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EXAMINING THE AGRICULTURE - ENERGY INTERFACE [1/]

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EXAMINING THE AGRICULTURE - ENERGY INTERFACE

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Introduction and Purpose of Paper

Food production and energy are two priority areas of concern in most developing countries; they are also priority components within a good many of A.I.D.'s assistance programs to these countries. However, while there are several recognized interrelationships between these two growing problem areas, for the most part, they have been treated as mutually exclusive concerns when, in fact, they have an extensive and critical area of interface that needs to be jointly addressed, rather than approached separately from each of the individual perspectives. In general, there has also been too little interaction within the Agency (and elsewhere) between those responsible for developing/managing programs, projects and activities related to food production (on the one hand) and energy source-development/generation/utilization problems (on the other). The result has been "less-effective-than-desired" efforts in addressing such concerns, wherein there is substantial overlap and important interdependencies.

The Joint Research Committee's Interest in Topic:

The Joint Research Committee (JRC) of the Board of International Food and Agricultural Development (BIFAD) is currently focusing its attention on this agriculture-energy interface, with a view to better identifying and understanding these inter-relationships and linkages (both technical, economic and social) between agriculture and energy production, utilization and conservation, especially in the lesser developed countries (LDCs). The ultimate purpose being to determine priority research needs relative to effectively addressing the mutual problems associated with:

A. Increasing LDC food production, within an environment of rapidly rising energy costs and a growing scarcity of traditional and conventional energy forms and materials; and

B. Seeking ways by which agriculture can also effectively contribute to easing this energy crunch, by providing a dependable and low-cost supply of renewable energy-materials to help meet the energy demands within agriculture and other sectors, without seriously reducing food production capabilities.

At first glance, the stimultaneous pursuit of the above (two) goals may appear to be conflicting, even at best. However, there is considerable evidence to indicate that this need not necessarily be the case. In fact, such a joint pursuit may not only be compatible but actually reinforcing,

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1/ The author is a member of the Joint Research Committee (JRC) of the Board of International Food and Agriculture Development (BIFAD) and also on the Energy Working Group of that Committee.

when carefully carried out. Moreover, because the problems which even partial success in such joint efforts could help resolve are so serious, there is really little choice but to investigate such possibilities thoroughly. Part of this thoroughness relates to identifying the necessary research that will be required; and this, in turn, becomes the ultimate focus of the Committee's present concern. Consequently, then, what are the priority problems to be studied; how can needed research efforts best be organized and carried out; and what should be AID's role in helping organize these efforts or assisting directly in the research itself?

In trying to get a reliable handle on these questions, the JRC would like to solicit the help and assistance of those in the Agency who are working in and knowledgeable of this area. And, because of the above-mentioned tendency to view energy as a distinct sector, separate from other economic activities and with little joint-involvement by agriculturalists, rural development specialists and energy experts, it is hoped that this paper will not only stimulate the in-house collaboration necessary to effectively service JRC's needs but also encourage longer-lasting cooperation, communication and interchange among all those involved - both inter-bureau as well as intra-bureaus. This can but only result in a more effective effort to both solve the growing food production and energy problems within the LDC community as well as in developing and carrying out AID's assistance programs in support of these efforts.

Elaborating on the Underlying Concern:

Two steadily-worsening world conditions, both of which erupted during the 1970's, provide the starting point for both examining this agriculture-energy interface, as well as in establishing a sound basis for addressing its several, interrelated aspects. The conditions referred to, of course, are:

A. the growing world food-deficit brought on by a continued high population growth and the inability of many countries to maintain offsetting growth-rates in their food production capability; and,

B. the so-called "energy crisis", caused by accelerating demands for energy fuels, especially fossil-based fuels; the resulting 3-4 fold increase in petroleum prices; and, the consequential economic and financial havoc this has wrought.

While the underlying causes of these separate developments have little relationship to each other, it is increasingly clear (as implied earlier) that satisfactory and effective solutions to many of the problems

associated with them are very much interrelated.[2/] In fact, it is precisely because of this interrelationship, and a concern that this linkage may not be fully recognized and/or taken into account by those developing or offering solutions to these interlinking problems, that constitutes the "felt need" for a more comprehensive approach wherein agriculture's overall (dual) role is thoroughly examined.

Thus, our concern starts with the need to significantly increase food production, especially in the lesser-developed countries where the food deficits mainly exist, recognizing the role that energy-inputs must play in achieving this greater agricultural output. However, it also begins with a recognition of the growing energy scarcities and rising costs; the need to both converse energy where possible, as well as develop dependable energy supplies from new and renewable sources; and, the role that agriculture can play with regard to the latter. From this starting point, our concern first centers on how greatly-increased energy costs, and the need to both reduce overall energy requirements as well as adjust to an increased dependence upon alternative energy sources and forms, will impinge upon efforts to increase food production; and, what can be done to offset any adverse effects. Finally, our concern broadens to include the extent, and in what ways, agriculture can best be assisted to carry out the dual responsibility of helping the search for new and reliable energy sources as well as meeting the increased demand for greater food production, focusing particularly on the role of research and the identification of research priorities.

2. Reviewing Food Deficits and Food Production Problems

The widespread and deep-seated food-deficit situation continuing to exist, and expected to intensify, throughout the third-world is well-documented. Thus, little time will be devoted to establishing this fact, except to cite a few statistics to stress the magnitude of the problem. Instead, attention is focused primarily on efforts needed to significantly expand food production capabilities and the constraints standing in the way of achieving these production increases.

Hunger and LDC Food Production Needs:

The Report of the Presidential Commission on World Hunger, as well as other studies/investigations, effectively points up the seriousness of the hunger problem, which is not so much in the form of periodic famine and resulting outright starvation but with the less-dramatic occurence of chronic malnutrition and its even more devastating toll on human lives.

2/ A third general area of concern also exists, which is and will be adversely affected by energy problem and their solutions, and needs to be given adequate consideration when chosing the, the environment. However, while important, this concern and its relationship to the agriculture-energy interface will not be given further attention in this paper.

The Food and Agricultural Organization of the United Nations estimates that as many as 450 million people were severely undernourished in the developing world in 1975.

This number can be expected to go much higher during the remaining two decades of the 1900s, unless food production capability increases faster than the 2.5 percent per year improvement, averaged collectively by the developing countries between 1950 and 1975. For, population growth during this same period exceeded 3.0 percent per annum and is expected to continue at this pace for some time, even though fertility rates themselves appear to have started to decline. By the year 2000, world population is expected to reach 6-6.5 billion, from its present level of around 4.3 billion - an increase of 300-400,000 people per day (to be fed) throughout the 1980s and 1990s.

Any successful attack on world hunger, and particularly the food-deficit problem in most LDCs, will require a concerted effort by both the developed as well as developing countries, including improved trade arrangements, food assistance and international food security schemes. But most importantly, it must include the expansion of food production capabilities within the countries where these deficits exist. In fact, the first priority of food policy in developing countries, particularly those of sub-Saharan Africa and South Asia, should be greater domestic production. However, self-sufficiency should not necessarily be the goal of all such countries. Specialization and industrialization should be pursued where conditions and resources dictate it to be the most efficient course. But, whichever the choice individually, collectively food production must be increased significantly between now and the end of the century, and most of this increase needs to take place in the LDCs themselves.

The Brandt Report (North-South: A Program for Survival) estimates the Third World will be importing 145 million tons of food annually by 1990 alone, unless greater agricultural progress in the developing countries is achieved. It is unlikely within the prevailing economic climate that these countries' exports, even with additional foreign aid, can finance such massive food imports. And even if the financing problems can be solved, there are doubts whether major producers (developed countries), especially grain producers, could supply the amounts needed. The developing world has to contribute over the next ten - to - twenty years, if any progress is to be made in allevating the present deficits and averting an even worse situation, as population growth and the increase in demand for food accelerates.

Increasing Food Production in the LDCs:

By the year 2000 the world will have to be growing 50 percent more food than today, just to maintain present (inadequate) intake levels.

Considerably greater increases will be required between now and the end of the century if we are to conquer famine and malnutrition and to accomodate the requirements for improved nutrition, as well as meet the increased demands arising from higher incomes. This is a formidable task and can only be achieved by an accelerated growh in food production capability world-wide, but especially in the LDCs wherein the greatest increase in the demand for food will come.

Sustaining this needed higher growth-rate of production can only come about by a modernization of agricultural production processes; that is, purchased inputs must be increased and resources used more intensively, in conjunction with an expansion of the land-base, in areas where this is possible. The funds and the physical quantities involved in achieving this will be tremendous - the value of current production inputs (from outside agriculture) can be expected to double between 1980 and 1990 and then almost double again by the end of the century, according to the FAO Conference Report, "Agriculture: Toward 2000".

Investment in the agricultural sectors of the lesser developed countries will particularly have to be increased substantially. The domestic industries and infrastructure to deliver the above-mentioned inputs and to handle the output (marketing) efficiently will also need to be developed. The rapidly rising demand for agricultural products, in face of limited natural resources, calls for an increased reliance on science and technology. Research must play a fundamental role in achieving this needed increase in production. This, in turn, will require greater investment in agricultural research, particularly in adapting present technologies to developing-country agriculural conditions as well as concentrating on selected areas and subjects where the pay-offs seem likely to be high.

This scientific effort must be buttressed by the development of effective institutional systems to carry its results to farmers and other agricultural producers-education, training and extension, as well as research will require much more support. For, in addition to the materials-inputs needed to increase production, the human factor becomes equally important; it is the way that resources are brought together and the transformation process organized and carried out that really determine effectiveness. Improved technologies are needed but, it is the management of these technological-based production systems that is crucial to achieving the output increases required.

Finally, producer prices must be judged renumerative by farmers if they are to respond adequately. Policies and government programs affecting agricultural production must be chosen carefully, as well as the choice of policy instruments. Restructuring of the production system may be required in some countries. Whatever the kind of land-ownership or land-use arrangements are followed, they must give security and incentive to the producer. More attention will also have to be given to the small

producer and his needs, but he will have to be converted into a bona fide commercial farmer, rather than a largely subsistence one, if he is to make any real and lasting contribution to meeting the growing food production needs.

The Energy Dimensions of the Task:

Returning now to the particular focus of this paper, (the agriculture-energy interface) it clear that many of the requirements outlined above involve energy use. And, while this dimension of the overall food-production effort will be taken up in a following section, it should be clear at this point, that the extension of low-energy production techniques now commonly used in most LDC production systems will not produce the surpluses needed to feed the rapidly growing populations, especially when much of this increased demand will come from the urban masses.

Likewise, no attempt will be made at this time to assess the energy requirements or to evaluate alternative ways of reducing these requirements (in veiw of the increased costs and growing scarcity of petroleum fuels) and/or meeting more of these demands from other (renewable) energy sources; however, some analysis of these aspects will be presented later. Nonetheless, two points can be made relative to future energy requirements and sources within LDC agriculture- these requirements will be greater, not smaller; and , new sources for supplying this energy must be found if future food production demands are to be met.

3. Energy Crisis in the LDCs

From a developmental perspective, energy ranks high as a necessary ingredient to socio-economic progress. The history of civilization is largely a story of man's progress in harnessing energy by converting it into useful and more productive forms. For that matter, a high level of agricultural (and/or industrial) productivity can be attained only when non-human energy sources can be so harnessed to supplement the productive capacity of raw manpower; the poorer areas of the world must develop and effectively utilize expanded energy sources before they hope to offer fuller lives to their people. Consequently, as economic and social progress requires the increased use of energy, additional energy supplies and new sources will be needed as populations increase and higher levels of development are achieved.

The Growing Demand for Energy:

Obviously, man's own power (energy) capacity is extremely limited and insufficient by itself to achieve and maintain a reasonable standard of living; other forms and sources of energy are necessary to supplement this means. Animal power and wind/water/solar power were all harnessed rather

early on. Fossil fuels, first coal/peat and later petroleum-based fuels, were subsequently developed and used to replace these and/or to supplement wood and other (natural) organic materials for producing heat, generating electricity and producing mechanical power through application of the steam and internal combustion engines. Total energy consumption per person increased four-fold during the past 100 years, most of this occurring during the last two decades.

However, to date most of this increase has taken place in the more developed countries. Moreover, consumption has been mostly in the form of petroleum fuels, natural gas and coal, all of which are finite resources whose excessive use (particularly the former) has led to one part of the present overall energy crisis faced by the LDCs - the high cost and scarcity of petroleum-based fuels. The other dimension of the LDC energy crisis has its roots in the developing countries themselves and pertains to the growing and serious scarcity of traditional cooking and heating fuels (e.g. - firewood, charcoal, dung and agricultural wastes). This latter phenomenon is also caused by rapid population growth; and, in the absence of any efforts to encourage the wise use and conservation of these renewable resources or efforts to ensure their continued production, is exerting new greater demands for the scarce petroleum fuels.

In total, the above situation is creating a very difficult dilemma for most LDCs Government. Because of their pressing food production (and other socio-economic development/requirements) LDCs need access to as much energy as they can get, as cheaply as possible; and this demand can not be met because of a deteriorating supply situation on two fronts. In fact, it is a combination of this accelerating high-cost (and scarcity) of fossil fuels (and the accompanying economic, financial and balance-of-payments problems this is creating) along with the diminishing availability of traditional, non-commercial energy materials upon which people in the LDCs principally rely, that is at the heart of our concern regarding the energy crisis in the LDCs.

Consequently, from a solution perspective, we see that as traditional fuels and energy sources become scarce, due to increased demands, regions are forced into the commercial market for conventional[3/] fuels (particularly petroleum-based fuels); and/or, firewood, charcoal and other customary fuels must be imported from other, more distant areas. At the same time, broader development needs are also pressing for the greater use of conventional fuels. Unfortunately, the possibilities of replacing dwindling traditional supplies with conventional sources, or the latter's expanded use by LDCs in achieving a modern, technology-based means of stimulating socio-economic development generally, as well as meeting the increased demands for greater

3/ The commonly used term "conventional energy sources" refers to petroleum fuels, natural gas, coal and even nuclear energy; all of which are also only available through commercial sources.

food production, have been severely set back by fossil-fuel price rises since 1973. Thus, the solution, as well as the problem is primarily one of supply, although there is much room for more efficient use and conservation of energy as well.

Efficiency, Conservation and New Energy Sources:

Needless to say, all of the above has resulted in a deteriorating economic position for the rural and urban inhabitants of most developing countries. A position which together with the mounting energy demands associated with increased food production and the broader socio-economic development needs (also cited earlier), places energy as well as food production high on the list of priority areas that must be effectively addressed by a majority of LDC governments. It also brings into focus the need to make more efficient use of limited (and costly) energy supplies, to converse energy in all ways possible, and to develop new, and particularly renewable energy source, if these demands are to be met.

Efficiency and Conservation: Prior to the present energy crunch, development policies, in both developed and developing countries were generally able to ignore proper management and the effective use of non-commercial energy sources, because of the cheap oil that was generally available. Nor was efficiency, in the use of petroleum-based fuels, given very much attention because of its relatively low-cost and seemingly more-than-adequate supply. This attitude is obviously now changing; there is growing interest in minimizing waste and inefficiency in energy use and in applying techniques for expanding productivity and production in all sectors with smaller increments of energy inputs.

And, while this need for greater energy-use efficiency does apply to all sectors, it should be stressed (and will be elaborated upon in the next section) that agriculture is not the primary culprit with respect to excessive energy consumption. As cited earlier, agriculture is an under-consumer of energy in the macro sense, even though there is room and need for conservation and efficiency in its more micro application. Moreover, despite possibilities (and the need) to conserve energy and to use it as efficiently as possible, agriculture should not be viewed as the place where LDC governments can best curtail commercial energy use; not if it expects to produce the increased volume of food that will be needed to feed the expanding populations and lay the basis for broader rural development.

Also, although agriculture (like other sectors) will ultimately have to survive without petroleum, requiring a switch to other, largely renewable sources, its more immediate (and increasing) energy demands will have to be met primarily from this and other conventional supplies. This fact further strengthens the need for conservation and efficient energy use of these fuels; and, in addition to the needed search for lower energy-requiring

agricultural production technologies and food production/processing/distribution systems, this also strengthens the call for concerted efforts (now) to develop both alternative energy sources and production/conversion/utilization systems by which these resources can be effectively and efficiently used.

New and Renewable Sources: While precisely speaking many of these "hoped-for" supplies are not new but (more correctly) little-used and/or not fully-utilized resources, the category of new and renewable energy sources include hydropower and geothermal resources, solar energy, bioconversion, wind energy and the energy potential of the sea. However, sticking to the focus of this paper (agriculture) further attention shall be limited to only a subset of the above. Other sources, which may also be increasingly relied upon in both the short and longer term, include animal power, fuel-wood/charcoal (where resources are available, or can be developed) and petroleum-fuels and oil shale, tar sands and heavy oils. With regards to agriculture as a supplier of energy materials, interest will essentially be restricted to biomass production, conversion and utilization with major emphasis on production aspects. Attention will also be given to improving the efficiency of the photosynthesis process and alternative sources of supplying plant fertility, including biological fixation, as well as the increased use of manure and improved cropping practices. In fact, efficiency in the use of energy as well as its conservation are important and major considerations that will also be addressed in more detail in a later section.

4. Focusing on the Agriculture - Energy Interface

First of all, compared to other economic sectors, LDC agriculture is not a large user of energy, particularly commercial 4/ energy (See Table 1); less than 5 percent (4.8%) of the total used in developing countries is used in agriculture. Although this is somewhat higher than the overall world-average (3.5%), it is exceedingly lower in terms of actual energy-input per hectare and per agricultural worker (also see Table 2). Second, it should also be noted that productivity (output) per hectare and agricultural worker is likewise lower in the LDCs; this being highly correlated with the level of commercial energy used. There are, of course, other important factors explaining this lower agricultural output in LDCs but these low-levels of commercial-energy use can not be ignored as a significant reason for the correspondingly - lower agricultural productivity. Moreover, as cited earlier, the needed increase in food production in most LDCs can only be achieved through substantially increasing this low level of energy inputs.

This is an important matter to keep in mind in developing a framework for our efforts to jointly address the problems of food production and energy. It does not mean that efficiencies can not be achieved nor that conservation efforts should not be pursued; quite the contrary, these become even more important in view of this requirement. But it also points up the

4/ Commercial energy refer to all energy fuels (gasoline and disel oil) or energy materials (fertilizers and pesticides) sold in formal marketing channels. Fuel-wood and charcoal, while marketed locally are not usually included in this category.

fact that more total energy will be required; thus, the need for new energy sources, as well as efforts to make present supplies go farther and to reduce energy costs per unit of output. Agriculture will have to become more efficient by increasing output per unit of energy input, through the adoption of low-energy production/processing/distribution technologies; and, it will have to contribute substantially to alleviating the energy supply shortage (itself) through the production of energy materials for its own use as well as other sectors.

Projected Energy Needs of Agriculture:

As stated earlier, if food demands are to be met, rapid increases in commercial energy-inputs are needed, especially in developing countries where the use of these inputs is very low. However, it has been, and will continue to be, difficult for most oil-importing countries (again, particularly the LDCs) to finance sufficient commercial energy imports as prices continue to rise. Thus, it is important for them to determine how much of their total supply of commercial energy is essential for agricultural production and to adopt policies and programs to meet those needs, as well as develop new, domestic energy sources in view of these requirements. Tables 3 and 4 show estimated and projected use of commercial energy of various country groupings both by use and by each of the four, leading energy-input categories; the topic of supply sources is taken up in the following sub-section.

As may be seen, energy-input requirements for agriculture in the developing countries are expected to increase by over 175 percent between 1972/73 and 1985/86, while percentage increases for the developed countries is projected to be less than one-third this level (56%). In absolute amounts, actual increases in demand for commercial energy also will be higher in the LDCs, during this period, than for the developed countries as a group. Energy inputs in the form of fertilizer will constitute the largest single input-category, increasing between 3-4 times earlier levels. By 1985/86, the use of commercial fertilizer will almost equal that of the developed countries, constituting over seventy percent of total commercial energy consumption.

Farm machinery manufacture and its use constitute the second largest energy input(23.5%); and, although slipping some, in terms of relative importance and in relationship to fertilizer-use, actual usage in LDCs is projected to also increase about 2½ times by 1985/86. Pesticide use in LDCs is, in fact, expected to show the largest percentage increase during these periods (almost six-fold), even though this category will still constitute less than 2 percent of total energy inputs in agriculture. Irrigation energy requirements are also projected to essentially double the LDCs between 1972/73 and 1985/86; however, as a percentage of total energy use its share will drop from 7.5 to 4.3 percent for the developing countries as a group.

Obviously, these projections are subject to considerable error and vary from country to country. However, despite their shortcomings, they do offer some insights into where more-efficient and energy-conserving technologies could make the greatest impact and/or where the greatest opportunities may lie, relative to using new and more abundant energy sources and supplies. This, in turn, gives some broad guidelines regarding where research efforts may wish to be concentrated as well.

Agriculture as a Supplier of Energy Materials:

As also noted earlier, with petroleum and other finite energy supplies becoming scarcer and their costs skyrocketing, interest in developing reliable, alternative energy sources has accelerated; and, from a supply perspective, the greatest possibility and the one most clearly related to agriculture, is biomass production/conversion. In fact, almost by definition, biomass production is synonomous with agriculture, although as a resource base this category includes the use of sewage sludge and municipal/industrial (solid) residues and wastes, as well as standing vegetative growth and agricultural/forestry residues and processing by-products (aquatic vegetative growths also holds great potential).

The latter three sub-categoreis are the areas of primary interest, with terrestrial vegetative growth, including woody (silvicultural) crops, particularly short-rotation tree crops; herbaceous crops; standing forest biomass, cull trees and non-economic stands; and, some conventional crops produced by traditional farming methods. Agricultural residues refer to such resources as wheat straw, animal manure, maize stalks, and basse; processing by-products, on the other hand, pertains to such items as rice hulls, wood trimmings, sawdust, etc. These can be used (through conversion processes) to produce heat, steam, electricity, liquid and gaseous fuels (including alcohols, synthetic petroleum and oils), charcoal, low/intermediate/high caloric value gas and other energy intensive materials such as petrochemical substitutes and fertilizers.

In total, it is estimated that about 15 percent of the world's energy-needs are currently provided from biomass; this is equivalent to 20 million tons of oil per day, and the percentage is much higher in the LDCs where petroleum and other fossil fuels are less utilized and where a larger proportion of the two billion people, who depend upon biomass for their primary energy source, live. In terms of potential, it is also estimated that the current world production of biomass, if converted by known means, would yield the equivalent of six times present total energy consumption levels. Thus, while good information does not exist relative to the geographic distribution, either of current production or its potential, it is generally agreed that biomass is an important and vital energy source which will be used increasingly as the petroleum-based fuels become more expensive and harder to supply. Vegetable oils and other products may also be used (almost) directly as fuls, although presently costs are still generally prohibitive.

5. Priority Problems and Research Needs

There is little question that food and energy requirements pose paramount problems for the world as a whole, as well as for a majority of the LDCs where the demand for food is growing most rapidly and where the economic, financial and resources situation relative to the energy crisis, is least favorable. Can a balance between energy and food supplies be maintained, as populations continue to grow and petroleum supplies remain uncertain? What alternatives are there to petroleum as an energy base? What range of options or alternative strategies should be considered by planners, agriculturalists and energy technologists? Where are the most pressing problems areas within this agriculture-energy interface and what are the priority research needs relative to these problems?

No attempt will be made (in this paper) to answer these questions; however, three broad categories, into which all efforts to resolve or improve the above-described food production/energy dilemma must fall, will be discussed briefly. But, it is through responses, hopefully stimulated by this effort, that such answers will be forthcoming, particularly with regard to the latter two questions concerning priority problem areas and research needs.

More Efficient Energy-Use Within Agriculture:

Much research has been devoted to increasing the efficiency of agricultural production, including water management, fertilizer use and machinery design, selection and operation. However, until now, the focus has not been on energy, although was discussed earlier, these are the big users of energy, and will remain so for the LDCs generally. Below are several broad, candidate-areas for efficiency improvement:

(a) Reduce energy waste through better management and improved farming practices.

(b) Investment in (new) more energy-efficient technology.

(c) Adoption of crop-livestock mixes and production systems that have lower energy requirements.

In addition, energy requirements can be reduced by changing consumer habits and improving food processing to conserve energy. There is also great potential for increased photo-synthetic efficiency, which needs greater attention by agronomists, plant bree-ers and bio-chemists. However, these offer only longer-run prospects; in the immediate future, energy savings and efficiency will have to be sought primarily within the food production process itself, as well as through reduced harvesting and storage losses, (better preservation techniques and facilities) and improved conversion of grain and forage into livestock products (through

selected breeding and good management practices). All of these will require continued research. Table 5 provides a rather comprehensive list of areas where energy savings can be achieved and areas where further research will likely be needed. This listing was compiled by two workshops sponsored by the U.S. Energy Research and Development Administration (1976).

Alternative Energy Sources/Supplies for Agriculture:

As we saw earlier, the total amount of energy consumed by agriculture will continue to increase, if the growing demands for food are met. This increase will occur despite efforts to conserve energy through the elimination of waste, adoption of low-energy systems and technologies and achievement of improved efficiencies in all aspects of agricultural production. Thus, with supplies of traditional and more conventional energy forms and sources disappearing and/or their costs increasing several fold, new, alternative sources (primarily renewable sources) must be found to supply or at least supplement agriculture's energy needs, especially in the more distant future. These new sources and forms will also require new application/utilization technologies, as well as technological advances in the production and conversion of these energy materials to more readily useable forms. Continued research is needed in all these areas.

Solar energy is perhaps one of the most obvious alternatives to conventional sources and, of course, is already widely used in grain drying and heating of water. The technical efficiency of such systems are expected to improve in the future as their economic competitiveness improves and the cost of fossil fuels continue to rise. Improvements in solar-powered cooling systems can also be expected in the near future, as well as development and use of small, solar-powered electric generators, suitable for communities remote from electric networks. Direct photovoltaic conversion systems can also be expected to become commercially available and put into use as development/installation costs come down. Wind energy and hydropower, particularly the former, also offer good potential for agriculture in some areas, especially for pumping water and/or generating electricity. Research and development efforts in all these areas are expanding.

Photosynthetic products (organic matter produced through plant growth), as mentioned earlier on, holds a tremendous energy potential for agriculture as well as other sectors. And, while this source will be disucssed in more detail in the following subsection (Agriculture as an Energy Producer), it should be mentioned here that the photosynthetic process (itself) is subject to technological advances as sophisticated in their own way as those for photovoltaics. And, when human utilization of sunlight is viewed as an energy source, the criteria for chosing and timing of crops differ from those conventionally applied. This conversion process by which the energy that has been trapped (by the photosynthetic process) and transformed into more useable forms (biomass conversion), is also outlined in more detail in the following subsection.

Finally, more use of animal and human power can probably be expected to take place, both because the cost of other power sources may become prohibitive and as a result of efforts to expand employment opportunities within agriculture. However, if such sources are to be used efficiently, improved tools and equipment will be needed to make these energy forms as productive as possible, otherwise they will become redundant as a viable power (energy) source.

Agriculture as an Energy Producer:

As cited above, through the production of biomass, agriculture holds great potential as an energy producer. However, foremost among the concerns of developing and exploiting this potential of LDC agriculture is the impact this would have on food production, because of a diversion of land and other agricultural resources and inputs to the production of energy rather than food. This effect needs to be studied and assessed carefully in all cases.

However, there is another concern regarding biomass production for energy that also needs further study and investigation; this is the effect that continuous removal of vegetative growth and/or agricultural residues from the land might have on subsequent plant/crop production, whether caused by a depletion of plant nutrients, resulting land degradation and erosion or through its influences on the larger environment. Many proposals to utilize plant biomass as an energy resources are based on the premise that it is unnecessary to return all residue to the land; however, much more information is needed regarding this whole area of concern before proceeding full speed into such energy producing schemes, particularly the effect these might have on food production capability.

Biomass Production. From a supply perspective, there are essentially two ways to obtain biomass for use as an energy source:

(a) to collect by-products, waste or other normally unutilized organic materials;

(b) to grow a crop for that specific purpose.

In most developed countries, the climate, economics of agriculture/forestry production and marketing, and/or land and water availability combine to limit the feasibility of growing organic matter for fuel purposes. However, as traditional and conventional energy costs continue to rise and price relationships change, the economics of such possibilities will become more favorable. On the other hand, in some LDCs, where land is available or non-harvested plants which are growing wild (African Savanna), production costs may be lower and the viability of such schemes now feasible.

Generally, however, collecting residues is more practical, especially with regard to wastes and by-products that are concentrated in one place (sawdust, bark, food-processing residue, etc.), or are already collected for various reasons (urvan refuse, manure, etc.). In these cases the cost of collection is low or even negative; but, very often their dispersed supply and/or periodic availability limits them as dependable sources.

In addition to the more conventional (technological) production improvements, much progress can be achieved by focusing on the photosynthetic process (itself). This not only involves developing and/or improving plant species that are more efficient energy-wise (e.g. C_4 plants, whose photosynthetic systems are 2-3 times more efficient) but also plants that can be grown under high-stress conditions (CAM plants, that are extremely efficient water users and do well in semi-arid regions). In fact, when plant production is viewed as an energy conversion process, with the end result energy fuels and/or materials, the criteria for chosing the type crops grown and, thus, the cultural practices followed changes. Insufficient study has been undertaken regarding ways of keeping a harvestable crop-cover on the land as much of the year as possible, multiple cropping, intercropping, nurse cropping, etc. Also, research is needed regarding new agronomic methods such as high density of plantings and mixture of crops; improved productivity of existing plants/crops under new environmental and stress conditions; and genetic manipulation of plants and micro-organisms.

Biomass Conversion Technologies. With the exception of direction combustion, through which biomass provides energy (directly) for heating and cooking, conversion processes are required to render biomass useable as an energy source, whether for agricultural activities or energy/power requirements in other sectors. Much more study and attention will need to be given to improving the conversion technologies by which the various resulting fuels and energy materials are utilized. These include both the biological (wet) and thermochemical (dry) processes and involve the particular processes of pyrolysis and gasification, as well as combustion, in the case of the latter; the former includes anaerobic fermentation (especially methanation) and alcoholic fermentation.

The type of conversion process chosen in particular instances will depend on:

(1) energy needs,
(2) what organic residues and/or materials are available, and
(3) size of conversion plant.

Conversion efficiency is also important and is affected by the moisture content of the materials to be used. Dry processes are generally not appropriate if the initial moisture context exceeds 50-60%, as less

than half of the potential energy may be recovered. However, studies indicate that many dry processes are better adapted to agricultural by-products than biological processes because of higher efficiencies and lower processing costs. Considerable research is being undertaken and needs to be carried out in this area of biomass conversion technologies, whereby the energy balance of such processes can be improved, as well as processing costs and the overall viability of biomass for energy schemes made more favorable and their wider-spread use more possible.

6. Follow-up and Request for Assistance

As set forth in the introductory section, the principal purposes of this paper are:

(1) to emphasize the importance of recognizing the interrelationships and interdependencies between efforts to address the problems of inadequate food production and the high cost and shortage of energy supplies in most LDCs;

(2) to encourage the joining of efforts in addressing these two separate concerns into a more comprehensive and effective approach, better dealing with the various aspects of these (two) broad problem areas between which an extensive and critical area of interface exists; and,

(3) to draw particular attention to research requirements within this agriculture-energy interface, seeking assistance from those within the Agency (and outside) in identifying priority research needs wherein AID should be directing its attention over the next several years.

Hopefully, by this point, the first two purposes have been more or less achieved; at least, a sufficient case has been made to persuade readers of the soundness of not viewing these two problem areas as mutually exclusive areas of concern, to be addressed separately and independently; but, rather, that effective solutions to these two, very serious problems for most LDCs have extensive inter-linkages which can be best addressed jointly, within a full realization of the interdependencies and interrelationships involved. Moreover, that this interface area, between efforts to increase food production within an environment of growing energy shortages and rising costs and that of trying to alleviate the broader energy crunch affecting all aspects of socio-economic development in LDCs (as well as food production in particular), provides both an important area for AID's research efforts as well as a useful framework [1/]

[1/] In fact, from a strictly energy perspective, this framework (agriculture-energy interface) in conjunction with the closely-associated shortage of traditional energy fuels for cooking and heating, and the need to improve their conversion/utilization efficiencies as well as expand the supply of these fuels, should constitute the main energy focus of the Agency.

for identifying the priority needs for carrying out such research efforts.

Regarding the final (remaining) purpose, it is also hoped that by this time the importance and need for AID undertaking/funding research in this area is not only recognized but that the diversified knowledge and expertise in the Agency, relative to problems within this interface area, can be effectively brought to bear in this latter task. Thus, the Joint Research Committee both invites inputs from agriculturalists, rural development specialists and energy experts in all parts of the Agency, particularly the regional bureaus and country missions and encourage them to not only let their general views be known but to identify specific major problem areas and priority research needs which AID should be addressing.

TABLE 1 - ESTIMATED TOTAL AND AGRICULTURAL USE OF COMMERCIAL ENERGY, 1972/73

	Total use	Agricultural use	Percent used in agriculture	Per caput consumption	Energy per agricultural worker
	.... 10^{15} joules			.... 10^{9} joules	
Developed countries	135 678	4 637	3.4	183	107.8
North America	76 933	2 140	2.8	333	555.8
Western Europe	42 912	2 114	4.9	119	82.4
Oceania	2 442	137	5.6	154	246.8
Other developed countries	13 391	246	1.8	99	19.1
Developing countries	19 317	920	4.8	11	2.2
Africa	1 569	70	4.5	5	0.8
Latin America	8 147	313	3.8	28	8.6
Near East	2 637	168	6.4	24	4.4
Far East	6 964	369	5.3	6	1.4
Centrally planned economies	64 091	2 048	3.2	54	6.7
Asia	14 289	415	2.9	17	1.7
Eastern Europe and the U.S.S.R.	49 802	1 633	3.3	141	28.5
World	219 086	7 605	3.5	59	9.9

TABLE 2. - COMMERCIAL ENERGY USE AND CEREAL OUTPUT PER HECTARE AND PER AGRICULTURAL WORKER, 1972 1/

	Energy/ hectare	Energy/ worker	Output/ hectare	Output/ worker
	..... 10^{9} joules		..... Kilograms	
Developed countries	24.8	107.8	3 100	10 509
North America	20.2	555.8	3 457	67 882
Western Europe	27.9	82.4	3 163	5 772
Oceania	10.8	246.8	976	20 746
Other developed countries	19.4	19.1	2 631	2 215
Developing countries ...	2.2	2.2	1 255	877
Africa	0.8	0.8	829	538
Latin America	4.2	8.6	1 440	1 856
Near East	3.8	4.4	1 335	1 386
Far East	1.7	1.4	1 328	781
Centrally planned economies	5.9	6.8	1 744	1 518
Asia	2.4	1.7	1 815	911
Eastern Europe and the U.S.S.R.	9.3	28.5	1 682	4 109
World	7.9	9.9	1 821	1 671

1/ Source: FAO. The State of Food and Agriculture, 1976, Rome (1977)

TABLE 3 - ESTIMATED AND PROJECTED USE OF COMMERCIAL ENERGY FOR INPUTS TO AGRICULTURAL PRODUCTION, 1972/73 AND 1985/86

	Fertilizer		Farm machinery		Irrigation		Pesticides		Total		Percent of world total	
	1972/73	1985/86	1972/73	1985/86	1972/73	1985/86	1972/73	1985/86	1972/73	1985/86	1972/73	1985/86
	10^{15} joules											
Developed countries ...	1 635	2 800	2 851	3 355	57.0	66.7	93.6	107.4	4 637	6 329	61.0	47.0
North America	750	1 429	1 299	1 427	36.6	42.0	55.3	64.5	2 141	2 963	28.2	22.0
Western Europe	724	1 130	1 337	1 656	15.5	18.4	36.8	41.4	2 113	2 846	27.8	21.1
Oceania	35	69	100	121	1.3	1.7	0.7	0.7	137	192	1.8	1.4
Other developed countries	126	172	115	151	3.6	4.6	0.8	0.8	246	328	3.2	2.5
Developing countries ..	586	2 003	257	670	68.6	122.1	9.3	53.4	921	2 849	12.1	21.1
Africa	38	111	30	73	1.2	3.1	1.2	8.3	70	195	0.9	1.4
Latin America	153	468	148	349	6.1	13.7	5.3	13.8	313	845	4.1	6.3
Near East	86	351	50	167	30.8	54.7	1.4	8.3	168	581	2.2	4.3
Far East	309	1 073	29	81	30.5	50.6	1.4	23.0	370	1 228	4.9	9.1
Centrally planned economies	1 160	2 808	778	1 349	50.5	61.3	59.8	73.7	2 048	4 292	26.9	31.9
Asia	317	683	40	108	35.3	39.5	23.0	32.2	415	863	5.5	6.4
Eastern Europe and the U.S.S.R.	843	2 125	738	1 241	15.2	21.8	36.8	41.5	1 633	3 429	21.4	25.5
World	3 361	7 611	3 886	5 374	176.1	250.1	162.7	234.5	7 606	13 470	100	100
PERCENT OF TOTAL	44.5	56.5	51.1	39.9	2.3	1.9	2.1	1.7	100	100		

TABLE 4 - ESTIMATED AND PROJECTED TOTAL ENERGY REQUIREMENT AND PERCENT FOR EACH AGRICULTURAL INPUT, 1972/73 AND 1985/86

	Total		Fertilizer		Farm machinery		Irrigation		Pesticides	
	1972/73	1985/86	1972/73	1985/86	1972/73	1985/86	1972/73	1985/86	1972/73	1985/86
	10^{15} joules		Percent							
Developed countries	4 637	6 329	35.3	44.3	61.5	53.0	1.2	1.1	2.0	1.7
North America	2 141	2 963	35.0	48.2	60.7	48.2	1.7	1.4	2.6	2.2
Western Europe	2 113	2 846	34.2	39.7	63.2	58.2	0.7	0.6	1.7	1.5
Oceania	137	192	25.5	35.9	73.0	63.0	0.9	0.9	0.5	0.4
Other developed countries	246	328	51.2	52.3	46.8	45.9	1.5	1.4	0.4	0.3
Developing countries	921	2 849	63.6	70.3	27.9	23.5	7.5	4.3	1.0	1.9
Africa	70	195	54.3	56.9	42.9	37.4	1.7	1.6	1.7	4.3
Latin America	313	845	48.9	55.4	47.3	41.3	1.9	1.6	1.7	1.6
Near East	168	581	51.2	60.4	29.8	28.7	18.3	9.4	0.8	1.4
Far East	370	1 228	83.5	87.4	7.8	6.6	8.2	4.1	0.4	1.9
Centrally planned economies	2 048	4 292	56.6	65.4	38.0	31.4	2.5	1.5	2.9	1.7
Asia	415	863	76.4	79.1	9.6	12.5	8.5	4.6	5.6	3.7
Eastern Europe and the U.S.S.R.	1 633	3 429	51.6	62.0	45.2	36.2	0.9	0.6	2.3	1.2
World	7 606	13 470	44.5	56.5	51.0	39.9	2.3	1.9	2.1	1.7

1/ Source: FAO. The State of Food and Agriculture, 1976, Rome (1977).

TABLE 5. - RECOMMENDED ENERGY CONSERVATION PROJECTS FOR PRODUCTION AGRICULTURE

Crop production systems

1. Reduction of transport energy in crop production
2. Energy conservation through reduced tillage
3. Cropping for more energy-efficient food chains
4. Reduction of harvesting losses
5. Multiple cropping for energy efficiency
6. Reduced vulnerability to weather
7. Alternative portable fuel systems
8. Systems approach to energy conservation
9. Effect of continuous crop residue removal on soil productivity
10. Agricultural utilization of nonagricultural by-products
11. Energy conservation through genetic improvement
12. More efficient nutrient utilization
13. Energy reduction through increased pesticide efficiency
14. Biological nitrogen fixation

Animal production systems

15. Improvement of the energy efficiency of animals by physiological and nutritional means
16. Matching of animal production to processing or manufacturing process
17. Recovery and development of energy from animal excreta
18. Conservation of energy used for handling livestock waste
19. Conservation of energy in the construction and use of buildings for livestock production
20. Conservation of energy used to control the environment in livestock housing
21. Improved motor efficiency and more efficient use of motors in farmstead equipment
22. Energy conservation in feed-handling equipment on the farmstead
23. Minimizing energy costs of environmental modifications in animal production systems
24. Energy self-sufficient animal production systems
25. Future requirements for energy in animal and poultry production
26. Conservation of energy in transport
27. Integrated milk production and sanitation systems
28. Utilization of industrial low-temperature waste heat
29. Development and demonstration of forage and grain handling systems
30. Promotion, acceptance, and adoption of energy-saving methods of livestock production
31. Potential for energy-flexible systems
32. Study of meat animals and energy use
33. Development of effective animal manure management systems
34. Improved milk handling procedures

Greenhouse and other production systems

35. Energy-effective use of lighting systems for heating and constant year-round production
36. Reduced heat losses in greenhouses
37. Reduced energy consumption for cooling greenhouses
38. Improved greenhouse heating systems
39. Greenhouse orientation and shape
40. Increased space utilization in greenhouses
41. Development of new construction materials for greenhouses
42. Biological and physiological alternations of crops
43. Systems analysis of intensive vegetable, grain and flower production for energy conservation
44. Reduction of energy use in the transport and marketing of vegetables, fruits and flowers
45. Substitution of scarce fuels
46. Combination systems for greenhouse production
47. Increased efficiency of materials handling systems in aquacultural production
48. Utilization of low-grade waste heat in aquacultural production
49. More efficient vehicle use in aquacultural production
50. Domestic aquacultural production
51. Combination systems for aquacultural production
52. Establishment of a data base for energy conservation in controlled-environment agriculture

On-the-farm processing

53. Annual cycle of energy systems applied to farm processes
54. Milk volume reduction systems
55. Demonstration of energy conservation through the recycling of heat from milk refrigeration units
56. Energy conserved and effect on electrical demands resulting from shifting peak load
57. Establishing energy use patterns for livestock feed processing and handling systems
58. Grain-drier fuel from non-grain plant parts
59. Heat recovery systems for grain driers
60. Low-temperature grain drying
61. Innovative design for grain driers
62. Investigation of the technical and economic feasibility of a coal-fired grain drier
63. Evaluation of technical and economic feasibility of heat pumps for grain drying
64. Direct oil-fired burner for crop drying
65. Utilization of lined tunnels below grade as a heat exchanger
66. Preservatives to delay drying as applied to cereal grains
67. Development and demonstration of "dryeration"
68. Use of industrial waste heat for crop drying
69. Containerization for low-energy grain handling

1/ Source: Energy Resources Development Administration. Report of the Proceedings of the Energy and Development Administration Workship on Energy Conservation in Agricultural Production. Washington, D.C. (1976)

TABLE 5. — RECOMMENDED ENERGY CONSERVATION PROJECTS FOR PRODUCTION AGRICULTURE *(concluded)*

Water resources

70. National impact of energy conservation on water resources
71. Energy limitations for the reclamation of submerged lands
72. Irrigation management
73. Energy conservation due to improved pumping-plant efficiencies
74. Development of educational material for evaluating alternatives to improved pumping-plant efficiency
75. Alternative sources of energy for pumping water: (*a*) wind; (*b*) solar energy
76. Improvement of motor and engine efficiencies
77. Improvement of pump efficiency
78. Development of new well screens and gravel-pack procedures to reduce draw-down in wells
79. Irrigation system efficiency
80. Water application efficiency
81. Crop response to limited water and nitrogen inputs
82. Management of pumped water
83. Energy conservation in agricultural drainage installations
84. Energy conservation through improved drainage pumping efficiencies
85. Drainage materials and design practices for energy conservation
86. Development of a simplified flow meter
87. Measures for retaining water on land to reduce irrigation pumping
88. Water harvesting as an alternative to pump irrigation
89. Recharging of aquifers to reduce lift in pump irrigation

Utilization of agricultural by-products

90. Development of methods for harvesting, storing and transporting crop residues
91. Availability of field crop residues
92. Definition of economical methods of whole crop harvesting for optimum grain quality, energy use, and residue collection
93. Practicality of redesigning grain crops
94. Demonstration of direct combustion of field crop residues
95. Off-the-farm use of field crop residues
96. Gas generators for farm and industrial use
97. Definition and demonstration of optimum liquid-fuel production systems
98. Definition and demonstration of optimum systems for the production of industrial chemicals from agricultural residues
99. Increased developmental efforts on the enzymatic hydrolysis of cellulosic residues to sugars
100. Demonstration of practical methods of CO_2 enrichment
101. Integration of feeding and fuel production in the use of crop residues
102. Use of the mineral content of crop residues
103. Relative efficiency and economic aspects of utilizing manure
104. Development of energy-efficient equipment to process livestock wastes for refeeding
105. Health and consumer considerations in feeding animal wastes to livestock
106. Demonstration of cascade feeding systems for poultry, steer and brood cattle
107. Feasibility of converting feedlot wastes into industrially useful oxychemicals