The Bioenergy Agenda 4

For bioenergy to make a substantial contribution to the U.S. energy mix, a number of technical, economic environmental, commercialization, and policy issues must be addressed. Two of these will be examined briefly here: research, development, and demonstration of environmentally sound energy crops; and market distortions and barriers which threaten to substantial y slow commercial adoption of these technologies.

For bioenergy to contribute substantially to the energy mix, many technical, economic, environmental, commercialization, and policy issues must be addressed.

RESEARCH, DEVELOPMENT, AND DEMONSTRATION

Research, development, and demonstration (RD&D) is needed at all levels of biomass energy systems. This includes RD&D on: high-productivity crop varieties; their planting, maintenance, and harvesting; their environmental impacts; their transport and storage; and their conversion to fuels or electricity. The focus here will be on their environmental impacts and how these relate to other aspects of biomass energy systems.

Chapter 3 discussed the environmental impacts in some detail. Many of the impacts noted there were based on studies of conventional agricultural crops and were extended by analogy to energy crops; there have been few large-scale or long-term field studies of energy crops themselves. These impacts need to be carefully researched in dedicated field trials of energy crops:

Soil quality. Key areas of RD&D include: the development of a "minimum data set" of key soil physical, chemical, biological, and other parameters as a means of monitoring soil quality over long periods of time for different crops and management regimens; nutrient cycling, particularly of biochemical processes; the return of organic matter to the soil under various intensive energy crops and cropping systems; and the impacts of necessary equipment and various tillage systems on soil quality. It may also be necessary to conduct this RD&D in parallel with study of adjoining land uses. This will improve understanding of the interaction of energy crops with the larger environment. Agreeing on what constitutes sustainability and means of realizing such systems are important issues.

- Agricultural chemicals. Research on the impact of agricultural chemicals on soil flora and fauna and on wildlife is needed. This includes research on the impacts on wildlife behavior and reproductive processes. Chemical pathways and fate need to be better understood, particularly when they affect more than the target species or move out of the target area. Understanding the dynamics of chemical use on energy crops, how to reduce movement of chemicals offsite, and how to reduce their use generally are important issues.
- Water quality. Research is needed on the impact of erosion/sedimentation and agricultural chemicals from energy crops, especially on riparian zones, and on the potential of various energy crops to serve as filters and buffers for riparian areas. Studies are also needed on how to best minimize potential leaching of agricultural chemicals into groundwater. Energy crops might be a useful tool for reducing nonpoint agricultural pollution, but data are needed to verify this and to provide better crop guidelines for realizing that end.
- Air quality. Research on the total fuel cycle emissions of various bioenergy crops, conversion, and end-use systems is needed in order to minimize air quality impacts. This includes better understanding of both rural and urban air quality issues and how to best trade them off to maximize benefits. Comparing the potential air quality impacts of bioenergy systems with those of a wide range of other fuel and energy technology options is a key issue.
- Habitat. Box 3-D listed a number of prototype guidelines for structuring energy crops in order to maximize their value as habitat, buffers, or corridors. Each of these prototype guidelines needs to be examined through extensive research in dedicated large-scale field trials and modified as necessary. Such research must consider the impacts of energy crops in the context of the regional landscape ecology and in the near- and long-term. Establishing overall goals for the desired habitat impacts—which species should be helped-of energy crops in the larger landscape will also require extensive analysis.
- **Restoration** of degraded soils and ecological functions. Energy crops may have the potential to reverse soil deterioration from human abuse in some cases. This might include improving problems of soil structure, loss of top soil or organic content, salinity, acidity or alkalinity, or even chemical or heavy metal pollution.[1] It might also include restoration of some water purification or wetland functions, including moderating flood damage. Research is needed to identify such opportunities, design systems to make best use of this potential, and verify performance in the field. Energy crop yields may be low on some of these lands, however, lowering the financial return to the land owner and discouraging such efforts. Means of overcoming such barriers may need to be explored.
- Greenhouse gases. The total fuel cycle (from crop production to end use) impacts of energy crops on greenhouse gases (including carbon dioxide, methane, isoprenes, nitrous oxide, etc.) needs to be evaluated for the various energy crops, conversion processes, and end uses. The development and use of a "minimum data set" of key emission factors would be useful for

[1] Growing plants will take up a variety of chemical or heavy metal toxins, depending on the precise substance and the particular plant species. This poses a problem for food crops, as it concentrates the toxins and puts them into the food chain. In contrast, for energy crops these toxins may be removed in the energy conversion process (for example, destroyed by combustion or concentrated in the ash) and so may allow a gradual cleansing of the soil.

determining these impacts. Related effects such as on soil carbon balances or vehicle refilling station VOC emissions should be included. These fuel cycle emissions can then be compared for agricultural or energy crops and for fossil or biomass fuels.

- Crops and multiple cropping. The potential risks and impacts of various genetically modified energy crops will need to reexamined. A variety of multiple cropping systems should be evaluated to determine how to ensure soil quality, habitat benefits, crop productivity, crop disease resistance, and other key economic and environmental criteria. At the same time, research is needed to determine how to convert agricultural lands to tree crops and vice versa; the soils and microflora and fauna are often much different.

It must be noted, however, that such research is not being done in a vacuum. Extensive research has already been done or is underway for many of these and related topics in parallel systems and can be made use of here.[2]

In addition to these factors, designing energy crops to mitigate or provide these potential environmental costs or benefits may also impact other aspects of developing energy crops, particularly their economics. Each of these may need in-depth study.

Energy crops must be cost effective for producers and users. This will require a careful balancing of environmental considerations—including near-term local and long-term global environmental impacts—within the overall bioenergy economics. Detailed integrated analyses of the economics and environmental impacts of various bioenergy fuel cycles are needed. The potentially significant environmental services energy crops may offer may need some kind of recognition and valuation by society and landowners. This may be quite difficult.

As part of such an analysis, the habitat value of polycultures may need to be weighed against the difficulty of converting thereto fuels or electricity. For example, some polycultures may not be easily converted by current enzymatic hydrolysis processes to ethanol.[3] In the near term, it may be more important to verify the cost and performance of these conversion processes using R&D already in progress for narrowly specified (monoculture) feedstocks. For the longer term, it maybe useful to begin R&D now to adapt these enzymatic hydrolysis processes to mixed feedstocks as needed in order to increase habitat benefits. Some research on mixed feedstocks is underway at the National Renewable Energy Laboratory. It tends to focus, however—and rightly so at this early stage-on a few common farm species that might be mixed with the primary feedstock by accident rather than a much wider range of plants that might be considered on the basis of their habitat value.[4] Research into the conversion of feedstocks must be tightly coupled with field research on the habitat and other environmental benefits of particular combinations of crops.

To avoid disrupting key lifecycle processes for wildlife, biomass harvesting and other activities may need to be restricted during nesting and other critical times. This may require that sufficient biomass be stored to keep the conversion plant operating during this period; it may also require idling capital equipment used for harvesting and transport. Alternatively, electricity generation, for example, might be powered during such periods by the use of natural gas, and there maybe additional important synergisms between the use of

---

[2] For example, the Electric Power Research Institute, the National Audubon Society, and others have initiated a National Biofuels Roundtable. This Roundtable is developing a framework for evaluating many environmental, socioeconomic, and policy issues associated with the development of bioenergy crops and conversion facilities.

[3] Under some conditions, polycultures may also contribute to slagging problems (the condensing of alkali metals on surfaces such as boiler walls, heat exchangers, etc.) in combustion equipment. Jane Turnbull, Electric Power Research Institute, personal communication, Aug. 31, 1993.

[4] Arthur Wiselogel, National Renewable Energy Laboratory, personal communication, Sept. 8, 1993.

biomass, natural gas, and renewable such as wind, photovoltaics, and solar therrnal.[5] On the other hand, a well established biomass industry may have a sufficient variety of crops and rotation cycles to moderate this disruption. Field trials are needed to determine the extent of these potential disruptions and means of moderating them.

Farm labor needs are largely determined by the intense effort required to plant and harvest conventional agricultural crops during a narrow window of time, usually spring and fall. Once planted, however, perennial herbaceous or woody energy crops may last 10 to 20 years, and harvesting may take place over a wide period of time. Adding such energy crops to the farmer's portfolio might then ease the burden during spring and fall, allowing better use of labor and capital equipment overall.

Bioenergy crops will also naturally move to their highest value use. This might be as a transport fuel, as a baseload backup to intermittent renewable, for industrial chemicals or fiber, or perhaps for environmental benefits. It will be useful to understand the full range of costs and benefits for each potential use of bioenergy crops, including budget and trade balance impacts.

These crops might best serve a variety of end uses simultaneously. In particular, the initial establishment of bioenergy crops might be assisted by coupling energy production with higher value uses of the feedstock. For example, an energy crop might be initially established to serve a higher value purpose such as the production of pulp and paper and only secondarily for energy. The experience gained through such partnerships may provide a foundation for further energy crop development and cost reductions.

Once a substantial market develops for low-quality wood fuels, there is the potential risk that will encourage owners to harvest low-quality timber that is serving as important wildlife habitat or to energy crop wetlands which are fertile but inappropriate for conventional agriculture. This is particularly important in regions such as the Northeast where forests are the primary biomass resource. Means of addressing such unintended side effects may be needed.

Increasing land-use constraints—environmental and other-on Federal lands may encourage pulp and paper and other biomass product users to move elsewhere. Competition for marginal and other lands may become more intense. At the same time, there maybe increasing land-use and environmental considerations for these agricultural or marginal lands. This may reduce the area available for energy crops. As noted above, however, combining multiple end uses such as pulp and paper with energy may assist the initial development and deployment of energy crops and their associated infrastructure.

The structure of the farm sector also plays a role in determining these environmental impacts and needs to be examined carefully. For example, roughly one-third of farms having fertilizer expenditures and one-quarter having pesticide expenditures in 1986 paid for some custom application procedures. Training such specialists in the timing and application of agricultural chemicals to minimize misapplication, potential groundwater leaching or runoff, or other problems may require one set of extension activities; reaching the two-thirds or more of farms which use on-farm hired laborers or do it themselves may require a different appreach.[6] Extension efforts will also vary between

[5] See, U.S. Congress, Office of Technology Assessment, *Renewable Energy Technology: Research, Development, and Commercial Prospects,* forthcoming.

[6] New technologies may also help avoid some of these problems. For example, the development of time-release fertilizers (or other agricultural chemicals) would allow farmers to continue the common labor-saving practice of only spreading fertilizer (or other chemicals) once per year while reducing the amount that must be applied to ensure that the nutrients are available late in the growth cycle. See David O. Hall, Frank Rosillo-Calle, Robert H. Williams, and Jeremy Woods, "Biomass for Energy: Supply Prospects," Thomas B. Johansson, Henry Kelly, Amulya K.N. Reddy, and Robert H. Williams, (eds.), *Renewable Energy: Sources for Fuels and Electricity* (Washington, DC: Island Press, 1993).

Table 4-l—Distribution of Farms by Sales Class and Percent of Total Cash Receipts by Sales Class, 1987

Sales class	Value of farm products sold	Number of farms	Percent of all farms	Percent of total cash receipts
Small, part-time	<$20,000	1,380,000	63.4%	5.2%
Part-time	$20,000 to $99,999	495,000	22.8	17.3
Moderate	$100,000 to $249,999	201,000	9.2	22.0
Large	$250,000 to $499,999	71,000	3.2	22.0
Very large	***>$500,000***	***29,000***	1.3	**37.4**
Total	—	**2,176,000**	**100**	**100**

SOURCE: U.S. Congress, Office of Technology Assessment, *Beneath* ***The Bottom Line: Agrcultural Approaches to Reduce Agrichemical Contamination ofGroundwater,OTA-F-418*** (Washington, DC: U.S. Government Printing Office, November 1990).

the very large farms and the small, part-time farms (table 4-l). Tenants and part-owners are operating an increasing proportion of farms and farmland acres and may have less concern about environmental costs and benefits of various crops and management systems than owners.[7]

Finally, to realize the benefits of energy crops as habitat, buffers, and corridors may in some cases require a level of regional landscape planning not often seen in this country. This will require much more RD&D on regional landscape ecology and its sensitivity to imperfections. It will also require considerable effort in developing new policy instruments to encourage participation in forming such a landscape across many public and private properties. These issues are examined further below.

MARKETS AND BARRIERS

Agricultural production of energy crops faces a variety of market distortions and barriers that may slow their adoption. These will be discussed here within two broad categories: products and markets; and land use and rights issues. Many of the issues of commercializing alternative transport fuels themselves have been recently addressed in a separate OTA assessment,[8] particularly the difficulties inherent in developing a new fuel distribution infrastructure. The focus here instead will be on the difficulties in producing the crops.

Products and Markets[9]

The first difficulty faced by producers and converters of bioenergy crops is the chicken and egg problem of developing a market. To justify producing an energy crop, farmers must have a reasonably secure market for their product at a potentially economic price. On the other hand, electricity generators or liquid fuels producers need a reasonably assured and economic supply of biomass before they can justify building a conversion plant. For both parties, the economics of energy crops are improving but remain expensive.

Lead times to develop crops and conversion plants are also long. Typical SRWCs require 3 to 10 years to mature. Farmers are often reluctant to make the investment due to this long lead time and the need for interim cash flow, particularly with current low and uncertain prices for other forms of energy.

[7] U.S. Congress, Office of Technology Assessment, *Beneath The Bottom Line: Agricultural Approaches to Reduce Agrichemical Contamination ofGroundwater,OTA-F-418* (Washington, DC: U.S. Government Printing Office, November 1990).

[8] U.S. Congress, Office of Technology Assessment, *Replacing Gasoline: Alternative Fuels for Light-Duty Vehicles,* OTA-E-364 (Washington, DC: U.S. Government Printing Office, September 1990).

[9] The primary source for much of this section, which contains far more detail than presented here is: U.S. Congress, Office of Technology Assessment, *Beneath The Bottom Line: Agricultural Approaches to Reduce Agrichemical Contamination of Groundwater,* OTA-F-418 (Washington, DC: U.S. Government Printing Office, November 1990),

Energy crops may also reduce the flexibility of farmers. It maybe difficult to quickly plow under a tree crop and plant the land with something else should crop productivity, market conditions, or other factors limit the return on the farmer's investment of labor, land, and capital. Thus, while the Conservation Reserve Program encouraged U.S. farmers to convert 12 million hectares[10] of marginal cropland to permanent cover during 1986 to 1989, only 1 million hectares of this was planted with trees.[11]

Farmers typically make production decisions within short timeframes and with maximum flexibility, which discourages investments in potentially longer term and less flexible energy crops. Economic factors are typically the most pressing in farmer decisionmaking; market prices, support levels, credit availability, and debt load are critical considerations at the individual farm level. Farmers often are forced to make decisions within a short-term, year-to-year planning horizon that can prevent them from taking risks or making the most economically efficient decisions over a longer term. Farmers asked to respond voluntarily to public concerns about environmental impacts tend to evaluate proposed technologies, crops, management, or other aspects for their relative advantage within the existing set of economic conditions.

Many farmers also make changes slowly. Farm management changes, even relatively minor ones, are not decisions made overnight. Farmer adoption of relatively simple, highly profitable technologies such as hybrid com has taken as long as nine years on average. The decision to change farming practices requires a considerable degree of deliberation, and maintaining new practices frequently necessitates on-farm experimentation and adaptation beyond that conducted during initial technology development.

Farmers tend to underestimate the severity of environmental problems on their own farms. Farmers tend to perceive, for example, that soil erosion and water quality problems are more severe at the national level than they are in their own counties. They also tend to perceive these problems as least severe on their own farms. This "proximity effect" indicates that farmers are aware of the need to protect soil and water in general but often underestimate the need on their own farms. As a potential moderator of such environmental impacts under the right conditions, energy crops are therefore likely to be valued less than if the severity of these problems was fully appreciated.

Farmers are most likely to adopt technologies with certain characteristics. Favored technologies are those that: 1) have relative advantage over other technologies (e.g., lower costs or labor, higher yields, etc.); 2) are compatible with current management objectives and practices; 3) are easy to implement; 4) are capable of being observed or demonstrated; and 5) are capable of being adopted on an incremental or partial basis. Diffusion research indicates that farmers are probably more likely to test technologies or practices that they think have these characteristics. The complexity of systems-oriented changes will likely slow their adoption. This poses particular problems for regional landscape planning in order to maximize habitat benefits of energy crops. Mechanisms for incrementally realizing habitat benefits may be needed should these programs go forward.

Individual and farm characteristics appear to explain only a small portion of behavior associated with adopting new crops or farming practices; institutional factors (e.g., farm programs, credit availability, etc.) probably are highly influential. Research on individual farm characteristics (e.g.,

---

10 The total now stands at approximately 15 million hectares. Thyrele Robertson, U.S. Department of Agriculture, Soil Conservation Service, personal communication, Aug. 26, 1993.

11 R. Neil Sampson, "Biomass Opportunities in the United States to Mitigate the Effects of Global warming," Donald L. Klass, (cd.), *Energy from Biomass and Wastes XV* (Chicago, IL: institute of Gas Technology, 1991).

size, specialization, land tenure) and farmer traits (e.g., age, education) and their relation to conservation adoption has yielded mixed results. Most researchers consider institutional factors to be much more influential, but few studies have been conducted on these to date. Studies on adoption of farm practices have also rarely examined the physical settings of adoption decisions or the extent of resource degradation as it relates to adoption of alternative farm practices.

Finally, farmers are a heterogeneous group with unequal abilities, unequal access to information and resources for decisionmaking, differences in willingness to take risks, and a wide range of objectives in even practicing farming. For example, farmers' objectives may include: making a satisfactory living (either as an owner-operator, tenant, or employee); keeping a farm in operation for family inheritance or other personal reasons, perhaps while working at an off-farm job; obtaining a satisfactory return on investments in land, labor, and equipment; obtaining tax benefits; obtaining recreation or esthetic enjoyment; and others. These objectives will influence the portfolio of crops, including energy crops, that a particular farmer will choose to grow.

Land Use and Rights

The potential habitat benefits of energy crops—as habitat, buffers, or corridors-will increase as they are integrated on a regional basis with the local ecology. Pursuing this to its maximum limit may require a degree of landscape planning that has rarely been seen in this country. This raises major issues in terms of land use and property rights, issues that are also at the center of controversies over the "Multiple Use, Sustainable Yield" philosophies of public lands management. These issues have been explored in depth in numerous publications and so will be only briefly mentioned here.[12]

Public and private properties already face a variety of environmental and other considerations in their use. These include zoning and land use planning, clean water and air laws, forest practice and pesticide control laws, endangered species laws, and a variety of other considerations. Whether and, if so, how such resource considerations might be extended to the production of energy crops will be a difficult but critical aspect of developing a bioenergy agenda.

Some of these controls maybe counterproductive if they are extended to bioenergy in an inflexible manner. For example, some argue that improving habitat on private lands may pose risks to property owners that if endangered or threatened wildlife establishes itself, the property owner will largely lose control of that land as well as on adjacent lands where activities might disrupt the wildlife.[13] As a consequence, anecdotal evidence indicates that some farmers may cut or bum potential habitat to prevent wildlife from using it; alternatively, the wildlife might simply be driven off or killed. Whether or not this is a significant problem or how widespread the problem might be is unknown. Using energy crops as habitat, buffers, or corridors will require understanding and carefully addressing these issues.

These issues thus address fundamental assumptions and values of, for example: what actually is private property (e.g., what is really owned?); to what extent can a person use or abuse private property and at what point do larger community interests become important; how does one value different environmental goods and services—including clean air and water, quality soils, wildlife, and aesthetics—and how can that be translated into functioning markets; and how does one determine and apply discount rates, if at all, to natural

12 See, for example: Congressional Research *Service, Multiple Use and Sustained Yield: Changing Philosophies for Federal Land Management?* Workshop Proceedings and Summary, Mar. 5-6, 1992, Committee on Interior and Insular Affairs, U.S. House of Representatives, Committee Print No. 11, December 1992.

13 John Miller, "Land of the Free: An Environmental Strategy for Republicans," *Policy Review*, Winter 1993, pp. 66-70.

resources? These issues pose substantial challenges to public policy.

CLOSE

Energy crops can potentially help meet a number of national goals, including: national energy and security needs, improving the trade balance, reducing Federal budget deficits, stimulating rural economic development, and improving the environment. Realizing this potential will require a long, dedicated effort in terms of research, development, demonstration, and commercialization of these technologies. Haphazardly implementing large-scale bioenergy programs without such a foundation could damage the environment and reduce potential economic benefits.