinths, algae, etc. are also being tested, but in view of the land and water constraints in the developing countries it may have little relevance unless they are grown in sewage or salty water.

Having estimated such country-wise potential, we turn to a detailed analysis of economic and organisational factors in promoting bio-gas.

Economic Analysis of Bio-Gas Plants:

There is a considerable debate surrounding this subject and estimates of benefits very widely depending on the assumptions made, particularly about the assumed use of waste cost of plants etc.

There are three different assumptions made about the use of dung before the construction of the bio-gas plant and the additional benefits are viewed against these assumed uses.

- The waste is already used as fuel, therefore the additional benefits of bio-gas plants could be only additional fertilizers and availability of more energy in an efficient form.
- The dung is utilized as manure; then the additional benefits could only be availability of fuel and the additional nitrogen, if any, due to more efficient and effective fermentation in the bio-gas plant.
- The waste is not utilized at all; here the benefits are of course twofold, namely the fuel and fertilizer obtained.

Health benefits are of course to be considered in all the three cases but they are not easily quantifiable in economic terms. Convenience of a fuel that can be turned on and off or one that is versatile enough to be utilized for fuel, lighting, or electricity is also not quantifiable in the absence of a market for such fuels in rural areas.

Those who make the last assumption of course come out with substantial benefits, especially if its is assumed that the alternatives would be to provide chemical fertilizers and commercial energy. Since at least one of the requirements come from the dung itself (for cooking only, not for lighting), it would not be proper to assume this particularly in the case of the Far East, where the dung is already used for one of the purposes. However, this assumption is not incorrect for the countries where dung is only used occasionally (Africa and Latin America). A detailed treatment of cost-benefit analysis using all the three assumptions is worked for India in the case of a family plant in Appendix 2.

<u>Techno-economic and other Parameters</u>.

In the following the technical and other parameters which determine various schemes are summarized to provide a quick check list.

i) <u>Ratio of Cattle Population</u>. For bio-gas to be a viable option for the entire village, 0.5 cattle per person would be required. Alternatively, the organic waste availability should 1 to 2 Kg. per capita per day to meet cooking and lighting requirements. Note that the cattle dung contains more volatile matter than most other wastes.

ii) Temperature ranges: The desirable range is 15^{0} to $40^{0}C$ for adequate yield of gas.

iii) Cost of the bic-gas: The cost of the family plant should not exceed $ 250 for a $2m^3$ plant assuming the availability of free labour to maintain the plant. Alternatively, the combination of all the costs, capital, labour, maintenance for any plant, village or family size, should be such that it should compete with transported coal or kerosene to the villages. The cost then works out to be 5 ¢ $/m^3$ assuming kerosene price 14 Cents per litre

iv) Agrarian Society: If the need for fertilizers is also present along with the need for fuels, then the chances of the acceptance are higher (as compared to that in the nomadic or pastoral society). It also helps if the tradition for using dung exists.

v) Other Alternatives: If the village has other alternatives for fuel such as using coal dust or wood, charcoal etc. then there may be less enthusiasm for putting in efforts and investments. However, the number of developing countries with very little scope for other alternatives is rather large.

vi) Village Plants: The chances of success of a village bio-gas plant is higher for those villages having houses in clusters rather than scattered over long distances and if a village administration structure such.as "Panchayat" in India or equivalent exists.

vii) Size of the Village: Since it is possible to run bio-gas on human waste and its bigger version could be a municipal sewage plant for urban areas as well, there is no practical limit on the size of the village but then the energy provided would not be sufficient for all the needs and supplementary fuels would be required.

It is being argued by Makhijani (1976) and others that bio-gas ought to be regarded as an option for electricity generation, but this is questionable on the following grounds:

(a) Economics of this proposition is little understood. (one estimate indicated by T.Turner $ 2.25/kwh)

(b) The organic waste available in a village is not sufficient to meet cooking, lighting and pumping requirements. If some big cattle owners were to set up his own plant for pumping too, it will only worsen problem of equity if because some others would not get enough of even cokking fuel, which is a basic need.

Thus bio-gas generation could provide almost 90% of the energy if need for the household sector in the rural areas in some countries if cattle to rural population is favourable and provide partial requirements for fertilizers as well.

4.3 Energy from Wood and Techno-economic Aspects:

The most important scurce of the rural energy today is fuel-wood. It could continue to be important in meeting the energy demand if its renewability could be assured by careful planning. However, so far in competition with other land uses, the extent of forests has been reducing and a point has been reached where wreckless clearing has taken its environmental toll as discussed earlier. This therefore must not continue and to prevent soil erosion to curb floods and famine and to preserve wild life as well as providing an energy crop, efforts for growing wood must soon begin.

The assured supply of wood will require investment and management in future. In evaluating the potential productivity of different ecosystems should be considered.

The supply of wood could be obtained from wood plantation and management schemes for refining natural forests. These two management options are not necessarily competing with each other but are rather required under different circumstances.

4.3.1 Wood Plantation:

In order that the wood is available near the populated areas, a different management may be required to ensure supply especially from woodlands, fallow land, or treelands existing near the rural areas. In the scheme of wood plantation, the land is divided into several plots and sowing and harvesting on these plots of land is done successively such that each year the demand is met by harvesting one plot. The number of plots required depends upon a crop rotation cycle that varies from 4 to 7 years. In the initial stage land is acquired progressively. The total land requirements depends upon the demand for wood, expected growth of wood and the selected crop-rotation cycle.

The important technical and other parameters defining success of the wood plantation schemes are summarized below:

i) Yield per hactare: This is the most crucial parameter in making this alternative cost effective as shown by the sensitivity analysis carried out in the World Bank / IIASA report by J. Parikh (1978a). The acceptable range should be 25 to 50 m3 of increment per hactare per year.

ii) Crop Rotation Cycle: The preferred range for crop rotation period (the years after which wood is ready for harvesting) should be 4 to 8 years. If it is 8 or more years, the yield should be very high (50 to 60m^3/ha) and the land rent should be low.

iii) Land Rent: The rent of the land per year should not exceed $ 150/ha, if the discount rate is 10% and wood is to compete with other fuels (Kerosene at 14 Cents/litre)

iv) Labour Wage Rate: If the labour wage rate is more than $ 2 per day for unskilled labour, this scheme may be uneconomical since it is labour intensive and appropriate for village scale in the developing countries, as illustrated in detail in Appendix 3 for E.Africa. (Developed countries also talk about this scheme but on a very large scale and high capital in mechanization).

v) Cost of harvested wood: Some flexibility in the above mentioned parameters is permitted as long as the cost per m^3/ or wood in the final analysis is in the range of $4 to 10/$m^3$. In that case, the charcoal made out of this wood can roughly compete with transported fosil fuels to the rural areas.

vi) Land requirements: The land requirement per capita is 1/3 to 1/5 of hactare, if the annual wood requirement is 1 m^3/person for 8 year rotation cycle for the yield of 25 to 40 m^3/ha. Thus a village of 500 persons would require 70 to 100 hactares of land for energy requirements of cooking and rural industries (potteries, brick making). Thus, for a large village of population above 2000 persons, the required land may not be available for countries with high population density.

4.3.2 Refining and Enrichment of Natural Forests:

Although some recommend clearing even natural forests to set up plantations, under certain circumstances it may be better to use the natural forests directly to obtain the wood. The refining of natural forests could be done by selective removal of the trees and vegetation not wanted for timber, for use as fuel-wood. The natural forests have a much lower yield (2 to $8m^3$/ha) and the advantages over the plantation scheme could be significant only when:

- the cost of plantation land is high and the cost of clearing is high;
- mixed forests are to be preserved to save the wide varieties of genetic species of flora to reduce damage to the environment. The disturbance to wild life by human interference cannot be avoided and the impacts have to be considered and weighed before initiating such schemes;
- other such as timber, chemicals and fibres are also to be obtained.

It should be noted that refining of natural forests could only be successful in the equatorial or tropical rain forests where the natural yields are high. (Earl D., 1975).

In order reduce transportation and storage costs, wood may be converted to charcoal for transporting over long distances at the ratio 4:1 (4 t of wood = 1 t of charcoal) with an energy ratio of 2:4. The tradition of making charcoal is available in the rural areas, and the whole operation, being labour intensive, and able to employ the very people who are currently deriving income from the wood trade could make this a successful scheme.

4.4 Solar Applications

Even if no substantial contribution could be expected before 1985 or 1990 from solar energy applications, it may be one of the important energy sources in future, transition to which may be necessary for countries with no fossil fuel resources. A discussion is required on this option if only to keep it in view when changing energy policy in future. The comparatively higher intensity of solar radiation in most of the developing countries given an advantage of a factor of 1.5 to 2 compared to some of the developed countries, in the exploitation of solar energy. However, this in itself may not mean very much and detailed analysis is necessary.

4.4.1 Technoeconomic Considerations.

i) Solar radiation: Preferable annual average range is 500 cal/cm^2 per day. However, the frequency of cloudy days, regions with shadow (due to mountains or otherwise) and nature of demand, all have to be analysed together with the average figure.

ii) Solar Thermal Applications: (a) Low temperature solar devices for heat requirements below 100° C such as hot water, space heating and cooling are cost effective today provided they are required for more than 3 months a year: (b) High temperature devices: for temperature above 100°C and below 300°C for which concentrating devices are preferable, would be cost effective particularly if they are required for daily (non-seasonal) use. These include solar cookers, water distillators and solar pumps for drinking water.

iii) Load Factors: It is unlikely that any solar devices would be cost effective, if they are required for only short duration or seasonal purposes i.e. for a couple of months in a year or less, due to their high capital costs. In all such cases oil based equipments (heat pumps, diesel pumps etc.) are likely to be cheaper even if oil prices were to double compared to their present values, because the oil required over a small period is not much and could be easily purchased from the interest on capital requirements of solar equipment. J.Parikh (1977) has demonstrated this in detail in the case of the solar pump for irrigation purposes which is a seasonal use having 10% to 20% annual load factor.

iv) Solar mechanical or electrical applications:

For the current and projected prices of solar collectors or photovoltaics, it is unlikely that these can contribute significantly to the rural energy supply in the developing countries as the technology is not based on self help concept and the already small rural earnings will go out of the rural areas for purchasing them.

v) Land Constraints: Since solar energy could be harvested only to the extent of few watts/m^2 the land required for a higher intensity use, such as industrial purposes or electricity generation, could be quite significant and perhaps prohibitive, for highly populated developing countries.

While discussing this it is worthwile to discuss one application Solar Cooker, in detail as is done as an example below:

4.4.2 Solar Cookers:

In view of the fact that a major part of energy use in the rural areas of many countries is for cooking (more than 70% for low income group countries as shown by our analysis on energy for subsistence), solar cookers are the single most important application which, if used by all, could alone take care of a major burden on the forests or fossil fuels resources in the developing countries.

Assuming that a family uses 2 kg of coal for one meal, 10.7 tons of coal could be saved during the 15 year lifetime of a solar cooker. Assuming 10% discount rate and $ 15 per ton of coal delivered in the rural areas, the break-even cost of a delivered solar cooker is nearly $ 90.

The conservative estimate presented here considers only one cooked meal and no rise in real terms in the cost of fuel and availability at a subsidized rate, the present international selling price being $ 40 per ton.

The solar cooker could be made available today at this price but the improvements desired are as following:

- the possibility of using the cooker within the home;
- the availability of controllable heat;
- convenience of use and installing a cooker due to limited availability of space.

But this does not require a major scientific break-through and could be developed if high priority is given to technological research. However, several designs should be tried out to suit different traditions, social customs and eating habits in co-operation with the people who are likely to use it.

. THE ROLE OF ELECTRICAL ENERGY

The fuel requirements have been almost 98% of the total rural energy requirements so far and would continue to be important. Yet electricity provides a high grade energy which is a superior form of energy in many respects. For example, for such specific functions as high temperature furnace, applying strong heat at certain points (welding), lighting, television, strong motive power required for drawing water from depth, grinding, crushing etc. Thus provision of electricity could give rise to new types of activities which otherwise may not be possible and can not always be substituted by other energy forms.

Such a superior form of energy which requires investment, planning and effort, may not be required for all the end-uses and its indiscriminate use is not recommended Yet electricity has a definite place in the program of rural development where rural electrification could help in the following:

1) Open up new activities which may be economically productive
2) Increase in welfare, and in particular improve education and health.
3) Advance Family Planning by reducing long dark hours providing other activities and through educational programs

4) Helping rural skills to stay in the rural areas by providing better opportunities and thereby reducing rural-urban migration by improving rural environment.

The main difficulty in rapidly expanding rural electrification arises from the fact that large capital requirements and low load factor in rural areas makes it financially uneconomical. Typically in the developing countries urban load factor is around 0.50 and the rural load factor varies from 0.10 to 0.25. However, the load factor could only gradually build up with the intesification of agricultural and industrial activities. Thus one would expect that rural electrification should give a spurt to rural development. This seems to be borne out by a number of studies for the agricultural sector made in recent years in India as reported in the report of the National Commission on Agriculture (1977).

(i) The Programme Evaluation Organisation (PEO) of the Planning Commission made a study in 1961-65 of 2,460 households which included existing and prospective consumers in 210 villages covering 36 districts in 15 States. All the villages covered by this study were electrified before March 31, 1959. The study revealed that as a result of the installation of electric pumps on existing and new wells, irrigated area increased by 67 per cent for khariff crops and 65 per cent for rabi crops. The irrigated area per farmer increased from 2.43 hectares to 3.91 hectares. New crops were introduced and the intensity of irrigation increased substantially.

(ii) The Indian Institute of Management, Ahmedabad, conducted a study of the economics of rural electrification in Gujarat. This showed that after electrification the average irrigated area per farmer had increased to 5.02 hectares from 2.08 hectares before electrification.

(iii) The National Council of Applied Economic Research (NCAER) made a study of the impact of rural electrification in Punjab and another on the economics of rural electrification in Kerala. The Punjab study showed that in the sample area there was an increase of 3.09 hectares in irrigated area per farmer due to electricity driven pump sets and tubewells and that the farmer saved in labour 354 bullock-days per crop year. The Kerala study revealed a substantial change in the cropping pattern in favour of rice crop.

(iv) A study undertaken as a research project in Tamil Nadu showed that after electrification the area under irrigation had increased by 36 per cent and the value of the crops produced had doubled.

Although, part of this could have been achieved from diesel pumps, the fact cannot be neglected that electricity is a convenient form of energy and that electrical equipment are in general cheaper than comparable equipment using other energy forms. Moreover, electricity makes it much easier for individuals to start small industrial and other non-agricultural enterprises of various nature. It opens up the possibility of self help. Thus inspite of its financial costs, most developing countries consider rural electrification a desirable objective and a necessary precondition for development.

However, the need to cut down costs in providing electricity through appropriate strategy and techniques cannot be overstressed.

5.1 Electricity requirements and their growth:

Unfortunately, there is no magic formula for establishing even norms for rural electricity requirements. Much depends on the i) potential for industrialization and agriculture ii) the size of population and income distribution iii) credit facilities for setting up enterprizes iv) available natural resources and skills in the rural areas being considered for rural electrification and v) other similar factors. Typical electricity consumption for various industries and agro-industries are indicated in Appendix 1. In the following a summary of this aspect from various studies on rural electrification in India, Tanzania and Kenya and by World Bank (1975) is presented.

Once the decision in favour of rural electrification is made, the next step is to increase the load factor (which is generally 5% to 15% in the initial stages) so that the capital invested in rural electrification is recovered from the revenues obtained.

However, various studies commissioned by the rural electrification corporation of the Government of India indicate that the load factor does not improve much for the first 5 years and in the subsequent years it grows in a step-wise manner. In the initial stages, the demand grows in the agricul-

agricultural and domestic sectors. The growth in rural industrial sector however, takes time and depends on the availability of credit facilities, extension workers (from whom ideas concerning the use of electricity and training could be expected) and other intrastructure. Setting up of the agro-industries usually precedes that of other small scale industries. Thus, only when one analyzes the villages which have been electrified for more than a decade that one sees the growth of industries. Therefore, concern for lack of industrialization is the electrified rural areas should be viewed in this light and the required gestation period should be appropriately considered.

Thus, assessment of demand based on population and a norm of so many kwh per person is too simplistic and may lead to overstimation. The demand for electricity connections have to be estimated from income distributions and the nature of activities that may come up in the cluster of villages.

Having assessed the demand, the choice of electricity generation and its likely costs per kwh could be determined as discussed in the following section.

5.2 Choices in Electricity Generation

The important available choices which can help in cutting costs of rural electricity generation are as follows:

5.2.1 Local Generation through diesel stations or Grid Connection

The choice between local generation of electricity or connection to a grid supply depends upon the distance from the existing grid, the expected load and the costs of local generation with diesel based motor - generator set.

A World Bank Report (1975) shows that in the rural areas, the capital costs of supplies from the grid are much higher than those of autogeneration, but the fuel, operation, and maintenance costs are much less. This is unlike large scale power plants ranging from 100 to 3000 kw where the capital costs as well as operational costs per kilowatt are less compared to a small plant. When the utilization of the plant is high, this strongly favors the more capital-intensive and less fuel-intensive investment in supplies from the grid.

Figure 9 shows the average costs of different schemes. Supplies from the grid are shown to be profitable compared to autogeneration for load factors of 25% and above and for short distances of 4 to 20 km from the main grid (World Bank, 1975).

Figure 9. Average Costs of Different Schemes (cents per kwh) For a 50 Kilowatt project

Load factor (%)	Supplies from Grid		
	4 kilometers	29 kilometers	Autogeneration
10	18	40	21
25	7	17	12
50	4	8	9

However, the critical distance varies depending upon local conditions. A comparison made for Kenyan conditions, indicates that for the particulars conditions considered, it appears that the breakeven point is 45.1 Kilometres in the case of a centre using 200000 kwh per annum, 63.5 Kilometer in the case of a consumption of 500000 Kwh per annum and 95.1 Kilometer in the case of a consumption of 1,000,000 Kwh per annum.

These results indicate the importance of the size of the demand, the local conditions and costs in deciding the breakeven distance. The expected load would depend on the activity and the density of population of the rural area.

5.2.2 Other Choices for Local Generation

The costs of local generation may be substantially reduced if local conditions are favourable for exploiting local resources. Of the technologies available or likely to be available in near future. For electricity generation two alternatives seem to be of particular relevance: (i) Small hydro generation and (ii) Wind generation.

Small Hydro Schemes

The rural areas could make use of small hydro potential which could be tapped from a nearby water resource with a fall of 10 to 20 meters. If natural fall is not available, in appropriate locations it could be artificially created providing employment to local labor.

Small reservoirs or earthen dams could be used to generate electricity with the help of small turbines. The estimate of such potential would have to be made on a micro level, regionwise or even district and village-wise.

For example, since 1966, China has 60,000 small hydro-power stations distributed through 1,000 hilly areas. The total generating capacity from small schemes is about 3000 MW. It increases annually by 400 to 500 MW. The stations are in the 40-250 kw range operating often on heads of less than 10 meters (E. El-Hinnawi, 1977). There are numerous hydro-power schemes consisting of a number of reservoirs and a small hydro-power station (5 to 53 stations).

Windmills

Windmills is yet another possibility for electricity generation. However, the energy demand for motive force (mechanical energy) ought to receive priority to reduce conversion and distribution and storage which are associated with electricity. A detailed account of different designs of the windmills appropriate for developing countries is given in the U.N. series on energy resources (ESCAP region, 1976). It mentions that village craft of making wooden mills with cloth or jute sails which existed a few decades ago in countries like Greece etc. needs to be revived so as to reduce the costs and to employ local labor.

The windmills are especially suited in the coastal and mountainous zones. The wind velocities required are in the range of 8 to 25 km/hr for mechanical energy for pumping and 15 to 40 km/hr for electricity production. The Cretan windmills start pumping at a wind velocity of 8 km/hr and reach optimum performance of 25 rev/min at 13 km/hr. The wind pump will increase speed up to about 40 rev/min in higher winds before it controls itself through excessive tip drag and sail fluttering, although the sails are usually reefed at speeds above 25 rev/min. Lifting water as much as 5 m, this type of windmill pumps 3,000 liters per hour, 10.12 hours per day, 4-5 months per year, and has an expected lifetime of about 20 years.

Each wind pumping system costs about US $ 480 (windmill US $ 320, storage tank US $ 120, pump US $ 40). The cost of water pumped is approcimately one US cent per m^3.

However, several studies have indicated that the potential for wind in Africa, India etc. is not significant (Economic Commission of Africa, 1976, A.K.N. Reddy, 1977).

A careful study that analyzes month by month wind velocities for 13 stations in various parts of Indonesia - a country with many islands concludes : ... "while the costs of transmitted power is 3 to 4 US cents/kwh, locally manufactured propeller type windmills may produce electricity at 15 US cents/kwh" (Djojodihardjo, H., 1976).

Thus the wind energy could be considered only a location specific resource for mechanical drive and electrical energy.

Bio-gas and solar are not considered as available choices. Bio-gas is better used as a source of domestic energy and not enough of it is likely to be available for electricity generation after these needs are met. Solar electric technology that can be operated at a village level and which is economical is not likely to be available for a number of years.

5.3 Other Suggestions For Reducing Costs

Choice of level of Reliability and Staggering

If the level of reliability can be lowered, then a number of cost-cutting choices become available in both generation and distributions. If load staggering is permitted, then a smaller generating unit may serve the purpose. In a rural enviornment such staggering may be possible to enforce. Also seasonal loads such as peak season irrigation requirement may be met by denying power at such critical times to other users who may have a lower priority.

Single Wire Distribution

Single-Wire Earth Return System can be adopted to reduce cost of rural distribution lines. In this system only one wire is provided instead of the 3 wires in a three phase line. Earth is used to provide the return path. Such a system, though not free of some technical problems, can offer substantial reduction in distribution costs and may be considered for the remote areas.

Network Lay-out Design:

The expansion plan of an electrical grid for rural electrification network should be prepared with a long term perspective on the development of electrification in the area. Keeping in mind the sequences of the villages to be electrified in the particular order which may be more economical. When designed with such a long range perspective, the resulting transmission network would be significantly less costly than if the expansion of the system were to be on an ad hoc basis. Only in former situation it becomes possible to consider alternative network configuration and select an optimal one.

It may also be desirable to consider clusters of villages or a rural region for electrification. Once the transmission line is laid to connect one village, the costs of extending supply to nearby villages may be only marginal.

Standardisation

In setting up transmission lines as well as in a number of isolated local generators, the role of standardization in costs reducing is important. It greatly facilitates maintenance and training of the operating and maintenance staff. Availability of trained staff can be a serious bottleneck in utilizing the investments in many developing countries.

An international agency such as UNIDO can play a useful role in promoting such standardization which is many times hampered by the fact that a particular country may get aid for rural electrification from many developed countries each with its own set of standards. The aid receiving country can then get stuck with a variety and a multiplicity of equipment which becomes extremely difficult and expensive to maintain as both the inventory size and also the skills of maintenance required increase.

6. TECHNOLOGY MANAGEMENT

The survey by T.Turner (1978) of the literature available on rural energy points to the fact that most of it concentrates on technical and economic matters and very little on software issues such as policy, management and administration which is the backbone which supports introduction of technology.

In this section, issues such as transfer of technology in the rural environment, the necessary organisational framework and the need for maintenance, standardisation etc. through a proper administrative framework are discussed.

6.1 Issues Concerning Transfer of Technology:

Here by "Technology transfer" we mean all aspects of technology transfer to the rural environment i.e. from planning, introduction and maintenance. It has to be recognised that the rural users cannot run an experimental energy system. Due weight has to be given to the perfection of the technology and the development of institutions which are required, such as establishments which look after the user's problems. The rural user's viewpoint could be classified into two categories; techno-economic and social or relating to the operating environment in which the technology has to be used. In general, the following points need to be considered.

(i) Private and Social Costs and Benefits:

The benefits, savings etc. are often calculated on national, state or village levels and not for the rural consumer who is going to use it. Though benefits at the national level, such as saving of foreign exchange, curbing environmental degradation, overall health effects etc., are important, they are meaningful only if the new technology is acceptable to the user. If the user does not benefit, yet technology needs to be promoted for national or social benefits, the individual user has to be compensated if he is to be induced to use it. This requires a national policy action where subsidy, financing facilities, tax rates, etc. have to be introduced to promote better technology.

Thus, the cost-benefit analysis should be done also from the user's point of view along with the analysis from the social viewpoint. One then identifies the loss, if any, that the user has to incur and to what extent the government might subsidize him judging from the indirect costs the society has to bear if the new technology is not promoted.

(ii) Comparison with other alternatives:

The economic benefits to the user should be calculated keeping in mind the best possible alternatives that a user has. For example, if the advantages of bio-gas plants are calculated by taking kerosene or even coal as the alternative, they would look substantial. But actually the comparison has to be made with the cheapest possible alternative, i.e. burning dung and purchasing fertilizers, if at all he needs it. Of course, the fringe benefits and conveniences and nuisances of both the alternatives should be weighed appropriately. Only then one understands why certain innovations are not catching on. In addition, possible future developments in the existing alternatives should also be considered (e.g. rising cost of fossil fuels).

(iii) <u>Scale of Technology:</u>

Some technologies may turn out to be inappropriate - economically or managementwise - if the proper scale is not chosen. For example, in some situations many small solar pumps may be more expensive than a large pumping station. Yet the small pumps may be preferable when the management problems associated with the different scales are considered. Again, giving an example of bio-gas technology that a village bio-gas plant may be more economical and socially desirable than family bio-gas plants. (Parikh J and Parikh K, 1977).

(iv) <u>Introduction of Technology:</u>

The manner in which a technology is introduced determines its success. Quite often adversely affected or less beneficiary groups may offer resistance. For example, if wood plantation schemes are introduced, legal measures for land use, employment for those who make living, gathering wood etc. have to be dealt with. Besides, at the planning stage itself, problems of co-operation, maintenance and repairs should be foreseen.

(v) <u>Compatibility with the environment:</u>

If an invention requires a change in lifestyle or is in conflict with the surroundings, it will face difficulties in its adoption. In such a case, the strength of the existing establishment of older technology should be carefully assessed and whether or not the society is ready for the change should be considered.

(vi) Acceptance of Technology:

An invention has to be appropriate for the kind of use for which it is meant. For example, as will be demonstrated la ter in this paper, there is a need to consider the manner in which a pump is presently utilized while designing a solar pump for agricultural purposes.

It is therefore, necesssry that a government with limited resources should evaluate new technologies carefully so that only appropriate ideas are encouraged. The development of inappropriate technology may waste precious manpower and limited research and development funds and also cause a loss in the credibility of new technologies in general.

6.2 Organizational Framework for Decentralized Systems

The decentralized systems have not caught on so far, simply because of a lack of an organizational framework supporting them. While appreciating the necessity of decentralized systems such as wood plantation, bio-gas, solar equipments, water turbines etc. it may be emphasised that there would be a need to institutionalize a construction and maintenance "apparatus" by creating appropriate organisations or enterprises. Isolated trials of technologies, even if successful, cannot bring about a major impact on the energy scene. Even if unskilled local labour is used as much as possible manufactured spare parts skills etc. would have to come from centralised organizations. UNIDO can play an important role in helping to set them up, first on an experimental basis. Such centralized organisations would build up expertise in coping with the technology under varying conditions and would avoid the mistakes made in other villages. They could also improve the techniques not only by learning but also by evaluating their performance and making the necessary changes in the designs, operation techniques etc. Apart from developing expertise, these organisations, which ought to be set up only after assessing the overall potential of a given technology, could also realize economy of scale by producing many units and build up the common infrastructure required which would be hard for each village to acquire.

For a large country such organisations may be even at a broad regional scale. These organisations should be self-supported although initially some subsidy may be given. In certain cases where such centralisation for energy schemes alone may not be possible for various reasons, it may be preferred to create rural technology centres (RTC) which deal with rural development and consider energy as an integral aspect of rural development. There is a need for redesigning traditional implements used by the rural population because the nature and scale of many activities have changed with time but not the implements used. On the other hand, there is a need to adapt modern implements imported in the villages so as to suit the rural requirements and life style. For example, tractors made in the developed countries are overdesigned to reduce manual operations and to operate on large farms where a simple equipment with a motor would do for these countries having small farms. These could provide technical know-how appropriate for the rural areas in the field of water, agriculture, handicrafts, energy, heat etc. Some countries where such extension centres exist already, their roles could be expanded or modified to look after rural energy schemes.

7. RECOMMENDATIONS:

Emerging recommendations from the study are summarized on which policy of the national government could be based.

(i) Statewise assessment of the present energy supply - commercial and non-commercial should be made and areas where severe shortage due to deforestation and otherwise are likely to take place should be identified as the priority areas where new energy technologies may be required.

(ii) Identification of the possibilities of economically productive activities and their locations should be made such that the rise in future energy demand in those places could be envisaged in time. If possible, their sectoral origin should be anticipated be it agriculture, transport, household or rural industries (such as pottery, brick and lime production, charcoal making, food processing, kiln based crafts (e.g. metal working) etc. The knowledge of sectoral origins could be used to assess the required fuel namely, oil, electricity, wood, charcoal, bio-gas or solar.

(iii) There would be a need for integrating non-commercial energy sources into organized energy sector by putting in investment and management efforts (such as bio-gas, wood plantation, solar etc.) thereby assuring the rural energy supply on a sustainable basis.

(iv) Initiation of rural energy supply schemes should be made after assessing their potential and necessary techno-economic parameters (as shown in detail for each technology in section 4). Following considerations enter while discussing priorities.

(a) Priority should be given to those schemes where the tradition of using those resources exist, e.g. dung in case of bio-gas, wood in the case of charcoal production from wood plantations etc.

(b) The land, resources and legislative requirements should be assessed for a given demand for various population densities.

(v) The likely demand for electricity should be assessed on the basis of the expected activities in the rural area under consideration for electrification. The choice of electricity supply from connection to grid or from local generation then may be made on the basis of the demand, resources, distance from existing grid and possibilities of decentralized systems such as mini hydel, wind wills etc. For efficiency and cost-reduction, staggering, standardization of equipment and optimal layout of electric network may be considered.

(vi) The problems of 'transfer of technology' into rural enviornment should be studied in pilot schemes in a variety of enviornments. Necessary organisational framework should be set up for introduction, promotion, extension work, maintenance and standardization such that sown seed of technology could grow and flower.

(vii) Co-operation among the developing countries of the same region could lead to efficient and economic energy systems in particular in sharing water for hydroschemes or setting up regional electrical grids, or sharing their experiences in setting up decentralized energy systems.

(viii) The co-operation of the developed countries in providing know-how and help in standardization of imported equipment for energy systems should be sought so that a developing country getting financial or technical help from several countries does not get burdened with a system which is difficult and expensive to maintain.

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Appendix 1

Input norms for energy uses in rural industries

Name of Industry	Consumption of electricity	Average Consumption of raw materials by units
Sugar Mill (Khandsari)	81,310 kwh/day	Sugar cane - 125 tons/day Sulphur - 10 tons/day Limestone - 20 tons/day Firewood - 25 tons/day Coal - 20 tons/day
Coffee Works	1 kwh/day	Coffee seed - 33 kgs/day
Rice Mill	32 kwh/day	Paddy - 40 Qtls/day
Flour Mill	36 kwh/day	Paddy - 24 Qtls/day (Grease/lubricants-1.5 kgs/month (Diesel oil - 550 litres/month (Mobile oil - 12 litres/month
Poultry Farm	47 kwh/day	Water - 1000 litres/day
Dairy Farm	50 kwh/day	- N.A. -
Sericulture Farm	1.1 kwh/day	Urea ½ kg per acre/year Ammonia 50 kgs/acre/year CAL - 50 kgs/acre/year
Textile Mill	95 kwh/day	Cotton 1,373 kgs./day Mobile oil - 0.56 litre/day Coal - 0.66 tons/day Boiler cumbustin oil - 6.58 litres/day
Wool carding	N.A.	Wool 1.64 kgs/day Diesel oil 1 litre/day Mobile oil 0.27 litre/day
	107 kwh/day	Wood - 79 cft/day Greece - 2 kgs/month Blades - 4 nos/month Crude oil - 29.17 litres/month Grinding stone - 1 no./month Mobile oil - 28.33 litres/month
Straw Board	N.A.	Waste paper - 1.7 tonnes/day
Press	3.02 kwh/day	Rs.1833.3/month service charges Mobile oil - 2 litres/month

contd.

Appendix 1 (contd.....)

Name of Industry	Consumption of electricity	Average consumption of raw materials by units
Tyre works	3.29 kwh/day	Rubber - 12.36 kgs/day Solution - 0.55 Firewood - 0.46 qtls/day Petrol - 1.[illegible] litres/day Water - 3,288 litres/day
Oil Mill	63.20 kwh/day	Groundnut - 2.96 tons/day Mobile oil - 0.96 litres/day
Painting	16 kwh/day	Paints - 1.67 litres/day Tarpentine 5 litres/month Tannery - 5 litres/month
Potteries	33.3 kwh/day	Water - 40 litres/day Greece 12 kgs/month Mobile oil - 30 litres/month Kerosene oil - 50 litres/month
Engineering works	30 kwh/day	Lubricant - 10 litres/month Transformer oil - 20 litres/month Welding rods - 200/month M.S.sheets - 3.2 tons/month
Iron & Steel Industries	10,411 kwh/day	B P & RC sheets - 1.67/month Furnace oil - 8.22 litres/day Raw Iron - 90.41 tons/day
Aluminium utensils	18.9 kwh/day	Aluminium - 133.33 kgs/day
Mechanical works	3.29 kwh/day	Rs. 1,500/month repair and service charges
Oil Refineries	N.A.	Castor seed - 10 m. tons/day

Source : Perspective plan for rural electrification in the Telegana region of Andhra Pradesh, India. Nation Council of Applied Economic Research, New Delhi, India.

Appendix 2

Economic Evaluation of family bio-gas plants:

A comparison of alternatives. An economic evaluation of a family sized bio-gas plant is given for each of the three conditions, under the condition of India. The Table summarizes the economics of the four alternatives for obtaining the same amount of fuels and fertilizers namely,

(A) set up a bio-gas plant, or

(B) use dung to burn and purchase fertilizers and kerosene for lighting), or

(C) use dung for manure and purchase additional dung and kersone to burn, or

(D) waste dung and purchase coal, kerosene and fertilizers.

The results for India indicate that for a person who uses dung for composting, the returns on investment in a bio-gas plant are higher under the existing price structure. It shows that the costs of obtaining the same amounts of fuel and fertilizers is $31 per year for bio-gas plants as opposed to $34.8 and $41.4 for the options where dung is either burnt or composted. In these calculations, the subsidy of $50 given by the Indian Government for setting up a plant is not taken into account.

It can be seen that under two different assumptions, only a few dollars can be gained per year from a bio-gas plant. The cost of dung is not assumed to be zero which is another reason why the gain does not seem so substantial.

If (A) is compared against (D), of course, the benefits are substantial. Besides, since the analysis is done from a viewpoint of a consumer, the national investments in mining and transporting coal and their opportunity costs are not considered. For those countries where there is no coal and oil has to be purchased in foreign exchange, the costs would be higher than that indicated in case (D).

Economic analysis of alternatives for a private owner of five animals (dry dung = 3.65 t/year).

Item	Alternatives (A)	(B)	(C)	(D)
1. Description of alternatives	Install a 1.8 m^3/day bio-gas plant and get fertilizer and gas for cooking and lighting	Utilize the dung for burning and purchase fertilizer and kerosene for lighting	Use dung for composting and purchase fuels and supplementary fertilizers	Do not use dung and purchase fertilizer, coal and kerosene
2. Investment (US $)	200	-	-	-
3. Interest depreciation and maintenance costs ($/year) a)	31	-	-	-
4. Bio-gas generated (m^3/year)	660	-	-	-
5. Effective heat obtained (10^6 kcal/yr)	1.905	1.296	-	
6. Fertilizer produced (kg N/year)	52.6	-	30	
7. Supplementary purchase: b)				
kerosene (kg/year)	-	25	25	25
dung cakes (t/year)	-	1.50	5.15	-
fertilizer (kg N/yr)	-	52.6	22.7	52.6
coal (t/yr)				3.3
8. Annual costs c)	31	34.8	41.4	76

a) Based on interest rate of 12%, life of plant of 15 years and cost of painting the drum of $5 per year.
(Annual capital charge) = (initial investment)/$\sum_{t=1}^{15} 1/(1.12)^{t-1}$

b) Based on:

(i)

	Calorific value	Efficiency of burning	Effective calorics
Dung	3100-3300 kcal/kg	11%	345-365 kcal/kg
Bio-gas	4770 kcal/m^3	60%	2860 kcal/m^3

(ii) Effective cooking energy needs amount to 1770×10^3 kcal/year and can be obtained from either 615 m^3 of bio-gas or 5.15 tons of dung cakes.

(iii) Either 25 kg of kerosene per year or 46 m^3 of bio-gas/year are required for lighting.

(iv) 1 kg of dung when composted gives 0.56 kg of compost with 1.5% nitrogen. Through a bio-gas plant it yields 0.72 kg of dry sludge with 2.0% nitrogen.

c) Based on prices of $0.12/kg of kerosene, $5.5/ton of dung cakes and $0.45/kg of nitrogen.

Coal delivered ($15/t)

Costs and Returns Estimates for Eucalyptus plantations (A) and Refining of Natural forest schemes (B) (East Africa)

Serial No. I	Years	Costs/Returns Costs per hectare	Scheme A ($) per year	Scheme B ($) per year
1.	1st year			
a)		Plantcosts (including tubing, fertilizers, insecticides and transport)	36.75	0
b)		Ground preparation	22.50	0
c)		Lining-out and pitting	18.75	0
d)		Planting costs	15.00	0
e)		Tending by clean hoeing	36.75	0
f)		Land costs	50.00	50.00
g)		Management costs	120.00	120.00
h)		Fencing costs	40.00	40.00
i)		Total establishment costs in 1st year	339.75	210.00
	2nd to 5th year			
j)		Annual Land costs	50.00	50.00
k)		Annual maintenance costs	3.00	3.00
l)		Annual management costs	8.00	8.00
		Total annual running costs between 2nd and 5th year	61.00	61.00
	6th (Final) year			
m)		Land costs	50.00	50.00
n)		Maintenance costs	3.00	3.00
o)		Management costs	16.00	16.00
p)		Harvesting & Hauling costs	33.75	67.50
		Total closing costs of the end of 6th year	102.75	136.50
	6th year	Returns:		
q)		If the yield rate is assumed to be 25 m^3/hectare/year, total returns at the end of 6th year = 6 x 25	150	150

NOTE:

1. For items a) to e) and also for the annual maintenance costs the data were taken from Appendix 2 of *"Forest Energy and Economic Development"* by D.E. Earl, where the figures were given in terms of the number of man-days. A wage rate of $0.75 per man-day was assumed.

2. Data for other important items were brought together from several sources, such as Central Bureau of Statistics, Kenya (1976).

3. Costs for management and fencing were estimated from reasonable considerations. For example, for management the figures assumed were: 60 man-days during the establishment period (i.e. roughly 1.5 hours a day), 4 man-days during the rearing period (i.e. around 1 hour once in 10 days) and 8 man-days during the closing period. The wage rate assumed for management costs is $2/man-day.

4. Though the above table shows annual land rental costs to be $50 and yield rate to be 25 m^3/ha, various land rents and yield rates have been investigated.

5. The cost data for the Far East are similar except for the land rent which should be around $50/ha. The wages for Latin America would be higher.

Regional summary of the various land availabilities and land requirements under the schemes A and B. (Refining natural forests) (wood plantation).

1973	Africa	Far East	Latin America
Total land/cap(ha)	6.1913	0.8469	6.9015
Arable land/cap(ha)	0.4729	0.2575	0.4206
Forest area/cap(ha)	1.4692	0.3038	3.1281
	Tropical	Dry zones	
Land required*(ha) per person (A)	0.04 to 0.07ha	0.08 to 0.20ha	0.02 to 0.05ha
Land required**(ha) per person (B)	0.20	0.33	0.14

*The ecosystems do not directly correspond to the geographical zones.-

**assuming annual productivity of 5,3,7m^3/ha respectively.

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