Appendixes

Appendix A: KEY TECHNOLOGICAL DEVELOPMENTS NEEDED TO HELP REACH THE BIOENERGY POTENTIAL

The 1985 bioenergy potential probably can be achieved with relatively direct development of existing technology, but the quality and success of these developments will influence the ease with which the potential is achieved. I n the longer term, there are numerous possible developments that could improve the potential for energy from biomass and help to make it an increasingly attractive energy option. I n addition, basic and applied research in areas directly and peripherally related to bioenergy can increase the body of knowledge on which new and successful developments ultimately must be based,

Some of the general areas of technological development that could be important to bioenergy use are listed below. The basic criteria used in choosing these are that: 1) the RD&D probably can produce usable results, and 2) it addresses an area that either constrains bioenergy development or shows promise for important new applications of biomass for energy. Although all of this RD&D can be carried out simultaneously, the areas are divided into near and longer term needs, based on the time it may take to achieve commercial applicat ions.

Near Term

Resource Base

- **Wood harvesting.** –A repertoire of wood-harvesting techniques and equipment should be developed. The goals should be to minimize occupational safety hazards, esthetic and environmental damage, and costs, particularly when handling small pieces of wood. Additional goals should be to ensure that the potential benefits (e.g., increased growth of commercially valuable timber) accrue as well as to improve the economics of harvesting and collecting low-quality wood from small tracts of forest.
- **Surveys.**– Surveys should be conducted to determine more accurately the biomass resource, and subregional supply-demand curves for various types of biomass should be developed. This should include the present and projected availability of cropland and potential cropland for energy production and the costs associated with using it.
- **Impacts of biomass supply uncertainties.** -A common feature of most biomass fuels is the uncertainty in supply. For most sources this will primarily be a local, short-term uncertainty caused by fluctuations in weather and local demand. But for grains and sugar crops, considerable uncertainty also surrounds future world demand for food, future crop productivity, and the ability of agricultural policy to stabilize farm commodity prices as the supply of good cropland that can easily be brought into production diminishes. These uncertainties should be investigated to determine their impacts on the biomass supply sectors — particularly agriculture— and on the way that fuel users will respond in order to reduce their risks. The emphasis should be on developing policy options that can better deal with these uncertainties.
- **Biomass storage and transport.** — Inexpensive means of compacting, storing, and transporting wood and particularly herbage and crop residues should be investigated in order to overcome the problems associated with the low energy density (energy per cubic foot) and poor handling characteristics of these materials.

Conversion Technology

- **Methanol from wood, grass and legume herbage, and crop residues.**— Conversion processes for producing methanol from grass and legume herbage and crop residues should be demonstrated, while those for producing methanol from wood should be developed further in order to decrease costs and increase the efficiency (i. e., greater carbon monoxide-hydrogen yields and lower char and oil formation). Furthermore, small-scale conversion facilities (less than 150 green ton/d input) should be developed in order to gain access to a larger fraction of the biomass resource. (A larger portion of the resource is made accessible with small conversion processes because the dispersed nature of biomass makes it easier to collect small amounts for conversion than to collect the large quantities required for large-scale conversion facilities.)
- **Airblown gasifiers.**— Various sizes of airblown gasifiers should be developed and demonstrated in order to improve the technology and gain operating experience.

- **Wood stoves.–** Wood stoves should be developed further to increase their efficiency and ease of operation and to reduce emissions, safety problems, and maintenance. This should also include the investigation and development of heat storage devices that can provide a steadier, more even flow of heat from wood heating systems.
- **New direct combustion technologies.** – New direct combustion technologies for wood and other feedstocks that show promise for increased efficiency and decreased emissions in industrial applications should be developed and demonstrated.
- **Ethanol from wood, grass and legume herbage, and crop residues.** — Development of processes for economically converting wood and herbage (including crop residues) to ethanol should continue. While most of the processes are not currently ready for demonstration, those that are ready and appear to be feasible should be demonstrated.
- **Anaerobic digesters.–** A variety of onfarm anaerobic digester systems should be demonstrated. The goals should be to lower installation costs and improve the digesters' reliability and flexibility.
- **Onfarm fuel production.**--Onfarm ethanol production may be popular as a means for farmers to achieve some degree of liquid fuel self-sufficiency and to divert crops in times of low prices. If so, then the maximum amount of oil can be displaced by using these crops to produce dry ethanol as an octane-boosting additive to gasoline. In order to do this onfarm, relatively automatic distilling equipment capable of producing dry ethanol safely and inexpensively should be developed. For dry and wet ethanol production, facilities should be developed that are capable of producing dry distillery byproduct and using wood and herbage as a fuel. Solar-powered distilleries also should be developed.

  There is, however, a mismatch between ethanol and farmers' liquid fuel needs (e. g., diesel fuel). Although this can be overcome with modifications in the farm equipment, other possibilities for onfarm fuel production also should be investigated. One example may be cultivation of sunflowers and the development of small presses that can be operated easily and inexpensively to separate the sunflower seed oil for use as a diesel fuel substitute, The research should determine which farming operations are best suited to onfarm fuel production, how many of each type of operation exists in the United States, and what fuel and energy savings can be achieved in each category. The emphasis should be on providing a repertoire of possibilities from which individual farmers can choose the alternative best suited to their needs.
- **Large-scale ethanol production from grains and sugar crops.** — If grains and sugar crops are to be converted to ethanol, methods for reducing the distillery energy usage and other ethanol production costs should be developed. The most important, at present, appear to be the development of means for storing sugar crops without deterioration of the sugar due to bacterial attack, processes for continuous fermentation that can be operated reliably without the need for redundant equipment, and new means for removing the ethanol from the fermented solution (distillation is used at present).

  Dry milling processes also should be investigated because of their potential for reducing the investment cost for distilleries capable of producing a distillery byproduct (corn gluten) that can be used in higher proportions in animal feeds and for different animals than distillers' grain.

End Use

- **Use of alcohol-gasoline blends.–** The problems associated with using blends of either methanol or ethanol and gasoline should be investigated further. Techniques for keeping the blends dry should be developed. The automobiles and engine designs most likely to be adversely affected by using the blends should be identified, the type and cost of necessary modifications should be established, and attempts should be made to identify or develop low-cost additives that minimize the adverse effects. Similar studies of the distribution systems should be carried out,

  Because of the potentially greater problems associated with methanol (as compared to ethanol) blends and the possibilities for producing significantly larger quantities of methanol than ethanol in the 1980's, the use of methanol fuel should be examined carefully. The entire system including oil refineries, distribution systems, and various end uses should be examined with respect to costs and oil savings to determine which strategies are best suited to introducing methanol into the liquid fuels system,
- **Data for National, State, and local decisionmaking.** –An important feature of bioenergy is that feedstock availability and cost vary considerably with time and geographic location. Local data and analyses should be developed that calculate the costs of using the local biomass for energy and the effects of the supply and cost variations

on the economics of using biomass. These models also should contain information on the local supply, type, and variation in supply of the biomass resource. This could aid individuals and businesses in making informed decisions on a site-specific basis as to whether or not to utilize this resource for energy. This will involve considerable survey work.

Longer Term

Resource Base

- **Crop switching.** — Various crop-switching possibilities that involve fuel production should be investigated further. One example is the cultivation of corn instead of soybeans. The byproduct of producing ethanol from the corn can then be substituted in animal feed for some of the soybeans not produced. Other possibilities include the cultivation of sugarbeets used for animal fodder. The crop-switching possibilities should be explored to determine the extent to which they can be used to produce fuels from agriculture without expanding the quantity of cropland cultivated. Included in this should be investigations of the effect of substituting current feed rations with varying amounts of forage — distillers' grain, and forage-corn gluten mixtures.
- **Crop development.** — A wide variety of crop types should be developed, including grasses, legumes, and trees; freshwater and saltwater plants; plants that produce or can be converted to liquid fuels suitable for transportation; and plants that can be cultivated on lands that are or may become unsuitable for food or feed production. Cultivation techniques (especially for aquatic plants) and the development of plant hybrids require special attention, because these unconventional crops are likely to have both unique potentials and problems. The criteria should be the net premium fuels (oil and natural gas) displacement per acre cultivated (for land-based plants), the utility of byproducts, the economics, and the environmental impacts. At the same time high-yield forage grasses and legumes should be developed, so as to free more pastureland for energy product ion.
- **Ocean farms.** — R&D into the engineering criteria for ocean kelp farms is needed to better understand, among other things, the stresses that such a farm would be subject to, how to build the farms economically, how to protect the kelp from storms and strong currents, and how to minimize the loss of nutrients applied to the farm.
- **Environmental impacts of biomass cultivation.** –The long-term environmental impacts of cultivating short-rotation trees on forestland and farmland and of whole (aboveground) tree removals from forestland should be investigated. The emphasis with respect to whole (above--ground) tree removals should be on its effect on the forest's nutrient balance and soil organic matter, and any subsequent long-term effects on the forest's productivity and capability of resisting stresses.

  Because grasses and some other perennial crops currently appear to be the most environmentally benign crops for cropland and because there is excellent promise for improved yields from these types of plants, screening and development of fast-growing perennial crops such as some grass and legumes could have a positive environmental impact. The emphasis should be on high-yield grass and legumes that can be cultivated easily and economically on a variety of cropland types with a minimum of fertilizers and pesticides.
- **Indirect costs.**–- Methodologies should be developed to help establish the indirect costs associated with bioenergy, particularly the competition with food and feed, the effects of increased forest management, the potential competition with the production of traditional forest products, and the effects on foreign trade. Developing the data needed for these analyses probably will involve considerable survey work.
- **Photosynthetic efficiency.**– Basic research in photosynthesis and plant growth should be continued to determine the efficiency of plants in converting basic photosynthetic material (photosynthate) to other products (e. g., cellulose, organic carbon, hydrogen, and oils) and to better understand the effects of various stresses (water shortage, heat, cold, poor soil, etc.) on plant growth. Research should also address the reasons for the low photosynthetic efficiency of plants and ways to improve it.

Conversion Technology

- **Thermochemistry of biomass.**–-The chemistry involved when biomass is combusted, gasified, or liquified, as well as secondary gas phase chemistry should be investigated. Substantial process and efficiency improvements and new applications in the production of chemicals and fuels from biomass could result.
- **Chemistry and physics of lignocellulose.**--- Investigation of the chemical and physical properties of lignocellulosic materials (e. g., wood,

grasses, legumes, and crop residues) should continue. New ways of separating the various components of lignocellulose from one another or exposing them to chemical attack should be researched and developed. Inexpensive pretreatment that make fibrous materials easier to handle should be investigated.

- **Biochemical conversions. —** The biology and biochemistry of the biochemical conversion processes (e. g., fermentation, hydrolysis, and anaerobic digestion) should be researched in detail so that these processes can be better understood and therefore controlled and manipulated. Various biomass feedstocks should be investigated, novel techniques (e. g., matrix immobilized enzymes) explored, and new types of bacteria and yeasts developed (e. g., by molecular and traditional genetics).

End Use

- **Uses for aquatic plants. —** Because of the possibility that large quantities of saltwater and freshwater plants may be available in the long term, techniques for harvesting the plants and suitable conversion technologies (e. g., anaerobic digestion) should be developed. Because large quantities of these plants are not likely to be commercially available for some time, basic and applied research into the fundamental physical, chemical, and biological properties of these plants should precede more advanced development efforts. The possibilities for very high yields from aquatic plants and the possibility of large aquatic energy farms (e. g., in the ocean or on land unsuitable for land plants) probably justify an active RD&D program even though many current concepts are speculative.
- **Use of alcohol fuels.–** Alcohols appear to be the liquid fuels that can be produced most easily from the biomass feedstocks in greatest supply. These can be converted further to liquids that are compatible with gasoline, but the conversion processes inevitably involve additional expense and energy loss. Consequently, vehicles capable of accepting fuels that may vary from pure gasoline to pure alcohol and all of the intermediate blends should be developed; the changes needed in the liquid fuels distribution system to accommodate alcohols should be assessed; and the alcohol-to-gasoline processes should be investigated in order to judge which is the least expensive long-term option for the consumer.

Other

- **Basic and applied research in peripheral areas. —** Basic or applied research in one area is never isolated from peripheral areas of research. The success of research usually depends on the body of knowledge being developed in related areas and often depends on the results in areas which, at first, seemed totally unrelated. Consequently, the quality of the results and the ultimate success of bioenergy research is likely to depend on the support given peripheral areas of research. These areas include the biochemistry and biology of plants, the chemistry (including thermochemistry) of organic materials, and the physics of biomass. No one can predict which areas ultimately will prove to be of fundamental importance to long-term developments. Bioenergy development, however, probably will be enhanced by supporting a wide range of basic and applied research in areas peripheral to the basic objectives.