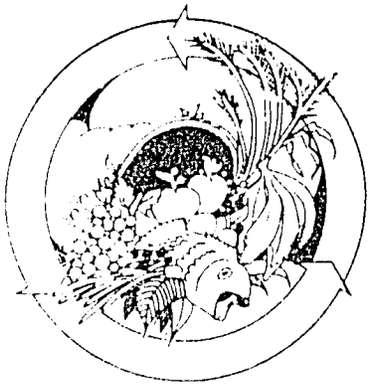

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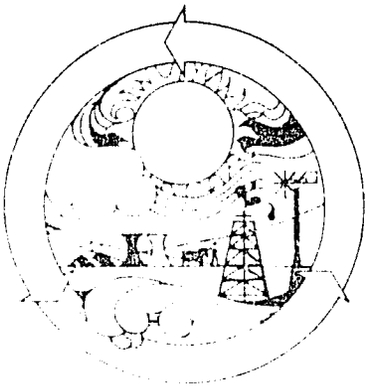

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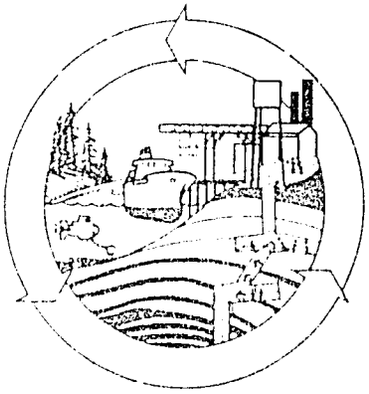

Energy for Rural Development
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ASSESSING ALTERNATIVE RESOURCES, TECHNOLOGIES, AND ORGANIZATIONAL MEANS FOR MEETING RURAL ENERGY NEEDS

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A preliminary report on research in progress as part of the inter-country Energy for Rural Development program, with support from the Agency for International Development

September 1980

PURPOSE AND AGENDA

The gift of energy is the source of human survival and growth. Given life, the energies of men and women sustain and shape their choices and creative powers. Sustenance, choice, and creativity--these are driving forces of the inter-country cooperative research program of which the current reports are a first result.

These forces have structured the Energy for Rural Development (ERD) program around aspects of social need and organization, renewable energy technologies, and rural policy opportunities by which rural areas and communities can renew the sources of energy with which they are endowed, making these resources more widely accessible as a basis for choice and productive use by the rural majority.

Rural energy's essentiality is its provision for life--food, light, water, heat, fiber, sanitation. Without adequate food and nutrition, made possible by appropriate uses of energy combined with adequate resources of land and water, human energies wither. Choice and creativity atrophy. Food deficiency is the ultimate entropy. Many express anxiety about the current status of rural energy--for its effect on human degradation and for poor sharing of resources as well as inefficient organization of their use.

Anxiety about the future of energy is also for its role in degradation of the environment, through depletion of forests and other vegetal cover, perceptible and invisible soil erosion, potential alterations in climate: "the slow smokeless burning of decay" (Frost, 1916). Are rural societies net consumers of nature's capital, or do cities and industry make the difference? Either way, can rural society reendow the future through resource renewal?

The excitement of renewable energy sources--perhaps especially for those of us who live in cities--is in their closeness to nature. Nature has moral and aesthetic appeal, and a quality of renewal that, through the life process, is the promise of the rural environment. Modern society's failure to value this quality properly, this capital-creating force, contributes to the present predicament. Choice and value must therefore be central themes of the inter-country program. Traditional societies' ways of valuing resources are still potential sources of insight for research toward new perspectives and methods of valuation and exchange. However, severe scarcity of energy and food resources, as revealed in preliminary ERD analyses, puts pressure on values and sharing. The research therefore seeks new principles and practices for the equitable sharing of rural energy resources, and new ways of inventing and organizing technologies for balanced use and renewal of those resources.

Plants, animals, and human beings are simultaneously producers, bearers, and transformers of energy. In the moment or lifetime of a healthy life process, energy need and resource are identical. A gap between need and resource sets in motion a series of problems. Gaps in energy balances and means of filling these gaps are an important focus of the research.

Rural citizens are the principal agents of purposeful energy transformations in farming, animal husbandry, and forestry. Choices by rural producers and consumers determine the productivity and social value of these transformations. A function of policy is to free and make space for effective local choise. Price-tax signals are one instrument for such choice. Equally important, and probably less understood, are development policies fostering rural organization for improved resource access and technological innovation.

Rural space has both freedom and frictions that set the stage for policy formation. The perspectives of rural groups on use of resources and environmental space can be important contributors to policy. These rural perspectives are sought in the ERD program, to shape policies for resource renewal, resource sharing, and new technologies that will enhance the lives of the rural majority, their choices, transformations and creativity.

Context

This report is the first of a series that will seek, at agreed intervals, to integrate the current findings of the inter-country Energy for Rural Development Program initiated at Chiang Mai, Thailand, in February 1980 (Resource Systems Institute and National Research Council of Thailand 1980a). It draws closely upon companion reports prepared at the same time, as cited, but is not an attempt to summarize these individual reports.

While the current series of reports is primarily the responsibility of the East-West Resource Systems Institute (RSI), they form part of and draw heavily upon the work of the inter-country ERD Program. Some sixty research and development institutions as well as ministries of energy, agriculture, rural development, science and technology, finance and planning, and human settlements in the eight participating countries have joined in planning and initiating the cooperating program, with the unifying objective: To gain information and understanding that help policy makers and implementers in the area of energy and rural development to promote improved quality of life, more equitable distribution of income and resources, and the generation of employment in rural areas.

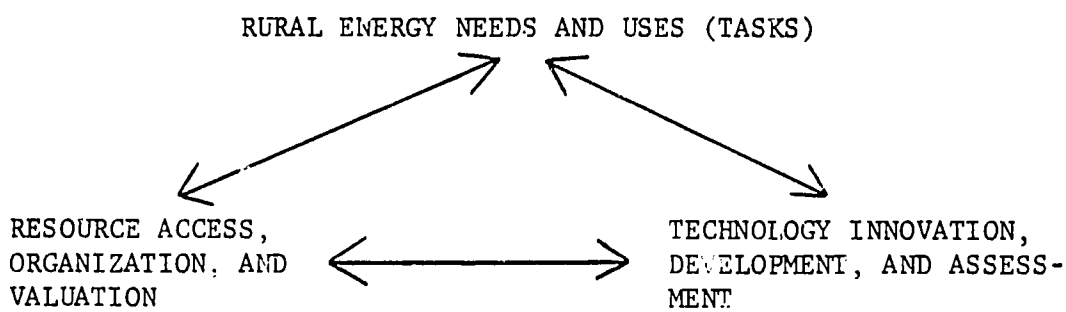
The most important research problem identified in the Program is to assess the energy needs of rural people in the context of energy resources in order to gain better understanding of policy and technology requirements for advancing rural development objectives. An iterative research process to clarify the relationship between rural energy programs and rural development objectives is underway. The research undertakes to account for the felt needs of rural people in both the formulation of rural development objectives and the planning and implementation of rural energy programs.

This series of research reports may therefore be seen as the product of an informal research group addressing and attempting to harmonize the varying organizational, policy, and technological dimensions that must combine

effectively if energy is to be shaped to meet human needs. Following this first period's reports, authored in large by RSI personnel and with important contributions by participants from cooperating countries, this series of research findings will increasingly reflect the joint research and authorship of cooperating institutions.

Structure of the Report

While seeking to obtain rural perspectives on energy, in its physical and social complexities, research must proceed by separating out these complexities into forms and terms that facilitate analysis and communication. The ERD program is designed to facilitate perception, information gathering, and synthesis along three principal problem dimensions:



These constitute the material elements of the ERD program, which seeks to understand the goals and perceptions of rural residents who experience energy needs; to discover new organizing modes for matching needs and resources; and to create or maintain policy environments, including price and investment instruments, that will foster rural choices and organizational steps toward more productive energy use.

The report examines the interwoven aspects of goals, organization, and policy on all three dimensions and in a variety of contexts.

ASSESSMENT OF RURAL ENERGY FELT NEEDS AND DEMAND

Energy needs as experienced and perceived by rural residents are the point of departure for the research implementation plan formulated by the inter-country workshop at Chiang Mai (NRC and RSI 1980a). The objective is to gain better knowledge of patterns of variation in rural energy uses, needs, and sources as a basis for guiding technological, organizational, and policy development. Orientation of the program to users' needs promises to correct the supply bias of many public programs (Paul 1980). The result should be information and products of practical use to rural decisionmakers, whether consumers or producers.

Evidence developed to date, though preliminary, reveals the following dimensions of need:

- food-fuel relationships and scarcity
- constraints of land and water
- sources of variation in energy use and availability
- user priorities and choice
- valuation, price and exchange

Findings on these aspects of need are highlighted below.

Scarcity of Energy and Food: Nutritional Effects

In two of the three regions intensively studied (Atje et al. 1980), large sections of the population experience serious food deficits. Against an estimated per capita cereal requirement in Nepal of 220 kg/yr, annual food grain consumption in the West of the village study area is 145 kg and in the North is 179 kg (Bajracharya, in Atje et al. 1980:3.32-3.35). One quarter of the surveyed households in the whole village panchayat consume less than 125 kg/yr per capita; in the North and the West, the proportion is one third. The proportion of millet and maize (the less preferred grains) in the diet, is 55 percent in the North. In this hill village the pressures from food shortages to expand agricultural land by clearing forest areas have a much greater influence on deforestation than those arising from use of fuelwood (Bajracharya 1980:3.51).

Gathering firewood in the Rinconada area of the Philippines is a rough indication of poverty, and may help somewhat to alleviate that poverty. Of 783 households interviewed, 69 percent gathered firewood, 25 bought firewood, and 6 percent did not use firewood. Households that gathered firewood have level-of-living scores below the mean for the sample. Those buying firewood have higher mean level-of-living scores, and those not using, significantly higher (Koppel, in Atje et al. 1980: 4.23). In this area, 60 percent of households are below a low poverty line of P2,400. Average incomes for this group range from P700 to P2,000 per household per year, making adequate access to basic needs very difficult. Analysis of persons-land ratios, palay (unmilled rice) yield, and tenure shares shows that palay available for consumption by most farm households is less than that required. A recent estimate is that 73 percent of preschool children in the Rinconada area are malnourished. Malnutrition is most severe among those under 30, with a strong concentration among nonfarmers who, in rural barangays (villages) include many unemployed and in the lowest income groups (Koppel, in Atje et al. 1980:4.10-4.15). Raising basic farm productivity and widening employment opportunities, requiring other forms of energy in larger amounts, appears to be prerequisite to raising of living standards to a level that might reduce

pressures on firewood.

Relative scarcities of fuel and food in different areas, interacting with quality of land and water supply, shape the choices open to small farmers. In semiarid zones of Rajasthan, India, overgrazing by cattle has contributed to soil erosion in recent years. High rainfall variability causes high uncertainty in respect to yields of field crops, principally sorghums. At recent levels of fuelwood and fodder demand, a shift from annual crops to woody legumes would result in improved benefit-cost returns to small farmers (Gupta and Mohan 1979).

Fuel-food competition is seen as perhaps the most significant and controversial policy research issue to emerge from case histories on biomass energy (Goodman et al. 1980). A series of arguments on both sides of this issue are presented, each depending on the complex set of variables existing in the particular regional or national setting (Goodman et al. 1980:). Fitting these arguments to particular sets of variables, shaped by local needs and resources, is a promising further line of research.

At the present stage of ERD research, evidence of energy constraints on agriculture has not yet been developed. However, food constraints on energy are observed, as reported above. This highlights the interdependency of rural energy and food systems for policy attention.

Land and water constraints

Underlying constraints of land, water, and environmental resources limit fuelwood, food, and fodder production and influence choices among them. In the Rinconada area, "the number of individuals depending on direct access to land to satisfy their basic needs is increasing more rapidly than productivity from the land" (Koppel, in Atje et al. 1980:4.12). This situation need not be elaborated here, but it points directly to the emphasis in the final section of this report on joining rural energy systems research and development (RESR&D) to current levels of progress in farming systems research and development (FSR&D).

Sources of variation in energy use and supply

Effects of variations in local cropping patterns on forms and quantities of energy use and supply, and consequently on the economic viability and contribution of a new energy technology, are demonstrated in the experience of the community biogas plant installed in 1978 after a careful baseline feasibility study in Fateh Singh Ka Purwa, in northern India. Utilization of the plant is significantly lower than was projected in the planning study, and is explained in part by relationships among

1. the specific kind of crop residues available as cooking fuel;

2. actual or perceived absence of alternative uses for these crop residues;

3. volumes of cow dung available; and

4. decision in the plan to allocate methane primarily for use as cooking fuel rather than for irrigation pumping that would increase winter crop production (Ghate 1980; Bhatia 1979; Bhatia and Niamir 1979).

The principal crop residues produced in the village, stalks from red gram and other lentils, accounted for 58 percent of the total energy utilized for cooking before the plant was installed, dungcakes 33 percent, and wood 9 percent. After installation, crop residues were still burnt, use of dungcakes virtually ceased except for special cooking purposes using small quantities, and all householders are using cooking gas. But the plant is receiving much less dung than the anticipated 12 kg per animal. Since stalks of lentil plants cannot be used for composting or other purposes, their burning as cooking fuel sets a ceiling on requirements of biogas for cooking. A leguminous crop, lentils utilize little dung or slurry as manure, setting a ceiling on farmers' requirements of manures. Selection for the biogas plant of a farming community with above-average cattle/person ratio, while meeting the target objective of releasing dung for use as manure, did not achieve the full potential that could have been realized if existing and potential cropping patterns had been fully taken into account.

In the West Java study, sources of variation in consumption of fuelwood in relation to crop residues and kerosene, include household size, monthly household income, per capita monthly expenditures, physical availability of fuelwood, home garden (kebon, talun) production of fuels, extent and reliability of the distribution system for commercial fuels (notably kerosene), promixity of an all-weather road, and promixity to a major urban center (Atje and Tarrant 1980). Factors that influence amounts of fuelwood consumed in a Nepal hill village are elevation, relief, and solar exposure, ethnic settlement patterns at different elevations, dietary and drinking practices of ethnic groups, types and quality of firewood accessible, season when collected, stove types, land tenure, and, as discussed above, quantities and types of food produced and cooked (Bajracharya 1980). Recognizing the difficulty of capturing each source of variation, it is scarcely surprising that the central range of estimates of annual per capita fuelwood consumption in Nepal vary by a factor of 7, while extreme high and low estimates vary by a factor of 60 (Donovan and Bajracharya 1980).

A structured statistical analysis that attempts to sort out and relate these and other determinants of firewood use is motivated by the need of planners and policymakers to clarify the objectives of policy and the specific instruments that may feasibly serve such objectives. The Rinconada analysis looks at the separate and combined effects of several classes of variables and indicators that relate to the region's ecology, households, villages, and structural interactions. To glimpse the insights and style of the study and the type of questions it raises for policy, two quotations are useful. On interaction with household size and complexity:

> Household size is a basic determinant of firewood demand. The complexity scale is a rough measure of village diversity. That diversity will include differentiation in occupations and in commercial development, among other things. Low complexity in Rinconada means an agricultural community with limited secondary uses of agricultural products. Electricity and commercial liquid fuels tend to be unavailable. The household will use as much firewood in part, as it needs, as reflected in the size of the household. More complex villages mean more occupations. Some people will sell firewood. Some people may avail themselves of limited commercial outlets to buy liquid fuels. Household size may still be a basic indicator of energy needs for cooking, but the relationship with firewood use is reduced by access to other options. In highly complex villages, household size is even less important as other factors (e.g., income and occupation) assume more importance. (Koppel, in Atje et al. 1980:4.42)

On policy:

> The examination of household-village interactions also raises some interesting questions about appropriate intervention strategies for rural energy policy. Who are the target groups? Households using large quantities of firewood wherever they are or villages with consumption rates above the mean? What are the most effective policy instruments? Strategies that alter or play on household level of living or strategies which indirectly influence fuel patterns by directly influencing village central functions? How can rural energy patterns be monitored most effectively? By focusing on types of villages, types of households, or types of interactions between villages and households? (Koppel, in Atje et al. 1980:4.48)

More information on these questions may be obtained in the next stages of analysis: in the West Java study, through classifying the data by traditional, transitional, and modern villages; in Nepal, by adaptation of micro-study techniques to other ecological areas; and in the Rinconada case, by incorporating detailed cropping system data.

User priorities and choice

Reportedly, farmers in Fateh Singh Ka Purwa holding land that could be served by irrigation pumping would prefer that biogas be allocated to this purpose instead of cooking (Bhatia and Niamir 1979). Utilization of the capacity of the plant would increase, as would food output. Choice by the people concerned has a clear implication for planners. Bajracharya offers two

perspectives:

> If the poor in Pangma had a say, their expressed desire under the present circumstances would be to strive first of all toward an adequate food supply. (Atje et al. 1980: 3.48)

> ...the 'ropeway' project...has given the villagers the opportunity to use the underexploited portions of the forest and allow the overexploited portions to regenerate. Clearly, these are healthy developments and demonstrate the feasibility of technological cooperation that combines the input of much-needed technological information and materials from extra-rural sources with decision making and control of choice by direct involvement of the people within the rural areas. (Atje et al. 1980: 3.50)

Valuation, price, and exchange

Nonmonetized and partly monetized transactions for fuelwood, crop residues, animal dung, and other energy sources are a key feature of rural economies. Coproducts and co-users make precise value assignments very difficult. "Anaerobic digestion systems are as much nonenergy technologies as they are energy technologies--that is, other nonenergy products or services provided by digesters rival their value as producers of biogas fuel" (Santerre and Smith 1980).

As analysis of cereal and oilseed crop alternatives in relation to dairy animal and fodder subsystems has demonstrated that a choice of crop-animal combinations suited to India's resource environment can result in adequate production of survival foods (cereals), and increased production of protective foods (protein dairy products and pulses), while satisfying energy efficiency criteria (Halse 1979). The model allocates crop residues for use as fodder, assigning them low opportunity cost because they are not suitable for human consumption. Use of crop residues for fuel is not reflected, however. Effects of scarcity values of crop residues where used for fuel should be incorporated in further analyses of crop-animal complementarities.

These examples demonstrate that crop, livestock, and forest enterprises interact in terms of both energy and food scarcity, productivity, and valuation. The interdependency of these productive activities sometimes results in complementarity and sometimes competition between energy and food values. More systematic methods of studying these relations and tradeoffs are required, from the perspective of both energy and food dimensions of cropping patterns.

Significance of Need-Based Policy Reseach

The large variations in uses and opportunities for rural energy support the orientation of the ERD program to assessment of local needs. The diversity of needs, only partly reflected in demand as evidenced in monetized

exchange, contributes to a principal proposition of this report. This is that direct involvement of farm producers and rural householders in assessment of energy needs can contribute to self-reliance and resilience in local economies by bringing unique local knowledge to bear in building the information base required for resource management and policy decisions. In summary, the significance of need-based, applied policy research is that:

- It builds on the knowledge of rural producers and consumers on energy constraints and opportunities.

- It is essential for gaining knowledge of suppressed demand and lack of associated environmental resources like land and water.

- It is essential for estimating magnitudes and values of quasi-commercial and non-commercial energy transactions and building these into macro-estimates of supply and demand.

- Need-based research counters the dominant supply orientation of many public programs and is more suited to differentiated regional markets.

- It matches recent advances in farmer-oriented farming systems research; need-based research, together with farming systems research can accelerate movement on the learning curve for energy development.

- The energy potential of publicly shared resources is identified in user-oriented reseach. This can serve as an organizational vehicle for local groups facing constraints in access to resources and technologies.

Inevitably, in examining needs in rural settings, knowledge of resource opportunities is also enhanced. Guidance emerges for achieving more intensive yet sustainable uses of resources, through selective additions and improvements in energy and other technologies. The stage is set for examining major constraints and opportunities faced by rural societies, now and in the foreseeable future, in obtaining energy supplies to meet their needs.

ASSESSING RURAL ENERGY RESOURCE, SUPPLY AND INVESTMENT STRATEGIES: THE MIDDLE DISTILLATE CASE

Individual countries, as well as international investment and donor agencies, are assessing competing claims for investment allocations between renewable and petroleum-based energy resources. How much energy is obtainable from nonconventional or renewable resources? (Center for Nonconventional Energy Development 1980). How fast can that energy be made available? How much time is available, in different country situations? What assessments can be made of the petroleum situation in specific countries, and how do they bear directly on rural needs and agricultural production? How can future benefits from current investment in alternative energy research and development be estimated and evaluated? Where should investment be directed? How can benefits/costs from rural electrification be compared with untested but

conceptually attractive autogeneration techniques that use renewable, locally-available resources?

Each of these questions has short-term, medium-term, and long-term implications that are important in the choices of both rural and national decisionmakers. The thrust of the ERD program is toward assessment of alternative technologies, as addressed in the final section of this report. But measures for comparison as well as information on constraints on petroleum-based rural inputs of energy are critical to these assessments.

The present section focuses on a specific set of petroleum derivatives: the middle distillates. Particularly for middle distillate commodities that have widespread uses in rural areas - diesel oil and kerosene - the ERD Program undertakes in its subsequent phases to assess farm-user requirements and impacts of actual or potential shortages on agricultural production. Here the supply dimension is examined.

Our aim is, in part, to provide some context for the individual country studies in the second report in the series, and also for the later reports dealing with specific technologies such as anaerobic digestion and solar icemaking. The country studies may be viewed as different approaches to quantifying and assessing the quality of the various types of fuel and the costs and benefits that accompanying their use and produce the particular mix of fuels in use in each area. In contrast, the reports that deal with specific technologies have implications for allocation of resources over the wide range of conditions to be found in and outside the countries selected.

The Middle Distillates Problem

This analysis is an attempt to assess the middle distillates outlook in the 1980s, given the structural changes that have taken place or are likely to occur in the world petroleum market, as well as the trends in petroleum prices. A package of alternative courses of action that may be followed in dealing with the middle distillates problem is offered. Although the paper is concerned with countries in the Energy for Rural Development Program (Indonesia, Nepal and the Philippines), the middle distillates problem has wide applicability among almost all developing countries, as well as some less affluent nations of the OECD. Although there is a lack of sufficient data for specific countries and products, the problem is a general one and it is hoped that the framework offered can be used directly by the specific countries after more information is made available by the participating institutions.

The middle distillates problem is an imbalance between supply and demand, due to imbalance between the refinery yield and the demand pattern. In many countries refineries of a less complex nature were designed and installed some time ago. There refineries typically produce 25-40 percent of their output as middle distillates: kerosene, diesel/gas oil and jet fuel. As the development process and urbanization continued, petroleum

products--particularly kerosene--replaced conventional fuels such as firewood. This structural change meant that the share of the middle distillates in the total petroleum demand began to grow. In many developing countries, middle distillates demand exceeded 50 percent of the demand for petroleum products. Even the more advanced of the developing countries face the same difficulty. In these countries, the development process affected only certain segments of the population and did not lead to a decline in the demand for middle distillates. At best, such demand was stabilized at over 50 percent of the total petroleum product demand. Two of the OPEC oil producers, Iran and Indonesia, are facing acute shortages of middle distillates, and many OPEC nations are beginning to feel the problem. In short, all the developing nations are likely to come up against the same problem sooner or later, unless strong and even harsh measures are taken in the early stages.

The imbalance between supply and demand for middle distillates creates particularly difficult problems. Traditionally, either middle distillates imports at high prices were used to fill the gap; or new, more complex and costly refineries were built; or isomerization units were installed in existing refineries at high cost to increase the middle distillates yield. However, as the imbalance worsens, the price of petroleum products increases, and the world petroleum market becomes more unpredictable, the old solutions are not likely to be sufficient, as we will see later.

Of the three major middle distillates, kerosene, diesel/gas oil and jet fuel, the latter is of least concern to the developing countries. For them, the main difficulty is kerosene, and then diesel. Kerosene is used for lighting, heating, and cooking, and indeed constitutes the major component of petroleum demand of the urban, and sometimes rural, poor. Automotive diesel oil is used for transportation of commodities, particularly foodstuffs, as well as for tractors and irrigation pumps. The issue of middle distillates prices and supply is an extremely sensitive political issue, since it reaches to the pockets of the very poor. There are few countries in the developing world where middle distillates and particularly kerosene are not subsidized directly or cross-subsidized.

An important tool for assessing the choices in dealing with the middle distillates problem is their cost. A conceptual framework for measurement of costs that will apply in most cases can be set up. Costs can be measured either directly through imports and indirectly through installation of new complex refining facilities or by the modification of existing units:

1. The import option is conceptually the easiest to deal with. Given foreign exchange availability and other import-related development priorities, shadow foreign exchange rates can be assumed to determine the cost of middle distillates imports.

2. The new refinery installation option can also be handled without much difficulty by considering the total capital costs, the extra costs associated with more complex units that maximize the middle distillates yield, and the opportunity costs of the foreign exchange components of

capital goods imports used in refinery construction.

3 The last option, that is, modification of existing units, is the most difficult for measurement of costs. Not only is there a conceptual difficulty with such measurement, but also this method seems to be the option mostly widely adopted by the developing world.

The difficulty arises from the problem of joint costs in refining. Since the refinery produces items that may not be essential, as well as products that are in high demand, it is not possible to allocate costs to the individual products. The practice of accountants or economists who allocate costs in proportion to demand for a certain product can lead to mistaken policy conclusions, particularly when the owner of the refinery is a government entity. A strong body of literature shows that the problem of joint costs cannot be tackled by applying average cost principles, but marginal cost/revenue consideration offer a solution (Stigler 1966:162-165; Porter 1966:418; Walters 1960; Weil 1968). Thus, while it has become clear that total cost cannot be allocated to joint products on an average cost basis, it is possible to decide costs on the basis of marginal costs.

But how can we calculate the marginal cost of any one product of a refinery? This is possible because certain installations and equipment may be added to a refinery to increase the yield of certain products (Table 1).

As we can see from Table 1, any addition of a unit to a refinery can affect the output pattern. Thus, if we desire to increase the output of middle distillates by installing a hydro cracking unit, the marginal cost of the increased output of middle distillates would be roughly equal to (a) the cost of installation (including the future discounted cost of maintenance and operation) of the cracking unit, and (b) the discounted present value of the loss in earnings over the whole life of the cracking unit, because of the fall in the amounts of the other oil products. The marginal cost estimated in this way will have an important effect on the decision-making process. Unless the discounted additional earnings over the whole life of the cracking unit resulting from the increased proportion of middle distillates, net of item (b), and discounted at least equals item (a), it would not be economically worhwhile to install the cracking unit.

Let us consider the special case of Tehran refinery. Because of the need to increase the yield of the middle distillates, an Isomax unit has been installed there. It is estimated that a complex refinery (which includes special purpose units) costs $49 million more than a refinery of the same size. It produces 18,600 b/d of additional distillate products at the expense of 22,100 b/d of fuel oil. Also, operation cost in a complex refinery is about 22.5 cents per barrel higher than those in a simple refinery. On the basis of these figures, the Stanford Research Institute concluded that the marginal benefits were less than the marginal cost, and that the national Iranian Oil Company may well be making a net loss on its sales of middle distillates (SRI 1971).

Table 1.

Percentage Yield of Various Oil Products from the Same Kuwait Crude by Applying Different Refining Techniques

Methods	Light Distillates	Middle Distillates	Heavy Ends	Refinery Loss
Distillation and platforming	11	28	56	5
Plus visbreaking	13	38	42	7
Plus catalytic cracking	21	36	35	8
Plus propane deasphalting	39	27	28	10
Plus hydrocracking	15	53	21	11

Source: Shell International Oil Company, "International Oil Prices."

TABLE 2

Likely Production and Export of OPEC Crude in the 1980s (Millions of Barrels Per Day)

	1980		1985		1990	
			I	II	I	II
Production	28.2	(47%)*	28.2	25.9	28.2	23.6
Export	26.0	(83%)*	24.3	22.0	21.9	17.3

*Percent of World Trade: Scenario I assumes constant output; Scenario II is based on assumption on the current policy plans and options discussed in Footnote 4.

In most developing countries where domestic prices are controlled and refining ventures are owned by governments, such measurement of the marginal cost of middle distillate output is not taking place. The reason may well be the knowledge that middle distillates prices are politically determined and would not be allowed to change even if the costs were accurately determined. While this may be true in the case of an individual refining company, for macro-economic planning, such measurement could prove extremely useful for formulation of policies which may reduce the growth in middle distillates demand.

The World Petroleum Trade

The structural changes in the world petroleum market in the 1970s and a new wave of expected changes in the 1980s have important implications for the supply of crude petroleum and petroleum products to the developing world (Fesharaki 1980).

The petroleum market of the 1970s was marked by a major shift in the balance of power from the oil companies to the oil exporters who took control of both production level and prices. The fourfold increase in petroleum prices in the last quarter of 1973 and its consequent recessionary impact, as well as a multitude of other factors, resulted in declines in the real price of oil from 1974 to the third quarter of 1971 (Petroleum Intelligence Weekly 1979). In retrospect, both the industrial and the developing countries did relatively well in the face of this rapid change in price. The industrial countries grew at a rate of 3.4 percent during 1970-1978, while the rate of economic growth for the developing world was 5.7 percent for 1970-1975 and 4.8 percent for 1977 (World Bank 1979). The Iran Revolution of 1979 brought about the realization that the false sense of security that many nations had enjoyed for a few years had come to an end. Not only did oil prices rise by 150 percent in only 18 months, but also the issue of crude oil availability came to be considered just as important as the price issue.

Can the petroleum market in the 1980s be handled with the same relative degree of ease as in the 1970s? There are indications that major irreversible structural changes that have taken place in the aftermath of the Iranian Revolution will make such a possibility highly unlikely.

1. Within OPEC itself, the power structure has changed. No longer can Saudi Arabia (and Iran prior to the Revolution), as the largest exporters, control the course of events. By pushing Saudi Arabia's production to the limit, the flexibility has gone out of the system. The actions of the small producers could have a major disruptive impact on the market.

2. The oil exporters face major domestic political pressures to reduce production.

3. With the increase in oil prices, almost all oil exporters now have balance of trade surpluses with little or no pressure for increased out.

4 The OPEC members have, in light of the Iranian experience, realized that development is an evolutionary process and too fast injection of capital will not bring about development, but might destroy the very fabric of their society. This, together with the depreciating petrodollars invested abroad, has made keeping oil in the ground the most attractive option.

5. Domestic demand in OPEC nations is on the rise. Domestic consumption of petroleum products of 2.3 million b/d in 1980 is expected to rise to 6.3 million b/d in 1990, reducing available exports.

6. There has been a major change in the distribution system of crude and refined petroleum products. The international oil companies' access to crude petroleum declined from 92 percent of world trade in 1973 to 58 percent in 1979. This was coupled with an increase in direct sales by the oil exporters (just under one half in state-to-state deals) replacing the traditional sources of distribution and again reducing the flexibility of the system (Petroleum Intelligence Weekly 1980).

7. The changes in prices are becoming, to a great extent, independent of demand. In other words, the real price of oil is likely to increase even if the world demand drops off. Oil prices that are increased by market forces or OPEC decisions at times of shortage and crisis will be maintained when demand falls, resulting in a decline in liftings and production. This year's lower production then becomes next year's ceiling on output.

Basically, the fear of supply insecurity, which is paramount in price rises within the market, is going to be with us in the 1980s. It is worth noting that despite the Iranian Revolution, more oil was produced and exported in 1979 than in 1978, while prices rose dramatically. During 1980, the surplus of 2-3 million b/d together with high stocks did not lead to a decline in the official prices. Table 2 shows that even if production does not decline, more increase in domestic requirement within OPEC will reduce supplies 6 percent by 1985 and 16 percent by 1990. If restrictive production policies are adopted, exportable supplies could well decline by one third in 1990. Table 3 projects the changes in the average price of crude oil. Thus, oil prices are likely to be around $50 a barrel in real terms in 1985 and over $90 in current terms. They could reach $78/b in real terms and $144/b in current terms if there is a crisis.

We are thus facing a situation where crude supplies are shrinking, crude prices are rising, and oil export trade is shifting to direct sales of crude and products. As the situation worsens, the developing nations will face a major challenge in securing their own crude and product supplies. So far, the OPEC nations have shown their preference in selling oil directly to the developing nations, though few price concessions are likely. But this oil will be in the form of crude. Should they build their own refineries at home and expand their existing facilities? Should they establish regional purchasing and refining authorities or should they buy up the existing refining facilities such as exist in Singapore? These are major policy questions which the

Table 3.

Oil Price Scenarios in the 1980s

($/b)

	1980	1981	1985			1990		
			Low	Medium	High	Low	Medium	High
Average OPEC Prices (Constant 1980 Prices)	31	31	31	38	45	31	48	73
Average OPEC Prices (Current prices)*	31	33	43	52	62	61	92	136

Low: No real price increase.

Medium: 5% real price increase.

High: 10% real price increase per year.

*Assumes 7% annual rate of inflation.

Table 4.

Imports of Crude Petroleum By Source

(10^3 metric tons)

Country	Year	Middle East	% of Total	OPEC	% of Total	Far East	% of Total	Other	% of Total	Total (100%)
Bangladesh	1977	N.A.		N.A.		N.A.		N.A.		1,080
	1973	N.A.		N.A.		N.A.		N.A.		550
	1968	0		0		0		0		0
India	1977	12,560	88	12,560	88	0		1,650	12	14,210
	1973	13,020	98	13,020	98	0		280	2	13,300
	1968	10,510	100	10,510	100	0		0		10,510
Indonesia	1977	N.A.		N.A.		N.A.		N.A.		2,942
	1973	0		0		0		0		0
	1968	0		0		0		0		0
Nepal	1977	0		0		0		0		0
	1973	0		0		0		0		0
	1968	0		0		0		0		0
Philippines	1977	7,100	74	8,290	87	1,630	18	750[a]	8	9,530
	1973	7,620	82	8,850	96	1,640	18	0		9,260
	1968	4,760	62	6,510	85	2,920	38	0		7,680
Sri Lanka	1977	1,460	95	1,460	95	0		70[b]	5	1,530
	1973	1,800	100	1,800	100	0		0		1,800
	1968	0		0		0		0		0
Thailand	1977	6,860	84	6,860	84	1,110	14	230[a]	3	8,200
	1973	6,400	85	6,400	85	1,110	15	0		7,510
	1968	2,390	98	2,430	100	40	2	0		2,430

[a]From Centrally Planned Economies

[b]From West Europe

Source: United Nations, World Energy Supplies, Series J, No. 22 (1979), No. 16 (1972).

developing nations will have to sort out for themselves. However, with reference to the very serious middle distillate problem, our analysis may be useful in arriving at a choice in these options.

The Current Situation in ERD Countries

Based on the limited statistical data available, the current situation and historical and future trends will be discussed below.

Table 4 shows the dependence of our specific countries on the sources of imported petroleum. Since no data were available for refined products, the table is confined to crude imports by source. Table 4 considers the dependence on sources of imports during the period 1968-1977. In all of the countries concerned, at least 84 percent of imports come from OPEC and at least 74 percent of the total originated from the politically volatile Middle East. Except for the Philippines, which has increased its dependence on the Middle East from 62 percent of the total imports in 1968 to 74 percent in 1977, most other countries have slightly reduced their dependence on the source of supply. This was possible by a small production of internal crude in some countries and some trade in the Far East originating from Indonesia and Malaysia. However is short be borne in mind, that the Middle East is and will remain by far the most important source of crude for the foreseeable future. The potential of or availability of crude from Indonesia and Malaysia is small and possibilities of further increases in domestic production are slight. Thus, there is a limit to how much these countries can reduce their dependence on the Middle East/OPEC and this limit will soon be reached if it has not already. Once the shortfalls shown in Table 2 come into effect, there will be at least proportional shortfall of available crude for these countries. Indeed, in a shortfall they will find stiff competition from the industrial countries. Without regional groupings they may well have less than proportional crude made available to them.

Tables 5, 6, 7, and 8 provide us with details of production of crude oil and refined products by type, as well as consumption of petroleum products and imports by type over a five-year period 1973-1978. The following observations may be made:

1. Except for India which depends on oil for 28 percent of its commercial energy consumption, Bangladesh's reliance on imported oil is 50 percent; Indonesia and Nepal, over 80 percent; and the Philippines, Sri Lanka, and Thailand, over 90 percent.

2. The rate of growth of consumption varies from country to country. The highest rate is recorded in Bangladesh (12.2 percent) and Indonesia (13.5 percent) and the lowest in India (2.2 percent). Two countries, Nepal and Sri Lanka, actually recorded a decline in consumption.

3. The ratio of imports to domestic consumption of petroleum products differs widely from country to country, depending on existing refining capacity and

Table 5.

Production of Crude and Refined Petroleum

(10^3 metric tons)

Country	Year	Crude Oil	Petroleum Products							
			Total	LPG	Aviation	Motor	Kerosene	Jet Fuel	Distillate Fuel Oil	Residual Fuel Oil
Bangladesh	1978	0	1,085	0	0	55	300	45	200	485
	1973	0	503	0	0	31	79	0	79	314
Average annual growth rate, 1973-1978			(13.7%)							
India	1978	11,188	19,379	400	0	1,521	2,380	1,070	8,486	5,503
	1973	7,198	15,450	259	0	1,647	2,631	851	6,118	3,924
Average annual growth rate, 1973-1978		(7.6%)	(3.9%)							
Indonesia	1978	90,010	21,284	45	18	2,440	4,690	115	4,230	9,670
	1973	66,957	14,982	8	4	1,510	2,511	124	2,062	8,568
Average annual growth rate, 1973-1978		(5.1%)	(6.0%)							
Nepal	1978	0	0	0	0	0	0	0	0	0
	1973	0	0	0	0	0	0	0	0	0
Average annual growth rate, 1973-1978										
Philippines	1978	0	9,421	150	0	1,800	415	275	2,150	4,600
	1973	0	8,220	172	0	1,939	432	263	1,723	3,659
Average annual growth rate, 1973-1978			(2.3%)							
Sri Lanka	1978	0	1,300	5	0	103	215	50	312	615
	1973	0	1,463	8	0	122	252	0	413	668
Average annual growth rate, 1973-1978			(-2.0%)							
Thailand	1978	8	7,605	125	0	1,380	225	650	2,450	2,775
	1973	6	6,921	106	0	1,195	191	714	1,932	2,783
Average annual growth rate, 1973-1978		(4.9%)	(1.6%)							

Source: United Nations, World Energy Supplies 1973-1978, Series J, No. 22, 1979.

Table 6.

Consumption of Petroleum Products

(10^3 metric tons)

Country	Year	LPG	% of Total	Gasolenes[a]	% of Total	Kerosene and Jet Fuel	% of Total	Residual and Distillate Fuel Oils	% of Total	Total, All Refined Products	100%	Petroleum Consumption as of Total Commercial Energy Use
Bangladesh	1978	0		78	5	370	31	753	63	1,186	100	50.5
	1973	0		51	9	130	22	415	70	596	100	38.8
Average annual growth rate, 1973-1978										(12.2%)		
India	1978	400	2	1,526	7	3,935	19	15,114	72	20,994	100	28.2
	1973	259	1	1,643	9	3,958	22	12,262	68	18,142	100	30.9
Average annual growth rate, 1973-1978										(2.5%)		
Indonesia	1978	44	0.2	2,578	11	5,555	25	14,181	63	22,434		84.4
	1973	6	0.1	1,366	13	2,583	25	6,366	61	10,516		92.0
Average annual growth rate, 1973-1978										(13.5%)		
Nepal	1978	0		19	25	23	31	33	44	75		80.7
	1973	0		20	25	25	31	35	44	80		83.8
Average annual growth rate, 1973-1978										(-1.1%)		
Philippines	1978	175	2	1,743	18	605	6	7,121	74	9,675		94.1
	1973	152	2	1,927	24	591	8	5,173	66	7,875		96.1
Average annual growth rate, 1973-1978										(3.5%)		
Sri Lanka	1978	5	0.5	105	11	310	33	531	56	951		90.3
	1973	8	0.7	122	11	272	25	671	63	1,073		94.3
Average annual growth rate, 1973-1978										(-2.0%)		
Thailand	1978	127	1	1,436	16	900	10	6,670	73	9,133		94.7
	1973	75	1	1,147	16	913	13	5,120	71	7,255		96.6
Average annual growth rate, 1973-1978										(3.9%)		

[a]Consumption figures are not disaggregated.

Table 7.

External Trade in Crude and Refined Petroleum

(10^3 metric tons)

Country	Year	IMPORTS			EXPORTS			NET IMPORTS		
		Crude Oil	Refined Products	Crude and Refined Products	Crude Oil	Refined Products	Crude and Refined Products	Crude Oil	Refined Products	Crude and Refined Products
Bangladesh	1978	1,200	118	1,318	0	5	5	+1,200	+113	+1,313
	1973	550	102	652	0	0	0	+550	+102	+652
India	1978	14,400	2,335	16,735	0	15	15	+14,400	+2,320	+16,720
	1973	13,443	3,446	16,889	18	150	168	+13,425	+3,296	+16,721
Indonesia	1978	3,000	2,434	5,434	60,000	878	60,878	-57,000	+1,556	-55,444
	1973	0	659	659	50,055	4,766	54,821	-50,055	-4,107	-54,162
Nepal	1978	0	75	75	0	0	0	0	+75	+75
	1973	0	80	80	0	0	0	0	+80	+80
Philippines	1978	9,920	1,039	10,959	0	335	335	+9,920	+704	+10,624
	1973	9,223	20	9,243	0	404	404	+9,223	-384	+8,839
Sri Lanka	1978	1,550	118	1,668	0	20	20	+1,550	+98	+1,648
	1973	1,746	30	1,776	0	20	20	+1,746	+10	+1,756
Thailand	1978	8,310	1,612	9,922	0	19	19	-8,310	+1,593	+9,903
	1973	7,540	921	8,461	0	534	534	+7,540	+387	+7,927

Source: United Nations, World Energy Supplies 1973-1978, Series J, No. 22, 1979.

Table 8.

Net Imports of Petroleum Products

(10^3 metric tons)

Country	Year	LPG	As % of Consumption	Gasolines[a]	As % of Consumption	Kerosene and Jet Fuel	As % of Consumption	Residual and Distillate Fuel Oils[a]	As % of Consumption	All Refined Products	As % of Consumption
Bangladesh	1978	0		+8	13	+25	7	+80	11	+113	10
	1973	0		+20	39	+51	39	+31	7	+102	17
India	1978	0		+20	1	+885	22	+1,415	9	+2,320	11
	1973	0		+16	1	+826	21	+2,454	20	+3,296	18
Indonesia	1978	-1	2	+125	5	+812	15	+620	4	+1,556	7
	1973	-2	33	-146	11	+8	0.3	-3,967	62	-4,107	39
Nepal	1978	0		+19	100	+23	100	+33	100	+75	100
	1973	0		+20	100	+25	100	+35	100	+80	100
Philippines	1978	+25	14	-57	3	-15	2	+751	11	+704	7
	1973	-20	13	-12	1	-59	10	-293	6	-384	5
Sri Lanka	1978	0		+3	3	+45	15	+50	9	+98	10
	1973	0		0		+20	7	-10	1	+10	1
Thailand	1978	+2	2	+56	4	+25	3	+1,510	23	+1,593	17
	1973	-31	41	-40	3	+8	1	+450	9	+387	5

[a]Trade figures are not disaggregated.

Source: United Nations, World Energy Supplies 1973-1978, Series J, No. 22, 1979.

the match between supply and demand for products. In Nepal where no refining facilities exist, all consumption was imported, but in Indonesia expansion of domestic refining capacity has reduced dependence on imports from 39 percent in 1973 to 7 percent in 1978.

4. As to the configuration of imports and consumption, the United Nations' figures do not disaggregate diesel/gas oils from other figures. It is therefore not possible to say with precision what the state of the middle distillates supply and demand is. However, figures for kerosene and jet fuel are available. They show that, except for Sri Lanka, other countries have succeeded in maintaining the same proportion of kerosene/jet fuel use in 1978 as existed in 1973. However, the growth in demand meant that domestic refining facilities could no longer provide the required kerosene/jet fuel and large imports were necessary. For instance, in Indonesia, consumption of kerosene/jet fuel doubled in five years maintaining its 25 percent ration in petroleum consumption. However, imports of these products had to rise from 8,000 tons in 1973 to 812,000 tons in 1978 to keep up with demand. Similarly, in Sri Lanka imports of these products doubled, and in Thailand tripled.

Though insufficient data on gas/diesel oil do not allow deeper analysis, the symptoms of the middle distillates problem can be seen clearly. First, these countries have been successful in not allowing the share of kerosene/jet fuel in total consumption to rise. This may be regarded as less the result of deliberate policy actions than the low standard of living and slow effects of urbanization on consumption of these products in the face of each period. The situation is sure to worsen in the 1980s. Second the imbalance between domestic supply of kerosene/jet fuel and domestic demand, which was explained in the earlier part of this study, has come to the fore in three of the countries discussed, resulting in large increases in imports of these products. This situation also promises to worsen both for the countries already facing the problem and for others, which can look to this development as a model of the difficulties that lie ahead. Coupled with the issue of rising prices, shrinking crude supplies, and problems in distribution and sales of middle distillates by the international oil companies to the countries concerned, the true magnitude of the problem and its implications become clear.

Possible Course of Action

Based on the experiences of other countries and with some foresight about future availability of petroleum and its price, a number of possible courses of action may be undertaken to reduce the middle distillate pressure on the consuming developing countries.

Short-term (one to two years)

In the short-term, governments can use fiscal measures to reduce middle distillates demand. The most obvious measure is to increase middle

distillates prices or at least change the relative position of the petroleum product prices. The governments usually have little difficulty in raising the price of gasoline and they have done so in the last decade. If such an action has led to a surplus in gasoline availability from domestic refineries and there is a shortage of middle distillates, a package of policies may be adopted to reduce middle distillates demand. First, the relative position of prices can be changed through imposition of taxes to make gasoline cheaper than diesel/gas oil. Second, the import of gasoline-using vehicles and machinery can be encouraged and diesel-fueled discouraged through imposition of tariffs and quotas. This would lead to full utilization of surplus gasoline and less demand for diesel. At the same time, existing diesel fuel trucks which carry foodstuffs, may receive a refund to avoid a large impact on the price of food.

Where automotive and heating gas oil have similar prices, a policy similar to those of many European countries may be adopted, whereby heating gas oil is taxed more heavily than automotive gas oil (Fesharaki 1980: Ch 12). This would again lead to lower gas oil demand.

The short-term policies discussed above are concerned with gas/diesel oil, not kerosene, because gas oil prices are far easier to deal with than kerosene prices. Ideally, the price of kerosene should be allowed to rise to reduce demand, but this is such a politically sensitive issue that many governments are reluctant to take this course of action. However, regular small increases are likely to be less troublesome than large increases.

Medium-term (two to five years)

Over the medium term, the government can encourage the use fo substitute fuels to reduce middle distillates demand. The best substitute for kerosene is liquefied petroleum gas (LGP), and for diesel is gasoline. LPG can replace kerosene for heating, lighting, and cooking. However, the availability of LPG is dependent on a number of options that may not be open to all countries. First, LGP may be available from domestic refineries or its production may be increased by installation of new equipment in existing refineries. Second, the OPEC nations, particularly in the Middle East, are embarking on such large refining and gas gathering systems that there may well be a 5-10 million ton LPG surplus in the world market by 1985, compared to current world consumption of around 10-12 million tons (Fesharaki 1980). Developing countries may be able to obtain long-term supply contracts from OPEC for LPG at prices below the level of crude oil prices. Third, availability of LPG alone is not sufficient for expansion of its use. LPG has to be transported in cylinders and can be used only if cookers, heaters, or lighting equipment are available for its use. The technology for manufacturing such equipment is simple and they could easily be manufactured in developing countries.

Another medium-term option is to upgrade existing refineries, which can be done by installing equipment to increase the middle distillate yield. This method can be extremely costly as explained earlier, but many governments

may have little choice but to go this route.

Over a five-year period, the government has flexibility in placing heavy emphasis on development and application of alternative technologies such as solar, wind, and biomass to reduce the demand for petroleum products. There alternative technologies are covered elsewhere in these Program Reports.

Long-term (five years and over)

Over the long term, it is hoped that policies for replacement of oil products by non-oil substitutes are already in place and having an impact. However, if the problem persists, refining activities will have to be expanded. This can be done in two ways, either by construction of new refineries or by establishment of joint refining ventures on a regional basis. These refineries will be constructed with a view to maximizing middle distillate yield and will be of a complex nature and extremely costly, since they will include special-purpose units. As was explained before, during the 1980s the developing world will be very much on its own for securing crude oil supplies and refining them. If individual countries attempt to construct new refining facilities that fit their existing demand pattern, they may well find themselves in difficult in a decade or so if that demand pattern begins to change. This is clearly possible, since the developing nations are at different stages of development with different petroleum product requirements. To utilize economies of scale for refining and transport of crude oil; to be a force in negotiations with the oil exporters; and to main flexibility in the use of products that are needed and the export of products that are not needed, regional groupings may prove extremely useful. Refineries may be constructed jointly with a view to the geographical advantages or, even better, refining facilities already in place by the international oil companies, in locations such as Singapore, may be purchased and jointly operated. This kind of action could lead to re-instituting the flexibility that is being lost as a result of the structural changes in the world petroleum market.

ORGANIZING LOCAL ENERGY SUPPLIES AND TECHNOLOGICAL INNOVATIONS TO MEET RURAL NEEDS

The purpose of this concluding section is to examine the kinds of policies and organizational guidelines that would foster local development of renewable energy resources and technologies for more productive and equitable use by rural citizens. The discussion is preliminary, but designed to give operational focus to the next stages of research.

The potential of new energy technologies for increasing rural productivity and overcoming poverty is first explored. Values are created by new technologies, but the uncertainty of the innovative process make values of new technology hazy as compared to patterns of fuels. Price-tax and price-subsidy policies are examined in this context.

Organizational development policies conducive to the invention of viable local technologies intersect with fuel price policy. Organizational theory is frequently ignored by macro-planners, although it has been shown that the goals and behavior of existing public organizations are often contradictory to signals from price-tax policymakers (Thomas 1975). The FLERT (Fuel-Linked Energy Resources-and-Tasks) approach (Smith and Santerre 1980) is discussed as a vehicle for bridging market and social valuations that has potential for community evaluations of technology and also for discovering unseen social and environmental dimensions that are the sources of innovation.

Guidelines for the lateral structuring of the innovative process are drawn from organizational research and their significance for improved resource access is suggested. In this setting, interdependency between rural energy potential and farming systems improvements creates opportunities for organizational learning and synergy. Modes and phases for building rural energy research and development in combination with farming systems research are sketched, with support from Appendix A, which introduces taxonomies of cropping systems.

Value Creation through New Technologies

The essential value of a new technology is in the uniqueness with which it permits abundant but hitherto unutilized or underutilized resources to be used. Energy itself is an underutilized resource as well as a mean for the transformation of other resources into forms that serve human goals and needs. It is critical for combining vectors of other resources. Suitably guided by human decisions, these combinations create motive power and change resources into forms that accomplish tasks and provide goods for society's use.

Prior to discovery of the new technology, realization of the use-value of the abundant resource was blocked or the use-value of scarce resources was reduced. A large share of the total increase in use-value that results from combination with other resources may be imputed to the previously unavailable technology that acted as an unperceived bottleneck or limiting factor. If labor, land, or water are resources that gain value through addition of the new technology, the increased total and net product can be apportioned to labor and to socially vested interests in land or water. If overcoming the bottleneck or gap is the direct result of publicly supported innovation, allocation of subsequent benefits from the combined resources can be determined proconnections between innovation, form of technology, and form of augmented resource use are organized in ways that benefit small farmers, rural housewives, and other rural groups, their stake in these advances can be realized.

Present Price Versus Future Value

A central area of uncertainty facing local energy users who are deciding whether or not to risk adoption of a new energy process or artifact is that of price. Subsistence and transitional economies exist in a matrix of

values that involve competitive and complementary food-energy choices and partly market-formed, partly negotiated norms of exchange for labor and other resource inputs. Prices of externally derived fuels have jumped sharply and unevenly, as we have seen, resulting in unpredictability of the relative values of indigenous and external fuels. Public taxation subsidy, fuel supply, and allocation policies intersect with these underlying forces in determining values.

It is essential to begin by understanding price mechanisms as they operate in rural energy markets. Substantial variation in the retail price of kerosene, a standard fuel commodity, was observed even within a single kabupaten (district) in the West Java study, where a doubling of price between villages was recorded (Atje et al. 1980). One of the factors determining the price of kerosene was often proximity of the village to an all-weather road. Extent and reliability of the distribution system (roads, depots, tank trucks) were found to be important determinants of kerosene use. Implicit or indirect policy environments, for instance through rural area development or development of roads and marketing infrastructure, can have more important effects on fuel substitution than explicit price-tax or technology policies (Sagasti et al. 1979).

The uphill course faced by unproven new technologies against convenient, widely distributed fossil fuels has often led to advocacy and use of subsidies to purchasers of the new equipment. Subsidies may be direct, through supply below cost, or indirect, through tax writeoffs or rebates. In contrast, policies to promote small-scale decentralized technology in the Peoples' Republic of China in the 1970s, rationed the most modern components or capital-intensive raw material inputs for newly developed technologies (The American Rural Small-Scale Industry Delegation 1977). Technologies were unpackaged, and delivery of such components to local production teams or communes was limited by slow requisition procedures, long leadtimes for delivery from urban industrial centers, or high charges. Acquisition of missing key components was dependent on local steps to mobilize labor and develop skills for local production of raw materials and capital components. The micro-hydro plants reported in this series are a case in point (Goodman et al. 1980). This experience demonstrates the importance of positive policies for technology development pointed to the specific skill and innovation requirements or the process concerned. Subsidies may look attrative, however, because of expected quick effect. Creating the organizational environment for innovative technology development entails behavioral and institutional change, as well as skill and managerial development. What mechanisms could offset the time bias that favors the short-term price signal?

Some preliminary guidelines are available. Clearly, if the price-tax struture for external fuels like diesel oil for imported equipment like tractors, or for electricity distributed from a central grid, is lower than the projected long-term supply price, the bias against indigenous innovation will be difficult to overcome. Prices over which governments have a measure of influence, including imported energy carriers, should reflect actual and anticipated scarcity values.

Decentralized sites where new technology may be introduced obtain some degree of natural protection from the costs of overcoming distance. It steps to obtain user guidance in technology design and selection are taken, the demand-pull may tend to offset short-term relative prices. Acceptance by marginal farmers and poor rural households is likely to be price-elastic, but with reliable expectations they will respond to long-term supply price, rather than subsidies. Maintenance, parts supply, and repair are crucial real elements in long-term price, since the farmer needs a dependable energy source or tool, serviced when needed. Making medium-term credit available to local manufacturers for working capital to build maintenance and repair services offers greater promise than subsidies in promoting acceptance. Indirect investment subsidies through well-directed technology research and development, at the cost-cutting frontier of the technology, coupled with these organizational elements, can move costs to the price-elastic realm of demand.

These initial propositions on price-tax and price-subsidy policies are offered for testing in the next stage of research.

Organizing Guidelines for Local Technology Development

What public policies are effective in promoting local technologies that augment the resources and productivity of marginal groups? Evidence and propositions on this issue may be drawn from recent studies on farming systems research (Consortium for International Development 1980), rural industrial technology (Carr 1980), rural development (World Bank 1978, McInerney 1978; Smith, Lethem, and Thoolen 1980) small enterprise project identification (East-West Technology Development Institute 1977), and programs for dairy development, food production, and population control (Paul 1980).

Three objectives for organizational design of public programs are identified:

1. strengthen lateral structures;

2. involve rural user groups through participatory processes

3. combine local knowledge with new information to increase knowledge with new information to increase the community's power of decision.

Strenthening lateral structures

Diversity, size, and uncertainty of the task environment of public programs are formative influences on the structure and processes of successful programs (Paul 1989). Organizations whose products and services must be highly differentiated and diversified to meet the variety of local environments and needs tend to move toward planning processes that are described as "decentralized and participative, adaptive to local conditions, and negotiative (Paul 1980). Uncertainty is high for organizations whose products are intended

to meet needs of majority population groups whose ability to purchase is low, or new and innovative, therefore slow on mobilizing demand. To cope with uncertainty, "the organization tends to move toward a decentralized structure that can adapt better to the increased constraints on information processing" (Paul 1980).

Structures that provide relative autonomy for local program managers are suggested in such task environments. "Differing practices and local adaptations are required when the environment (client groups, institutions) is diverse. Speedy responses are called for when uncertainty renders tardy decisions obsolete" (Paul 1980). Motivation to use effective local autonomy is then an organizational feature of successful programs.

Energy technology development utilizing renewable, diverse resources is evidently a task exhibiting these organizational features. Adapting successful organizational principles, multifunctional and multidisciplinary capabilities must be fostered in program structures. Lateral exchanges of people having the specialized knowledge and skills required to transfer and adapt learning experiences are required. Lateral movement of ideas, experience, and information denotes a more dynamic organization than is conveyed in the word "decentralized" (Barnard 1938). A pattern for such lateral development of energy capabilities is articulated in the later section on farming systems.

Involving user groups in task definition and evaluation of designs

Technology planning based on felt needs of rural residents and their perceptions of resources and opportunities was the focus of the first section of this report. Energy for rural developmet implies three basic questions, that have similarly been posed for forestry: "Who participates? Who decides? Who benefits?" (Umali 1979). People's participation is not only a goal of development, umali emphasizes, "It is also a <u>means</u> and a <u>pre condition</u> for authentic development".

Weak linkages between farmers as a group and the larger society that supports their activites inhibit effective resource use in the early stages of agricultural development. more farmers participating in and contributing to agricultural development may then be a dominant program goal (Green 1974). Participation activities include using new production techniques, new kinds of planning, new approaches to valuing land, water, and labor resources, and group action. Group negotiating and decision processes are the essential basis for change in subsistence and transitional economies where values for commodities and services are established by use of inherited exchange and negotiating rules and norms. How could local resource planning occur without the active engagement of those who know the existing norms and are the principal parties in the bargaining process?

Users' involvement in resource and technology assessment can be given practical content through introduction of the FLERT approach for evaluating

small-scale rural energy technologies (Smith and Santerre 1980; Santerre and Smith 1980) as discussed below.

Combining local and external information

Current awareness of folk or indigenous technical knowledge as a source of practical experience, information, and ideas for technological innovation contributes to these organizing guidelines (Howe and Chambers 1979, Howe 1979). Rural societies are testers and integrators of information because their existence is a succession of experiencing and anticipating environmental changes, negotiating the new exchange and benefit-cost relationships shaped by these changes, and taking production decisions that fit the folk-space-time continuum.

Local community innovators perceive and combine hidden dimensions of the social and physical environment to form new productive enterprises (EWTDI 1977). Stimulus from external information is often a key ingredient in discovery and invention of a new product or technique. Indeed, a critical requirement for economic self-reliance is possession of reasonably good knowedge of external or "other" forces that are likely to affect the local area. Transfer of knowledge of innovations that have succeeded in comparable areas is a similar ingredient. Poor or uncertain information on external resources or price trends that could disrupt local value relationships is damaging not only to self-reliance but also to the planning and maintenance of specialized or comparative advantage in the local area's economic initiatives.

Techniques of infusing relevant information are among the most elusive of development skills. Traders who form primary links to outside markets frequently have the edge in obtaining timely information on price and supply. Equipping small farmer organizations, artisan cooperatives, and women's associations with telephone service to nearby market nodes is a public systems device for reversing this bias, overcoming a critically felt bottleneck (Stanford Research Institute et al. 1968).

FLERT: A Potential Instrument for Peoples' Assessment of Technologies

Values for rural energy technologies are imperfectly captured in price, for reasons specific to their scale (Brown and Smith 1980), localization (EWTDI 1977), and the negotiating inequalities of groups with differential resource access. A new formulation of social, environmental, and physical criteria and measures to augment use of price in project assessments is provided in the FLERT approach (Smith and Santerre 1980), which has been applied to anaerobic digestion systems for rural areas (Santerre and Smith 1980).

FLERT is a complex but coherent system of energy attributes and notations, close to the natural environment in which rural people reside. Fuelwood equivalents are suggested as fuel replacement values for local fuels.

For external fuels, kerosene equivalents are chosen. Principal physical energy tasks in rural areas are specified, and standard units of measure are defined for each as a basis for data development under controlled field conditions. Fuel flow specifications are presented in defined units and with approximate conversion factors for the principal fuel forms: liquid, gaseous, solid, electricity, mechanical power, and heat. Time and space characteristics of rural energy tasks are specified, with criteria for their evaluation. The FLERT "specification plate," intended to simplify the use of criteria, provides seven categories fo evaluating physical resources, seven for social resources, and nine for environmental resources.

While focusing on local system boundaries, FLERT uses units that would facilitate aggregation to national magnitudes. The effort to treat spatiality in relation to resource access and siting is analogous in some respects to empirical location analysis. It may thereby contribute to the major existing bodies of theory and empirical work in location and transport economics and regional analysis that bridge macro- and micro-economics. Typologies on energy technologies on the spatial axis may subsequently be identified, analogous to small industry typologies (Staley and Morse 1965).

In its direct application, the FLERT approach may be viewed as a first effort at forming an explict analog to the within-the-head calculus by which users of energy in its most direct forms evaluate daily and seasonal choices, constraints, and opportunities. Here is a potential tool for community information-gathering that could be set against prices prevailing in the marketplace to improve valuations and local negotiating abilities. FLERT could contribute to the entrepreneurial function of detecting gaps and disequilibria in the market, as a basis for offering or bidding at prices different from the prevailing price (Morse 1975; Kirzner 1973).

If translated into local terminology--with conversion to local units for the defined units of measure--the FLERT instrument could be useful not only in evaluating but potentially in generating local innovations. Its sketches and diagrams, reviewed by village discussion groups, might elicit differing visual and spatial perceptions relevant to design. Rural residents in a given setting would select or assign higher weight to some criteria than others, reflecting their own resource valuations, or valuations of time and distance. Made over in the local image, FLERT could serve rural assessments of proposed technology fits, and could be a vehicle for bringing together the unseen dimensions on which new technologies must eventually pass muster.

While the FLERT approach undertakes in a preliminary way to incorporate social attributes objectively, its interest for social organization could well arise in discussion by village groups of their own structures and behavioral dynamics. From such interaction with an environment seen afresh, renewed self-awareness might be gained.

Cultural perceptions implicit in the creation of the FLERT approach are those of science, definition, and measurement or indexation. Rural people who work with soil, water, slope, sunlight, plants, and animals have direct

tactile, visual, and depth perceptions of these energy-bearing materials. Cross-cultural comparisons should be revealing, and, the potential stimulus for innovation.

Adapting Farming Systems Research to Energy for Rural Development

Scarcity of food and energy associated with constraints on land and water availability was identified earlier as a critical dimension of need in two regions analyzed. Organizing policies for technology development must address the needs of groups with poor resource access, strengthening their information base and ability to influence values assigned to resources they control.

Farming systems research deals explicitly with critical limiting scarce factors in environmental resources and seeks to promote better choices and organizing modes to increase productivity from these resources (Harwood 1979). However, energy sources such as livestock, trees, and crop residues have not received the attention they deserve (Shaner 1979). To fill this critical gap in attention to energy-producing animal and forest enterprises, and to incorporate lessons from successful farming systems research, clear directions for rural energy research and development are indicated.

Farming systems research as increasingly practiced is based on close interaction with farmers to understand their goals and to learn how they perceive and decide on environmental factors in selecting crop combinations. Since scientists and farmers work closely together in this exchange of information and in decisions to experiment with new farm practices, newly created or shared information at once becomes part of the wider system. The thrust of farming systems resarch, therefore, is dynamic, yet changes that result, are shaped by the farmer's goals, perceived opportunities and constraints, and decisions.

Richard Harwood's exposition of farming systems research may serve as a point of departure for constructing a conceptual framework for understanding and improving rural energy systems (Harwood 1979). Harwood articulates a clear strategy for progressive development of subsistence farms, structured upon a lucid analytical and classificatory body of knowledge derived from work with hundreds of small farmers and scientists. Development strategies at the core of this approach include:

1. Farm development is a progression to more efficient and more productive use of limited farm resources, notably land and water, in combination with sunlight and technology.

2. More intensive interaction of varied but complementary farm enterprises is the key to productivity when resources are limited. Identification of significant interactions--of people with plants, plants with animals, plants with other plants--is the starting point for analysis of farming systems. The aim is to identify situations in which existing farm

resources are inefficiently used, and define changes in the farming system and its interactions that will result in increased productivity.

3. This progression nearly always implies an increase in labor productivity. Often, in early development stages, it does not imply an increase in commercialization or monetary profitability.

4. The analysis and attack are based on the agricultural systems in use by the farmers. The planning process involves the scientist with the farmer in gaining understanding of the system and deciding what changes and innovations to try. The farmer contributes an intimate understanding of the existing situation. The scientist brings broader, empirical information based on observation and measurements of alternative production technologies elsewhere. Identification of critical, limiting elements is a prerequsite to progress.

5. Farmers' goals, values, and concepts of utility shape their farming decisions and must be comprehended as the basis for considering potential new combinations of productive enterprises. The farmer focus of small farm development strategy is thus accented (Harwood 1979).

Tradeoffs between qualitative understanding of farming practices and quantitative estimates to support this insight are still being evaluated (Shaner 1979). The parallel in strategies for rural energy research and development is apparent. In operation, the most important feature of the farming systems approach is the emphasis on field teams working daily with farmers making on-farm analyses and testing new technologies (Consortium for International Development 1980). The field team is interdisicplinary and may include an agronomist, an agricultural engineer, a crop specialist, an agricultural economist, and a sociologist. Scientists specializing in particular commodities and disciplines and the extension service, interact regularly with the field team and project farmers.

The structure of applied rural energy research established in the ERD program has evident parallels with farming systems research, and may serve as testing ground for interagency and interspeciality cooperation in accomplishing qualitative understanding and improvement of energy as it contributes to agriculture and levels of rural life. To strengthen quantitative grounding of field applications of technology and their assessment by rural communities, well-focused data collection and analysis are required. As a contribution to quantitative analysis, the appendix to this report makes clear the distinction between farming and cropping systems and develops taxonomies that demonstrate approaches to systemic data development and interpretation. Quantitative advances, in turn, will be built by participating institutions into field activities fostering local development, assessment, and generalization of improved rural energy technologies.

APPENDIX A

CROPPING SYSTEM TAXONOMIES FOR RURAL ENERGY ANALYSIS

This appendix explores and illustrates cropping system taxonomies as a potential framework for rural energy analysis. It is presented for assessment by participating ERD institutions in their own country circumstances, as a basis for review and further development in the context of the ERD Methodology Workshop in Indonesia in early 1981.

The paper first defines cropping systems, including animal and forest enterprises, as a subset of farming systems. The focus of taxonomy development is on cropping systems. The focus on taxonomy development is on cropping systems, because these present direct material needs for energy inputs and have direct energy outputs. A locational taxonomy of cropping systems is formed through cluster analysis and a taxonomy including seasonal crop rotations is derived from a land-use map. Uses of such taxonomies are indicated for analyzing energy inputs to cropping systems for irrigation, fertilizer, and farm operations and energy outputs for cooking and other rural needs.

In conclusion, the wider dimensions of farming systems are briefly discussed. Classification factors are outlined for the study of socioeconomic and environmental dimensions of a farming system. These provide a change-oriented context for the use of crop taxonomies in studying energy constraints and opportunities in rural areas.

Cropping Systems as Subsets of Farming Systems

Energy constraints of agriculture, energy needs of rural households and opportunities for energy development based on renewable resources are directly associated with existing and potential patterns of crop, livestock, and tree production in specific rural areas. The study of cropping systems--defined for this purpose to include crop, animal, fish, and forest products--is therefore an essential foundation for rural energy analysis.

Cropping systems develop over time as a result of farmers' and communities' perceptions and decisions on ways of organizing biological production processes to produce plant and animal products, using resources of the environment such as sunlight, land, and water. Farmers' and communities' access to these environmental resources, against the context of subsistence needs and market demand for their products, constitutes the socioeconomic basis for their crop selection decisions. Farming systems in the full sense of the term encompass social and organizational factors, including distribution of resources and benefits, resulting in farmers' decisions and actions to choose or modify particular cropping systems using given environmental resources.[1]

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1. This holistic definition of farming systems corresponds with definitions currently in use by practitioners of farming systems research. Two may be

(Footnote continued)

These aspects of farming systems are sorted by Harwood into three major dimensions as a basis for analyzing and ordering these complex phenomena (Hardwood 1979). Each of these dimensions serves as a basis for developing classificatory factors and taxonomies. These major dimensions are as follows:

Environmental resources. Critical limiting resources and characteristics including water, topography, tillage, and fertility aspects of soils are assigned priority attention by Harwood.

Cropping systems. These include the most frequently observed as well as potential new combinations of crop and livestock enterprises. Forest enterprises must be added for purposes of energy analysis.

Socioeconomic and organizational factors. Socioeconomic determinants are organized by Harwood in a conceptual framework of development stages of subsistence, transition, and commercial small farming as a basis for analysis.

It appears that these major categories of farming system characteristics offer a useful and valid framework for organizing research on allied rural energy systems. An attractive feature is that much data has been organized, and is rapidly accumulating in analytic form, on farming systems in the humid tropics. It is feasible to adapt and add rural energy research to these conceptual and analytic frameworks, logically and in manageable research steps.

Phasing of Research

A logical sequence of research steps is set out below. In each country or subregion, the availability of data and stage of data and stage of research already attained would of course influence the combining of steps for locally oriented research. Steps are:

1. Analysis of existing systems (static analysis)

a. Develop locational taxonomies of the principal crop, forest, and livestock production activities as a basis for analyzing cropping system-energy interdependencies. Taxonomies would further be used to guide definition of sampling criteria and selection of crop types and areas for survey purposes.

b. Survey farm households on the established sampling basis. Questionnaires would focus specifically on energy input-output data for the

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1. (continued)
cited. "Farming systems, at any level of technology, include all the interactions of the commodity or commodities with all the physical, biological, economic, and sociological factors of their environment" (Consortium for Inter-national Development 1980). "The farming system is a set of biological processes and management activities organized with the available resources to produce plant and animal products" (Hardwood 1979).

principal crops in question and on energy uses and needs related to these cropping patterns.

c. Analyze sample data to determine if coefficients or ranges of coefficients between energy use and supply and principal cropping patterns can be established. Analyze variances in these relationships and differences among cropping systems. Reach a conclusion on the validity and utility of the identified coefficients, and of this approach, for quantitative estimation of aggregate energy-cropping system inputs and outputs.

d. If a positive conclusion is reached, adapt and apply this tested method to other subregions and crop taxonomies.

e. In combination with or in sequence to the above steps, extend the analysis from cropping systems to farming systems. Steps include: (1) form a conceptual framework and classificatory categories for studying the influence of socioeconomic and organizational factors on cropping system decisions; (2) establish and apply classificatory categories for analyzing environmental resource factors and their relationships to cropping system-energy patterns; (3) use the established classificatory schemes to identify measures and devise indicators of socioeconomic and environmental influences on cropping systems; and (4) use secondary data or, where necessary, obtain new data to establish associative patterns, regularities, or differences between farming system characteristics and cropping system-energy relationships. Classifactory categories relevant for this step are introduced in a later section.

2. Analysis of potential and prospective changes in farming systems (dynamic analysis)

a. Combine the understanding developed on socioeconomic and environmental determinants with the information obtained on cropping system-energy relationships to identify and evaluate prospective changes in cropping systems.

b. Analyze prospective related changes in energy inputs and outputs. This analysis would focus on contributions which new forms and quantities of energy could make to changes in farming system productivity and the distribution of benefits, and to meeting rural food and nutrition needs.

The purpose and use of this taxonomic and classificatory approach is to strengthen comparative analysis. As participating research institutions develop, refine, and compare results obtained through use of taxonomic characteristics, a basis will be created for wider generalization and projection of results. Taxonomies of cropping systems and classificatory characteristics of environmental and socioeconomic systems are illustrated below as research tools for these analytic steps.

Development and Use of Cropping System Taxonomies

To structure the analysis and take best advantage of existing data, the first step focuses on cropping systems. Specifically, the locational or spatial distribution of crop mixes and interdependencies is taken as a basis for establishing analytic constructs and sample survey procedures.

Where available in hectares, spatial distributions of crop mixes and seasonal rotations constitute estimation factors for the aggregation of related energy data. For this purpose, of course, coefficients of energy use and supply for the cropping system concerned are required. On a partial basis, more or less complete for the crop-animal-forest patterns concerned, such coefficients have been developed in a number of micro-area studies including those reported in PR-80-2. Use of these coefficients in conjunction with the development of crop taxonomies would contribute to definition of the scope and sampling procedures for the next round of micro-area studies.

A Locational Taxonomy of Cropping Systems. As a step in establishing systemic approaches in inter-country energy-cropping system studies, a cluster analysis of the locational distribution of crops in India is presented. For each of 21 states, the percentage distribution of gross cropped area sown to each of 31 crops is taken as a pattern vector. States are grouped through cluster analysis by their degree of similarity in crop distributions. Table 1 presents the principal clusters and crop percentages (to simplify, the table omits two small states and combines eight minor crops in the "other" category).

Eight groupings of states are formed in this procedure. The groups broadly conform to well-known geographic and ecological features of India. The cropping taxonomies are also well recognized (Duckham and Masefield 1969) and quite distinct among the groups of states. The cluster procedure gives a definite quantitative structure to these patterns. When represented as hectares sown to each crop in each cluster of states, in Table 2, a clear quantitative framework is established for systematic study of cropping patterns.

The crop distribution patterns in Table 1 vary from extreme specialization to substantial diversity. Most specialized is the monoculture Eastern Region (Assam, Orissa, West Bengal, Manipur, Tripura) with 68 percent of the cropped area in unirrigated rice plus 10 percent in irrigated rice. Broadly diversified, also with low irrigated area, are three states of the Western Region (Gujarat, Karnataka, Maharashtra) with 22 percent in jowar (sorghum), 13 percent in bajra (millet), 13 percent in oilseeds, 13 percent in cotton, and 9 percent in pulses. Quite different crop mixes characterize other major groupings.

A separate cluster analysis of sources of irrigation including canals, tanks, wells, and tubewells lends itself to study together with crop distribution clusters. Combined, they form a preliminary framework for structuring study of energy requirements for irrigation, by area and crop.

Four principal improvements in such taxonomies should be sought prior

Table A.1.

CLUSTERING OF STATES IN INDIA BY DISTRIBUTION OF CROP AREAS

Group of States	Crop											
	Rice (I)	Rice (U)	Jowar	Bajra	Maize (I)	Maize (U)	Ragi	Wheat (I)	Wheat (U)	Other Cereals	Gram (I)	Gram (U)
	Percent of gross cropped area (group mean)											
Andhra Pradesh Tamilradu	29.5	2.2	15.5	5.5	.1	1.1	1.1	0	0	8.0	.1	.5
Kerala	13.4	19.2	0	0	0	0	0	0	0	1.5	0	0
Bihar Madhya Pradesh Uttar Pradesh	7.4	22.4	4.8	2.1	.5	6.0	.7	9.5	9.9	4.4	.7	5.4
Gujarat Karnataka Maharashtra	2.9	4.8	21.7	12.7	.2	1.0	3.9	1.5	2.7	2.5	.1	1.0
Haryana Rajasthan	2.8	.5	5.7	24.9	.6	2.9	0	12.6	3.4	0	3.3	12.6
Punjab	7.5	.5	.5	3.9	7.9	3.1	0	36.1	5.3	0	1.5	3.8
Himachal Pradesh Jammu and Kashmir	14.5	3.3	0	1.1	2.7	28.9	.9	4.8	24.4	1.1	.5	.8
Assam Orissa West Bengal Manipur Tripura	10.2	67.9	.1	.1	0	.6	1.0	.3	.5	1.0	0	.5

Table A.1. (Conc.)

	Crop											
	Other Pulses	Fruits (I)	Fruits (U)	Vege-tables (I)	Vege-tables (U)	Oilseeds (I)	Oilseeds (U)	Cotton (I)	Cotton (U)	Jute	Other Nonfood Crops	Other
	Percent of gross cropped area (group mean)											
Andhra Pradesh												
Tamilnadu	7.0	.3	.7	.3	.5	2.2	14.1	.6	2.5	0	6.0	2.1
Kerala	.8	.8	11.5	.4	16.1	1.5	15.0	0	0	0	15.1	4.4
Bihar Madhya Pradesh Uttar Pradesh	10.5	.1	.4	.5	.3	.2	4.0	.1	1.1	.6	3.3	5.1
Gujarat Karnataka Maharashtra	9.0	.2	.1	.2	0	.4	13.1	1.1	13.3	0	3.0	4.2
Haryana Rajasthan	6.7	0	.2	.5	.2	.7	3.9	2.4	.2	0	7.6	8.3
Punjab	1.0	.2	.1	.3	0	1.7	2.8	8.1	.1	0	12.4	3.2
Himachal Pradesh Jammu and Kashmir	4.5	.2	1.4	.7	.2	1.4	0	0	.1	0	2.4	5.8
Assam Orissa West Bengal Manipur Tripura	3.3	0	1.1	.4	.7	.4	2.8	0	0	4.5	3.1	1.5

Legend: I Irrigated
U Unirrigated

Source: Data: Government of India, Ministry of Agriculture and Irrigation, All India Report on Agricultural Census 1979-71. New Delhi, 1975.

Analysis: Resource Systems Institute. Cluster Procedure: SAS Institute, Inc., SAS User's Guide, 1979 Edition

Table A.2.

GROSS CROPPED AREA BY CROP IN CLUSTERS OF STATES, INDIA
(hectares)

Group of States	Crop											
	Rice (I)	Rice (U)	Jowar	Bajra	Maize (I)	Maize (U)	Ragi	Wheat (I)	Wheat (U)	Other Cereals	Gram (I)	Gram (U)
Andhra Pradesh Tamilnadu	5,426	413	3,232	997	23	256	265	3	8	1,429	15	131
Kerala	211	303	0	0	0	0	0	0	0	24	0	0
Bihar Madhya Pradesh Uttar Pradesh	3,151	10,999	2,920	1,366	313	2,884	236	5,596	5,462	2,398	463	3,215
Gujarat Karnataka Maharashtra	1,021	1,955	9,169	4,758	63	326	1,315	549	1,078	841	34	420
Haryana Rajasthan	314	76	1,393	6,123	83	783	0	1,891	647	0	548	2,160
Punjab	411	27	27	215	431	169	0	1,974	288	0	85	205
Himachal Pradesh Jammu and Kashmir	254	60	0	19	48	514	16	86	437	19	1	15
Assam Orissa West Bengal Manipur Tripura	1,925	9,211	23	37	1	120	348	75	123	293	5	130

Table A.2. (Conc.)

	Crop												
	Other Pulses	Fruits (I)	Fruits (U)	Vege-tables (I)	Vege-tables (U)	Oil-seeds (I)	Oil-seeds (U)	Cotton (I)	Cotton (U)	Jute	Other Nonfood Crops	Other	Total
Andhra Pradesh Tamilnadu	1,419	58	144	51	86	367	2,744	90	462	0	1,229	343	19,191
Kerala	13	12	182	6	254	23	236	0	0	0	238	69	1,571
Bihar Madhya Pradesh Uttar Pradesh	5,510	27	179	284	125	94	2,318	53	673	202	2,003	2,956	53,427
Gujarat Karnataka Maharashtra	3,727	93	37	96	20	133	4,749	364	5,261	0	993	1,699	38,701
Haryana Rajasthan	2,049	5	19	63	26	125	1,077	330	73	0	2,587	1,203	21,575
Punjab	52	10	3	15	1	95	155	442	8	0	677	176	5,464
Himachal Pradesh Jammu and Kashmir	80	4	25	13	4	5	25	0	0	2	43	105	1,775
Assam Orissa West Bengal Manipur Tripura	276	8	103	109	121	117	691	0	2	640	625	128	15,811

Legend: I Irrigated
U Unirrigated

Source: Resource Systems Institute.

to use as a basis for sampling procedures:

1. Forest areas, by principal forest species, should be included in the cluster analysis if data is available.

2. Livestock data should similarly be introduced through a scale or index related to location incidents.

3. Disaggregation of the larger states into groups of districts forming recognized ecological zones should be attempted, if secondary data on crop area is available for districts.

4. Data for the latest available year should be clustered.

It is proposed that research teams in each participating ERD country ascertain and evaluate, in preparation for the 1981 methodology workshop, how far such data on crop distributions is at hand for comparable clustering procedures. The standard SAS cluster program used to develop this preliminary taxonomy is cited in Table 1.

Seasonal Variations and Cropping Patterns. The taxonomy just examined does not explicitly show seasonal rotations or variations in crop combinations for the areas analyzed. Whether for the analysis of existing or future energy-crop relations, seasonal sequences and alternatives must be established. Such a taxonomy of seasonal crop rotations and cropping intensity in relation to underlying land and water resource characteristics is provided in map form for regions of Bangladesh (World Bank/FAO 1971). The three rice growing seasons that form the basis for the map are as follows:

Aus. Pre-and early monsoon. Seeding March 15-May 15 (broadcast), March 1-April 15 (transplanted). Harvest mid-July to mid-September. Non-photo periodic, i.e., fixed growing period not affected by day length.

Aman (kharit). Monsoon. Seeding March 15-April 30 (broadcast), July 15-September 15 (transplanted). Harvest November 15-January 15. Photo periodic, i.e., length of growing period determined by day length, irrespective of when sown.

Boro (rabi). Dry season. Transplanted November-February. Harvest end of March-May. Non-photo periodic.

The underlying structure represented in the Bangladesh map is of 58 "Land Development Units". Each Land Development Unit is defined by distinctive topographic, hydrologic, and soil characteristics. Flooding and drainage characteristics are prominent. This basic mapping of land capability factors corresponds to the Environmental Resource dimension identified in farming system research.

Plant growth patterns are identified on the Bangladesh map in 31 combinations of crop, forest, grass, and fruit species. The 31 cropping

Table A.3 Principal Crop Rotations and Combinations, Bangladesh

Crop Rotation Type (Code)	Main Regional Incidence	Land Uses and Crop Rotations		
		Main Land Use	Secondary Land Use	Other Land Use
		MAINLY TRANSPLANTED AND RICE ROTATIONS		
12	NW, C, SW	Transplanted aman - fallow		
8	NW, C	Aus (part jute) - transplanted aman - fallow	Aus (part jute) - rabi crops (part fallow) on high ridges	
10	NW, C	Aus (part jute) - transplanted aman - fallow on poorly drained land	Mixed aus and deepwater aman - fallow in basins	Boro in basins
11	NW, C, E	Aus - transplanted aman - fallow	Transplanted aman - fallow	
7	SW	Aus (part jute) - transplanted aman - fallow		
5	SW	Aus (part jute) - transplanted aman - rabi crops		
6	SW	Aus - transplanted aman - rabi crops		
13	E	Kharif dryland crops and transplanted aman - fallow on river terraces	Transplanted aman - fallow in valley bottoms	
9	C, E	Aus (part jute) - transplanted aman - rabi crops	Mixed aus and deepwater aman (part jute) - rabi crops in basins	

Table A.3 (cont.)

Crop Rotation Type	Main Regional Incidence	Land Uses and Crop Rotations		
		Main Land Use	Secondary Land Use	Other Land Use
(Code)		MAINLY BROADCAST AMAN (DEEPWATER) ROTATIONS		
14	NW, C, WS, E	Mixed aus and deepwater aman - rabi crops	Deepwater aman - fallow in basins	Aus (part jute) - transplanted aman - fallow; aus - rabi crops on highest ridges
16	NW	Deepwater aman - fallow (part rabi crops)	Mixed aus and deepwater aman - rabi crops (part fallow)	Aus (part jute) - rabi crops on ridges
17	NW, C, E	Deepwater aman - fallow in depressions	Aus - transplanted aman - fallow on ridges	Transplanted aman - fallow on ridges
19	C, E	Deepwater aman - fallow	Mixed aus and deepwater aman - fallow on ridges	Boro in basin centers
20	NW	Deepwater aman - fallow		
		MAINLY AUS RICE ROTATIONS		
3	NW, C, E	Aus (part mesta) - fallow (part rabi crops) on well drained land	Transplanted aman - fallow on poorly drained land	Deepwater aman - fallow; aus - transplanted aman - fallow
1	NW	Aus (part jute) - rabi crops on ridges	Aus - transplanted aman - fallow in depressions	
4	SW	Aus - fallow	Swamp grassland	Deepwater aman on basin margins

Table A.3 (conc.)

Crop Rotation Type	Main Regional Incidence	Land Uses and Crop Rotations		
		Main Land Use	Secondary Land Use	Other Land Use
(Code)		MAINLY BORO RICE ROTATIONS		
21	E, C	Boro	Grassland	Deepwater aman - fallow
		FOREST		
25	C, E	Forest	Aus - transplanted aman - fallow in valleys	
26	SW, E	Forest or forest reserve		
		GRASSLAND		
27	E	Grassland and scrub regrowth with jhum (shifting) cultivation of aus rice intercropped with maize, cotton, sesamum		
30	E	Seasonally flooded grazing land	Cultivated land (aus, deepwater aman, boro or rabi crops)	
31	NW, C, SW, E	Pioneer grassland	Bare alluvium	Cultivated land (aus, deepwater aman, transplanted aman, millet, cheena or other rabi crops)

Legend: NW - Northwest. C - Central. SW - Southwest. E - Eastern

Source: World Bank/FAO. Bangladesh Land Use Associations, Map V, 1971 (Preliminary). Scale 1:500,000.

patterns (termed "Land Use Associations" on the Bangladesh map) are overlaid upon Land Development Units, permitting inspection of correlations and differences between land use and land capability patterns. Color codes facilitate direct study of crop-environment systems and subsystems.

To draw implications from Bangladesh Land Use Associations for energy analysis, the principal cropping variations and their seasonal patterns are translated from the map to the taxonomy of crop rotations, species, and varieties presented in Table A.3.

To simplify, the 31 crop rotation and crop mix types shown on the Bangladesh map are reduced in Table 4 to 23 types that account for virtually the entire area mapped. These could be further grouped to form sample areas for energy analysis.

As a framework for ERD research, Bangladesh planners anticipate using the eight ecological regions established for purposes of integrated rural development planning. Pricipal crop rotation types reflected in the Table 4 taxonomy, selected to represent each of the eight regions, constitute a basis for selection of sample areas for rural energy analysis. The pioneer study of 23 villages in Nabagram Union, Barisal District (Islam 1979), interpreted in the context of the cropping type within which this union is located, offers a foundation for evaluating sample size and areas.

Classificatory approaches for socio-economic and environmental determinants of cropping systems

Attention is directed here to step le, the identification of associative factors between cropping systems, on the one hand, and existing socio-economic and environmental influences, on the other. Before designing micro-area studies for the purpose of observing and measuring energy-cropping system coefficients, awareness and structuring of influential social, organizational, and environmental factors is desirable to sharpen local studies and, hopefully, reduce their complexity.

Small farm development stages. The descriptive classification of small farm development stages and associated propositions on crop diversity and farm power requirements, formulated by Harwood, is presented here in summary form as a means of promoting systematic study of socio-economic and organizational determinants of crop-energy relationships (Harwood 1979). Two overall propositions advanced by Harwood are central to the analysis: (1) when resources are limited, increasing interactions among complementary farm enterprises is the key to improved productivity, and (2) for small farmers, the critical factor in more intensive and efficient use of scarce resources is diversity. "As any resource becomes scarce enough to limit production, diversity becomes increasingly important to its optimum utilization...The farmer can increase the efficiency of his labor and power use in a single-crop, intensive sequence by planting varieties of differing growth periods, by using a variety of planting methods, and by planting at different times" (op cit, p. 118).

The starting point of farming systems analysis in this context is the identification of significant interactions - of people with plants and animals, plants with other plants, and plants with animals. More efficient uses of animal wastes and crop residues for energy - or food - purposes are equivalent to new farm enterprises. Increases in the number of enterprises are regarded by Harwood as particularly important in the transition from subsistence farming. This is represented in Figure 1, which summarizes the principal small farm development stages identified by Harwood.

Principal economic determinants of crop type and cropping intensity, for a given physical environment, are labor, management capability, power, cash, and subsistence or market demand. Farmers' goals, values, and utility concepts shape their cropping decisions, given their resource position. Size of farm, land tenure, and farm layout are additional key factors in farming intensity and crop-animal-forest combinations.

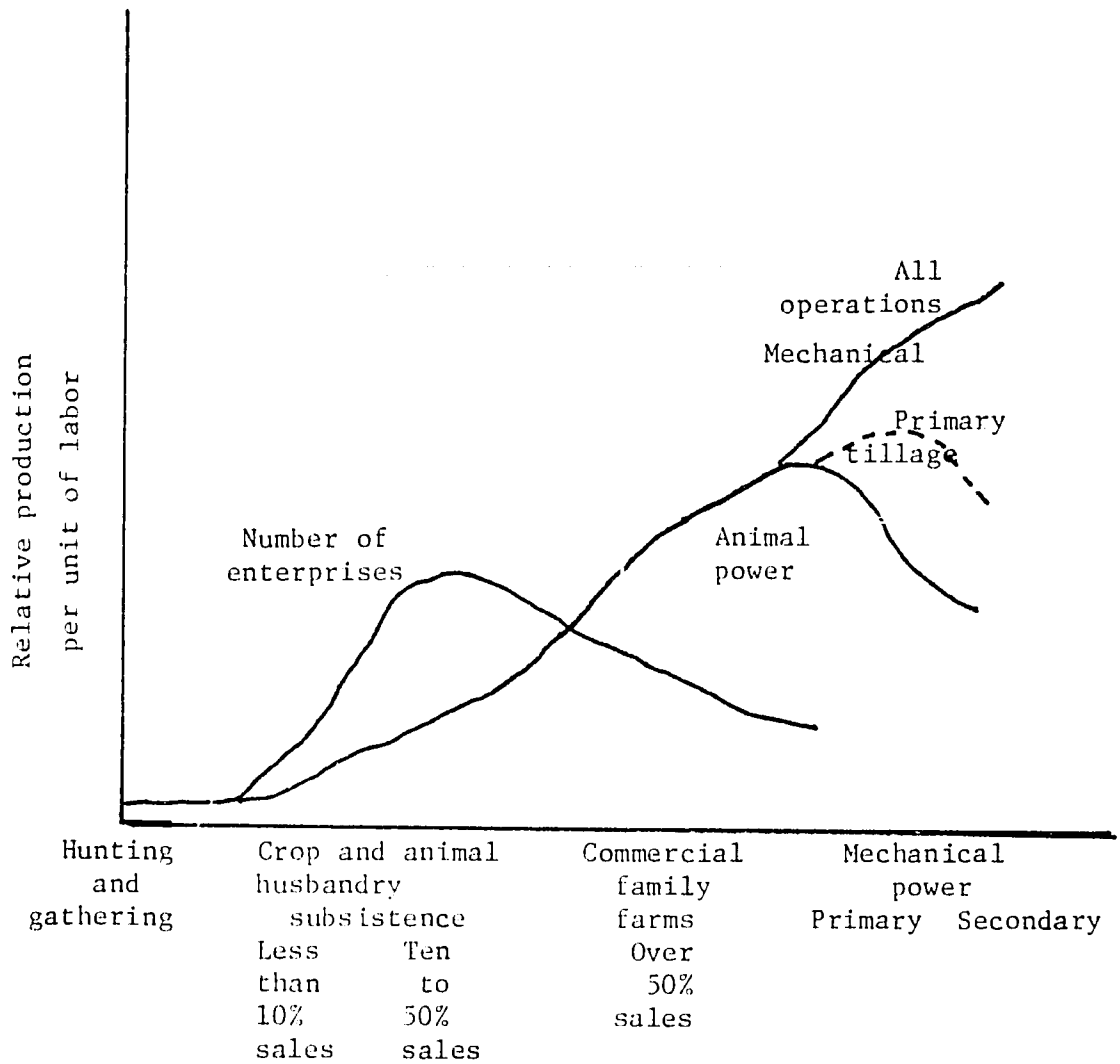
In selecting sample areas, villages, and farm households for data collection, available secondary data on the proportions of farms and areas represented in each of the principal development stages should be reviewed. Sample size should reflect these variables. Differently phrased questions will undoubtedly be needed for subsistence as contrasted to commercial farms, diversified as contrasted to single-crop farms, and animal-powered versus tractor-powered farms.

Critically limiting environmental factors

Critical environmental resources of land and water are subject to classification and analysis as the basis for assessing potential cropping improvements. Number of months' rainfall less than 100 mm and 100-200 mm influence the annual number of growing seasons where irrigation is not provided. Land characteristics of topography, tillage, fertility, and drainage are assayed. Seasonal crops, annual crops, and long-gestation crops including trees are evaluated against these environmental resource factors, identifying opportunities for more productive combinations of enterprises.

Figure 1.

SMALL FARM DEVELOPMENT STAGES



Source: Adapted from Harwood 1979.

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