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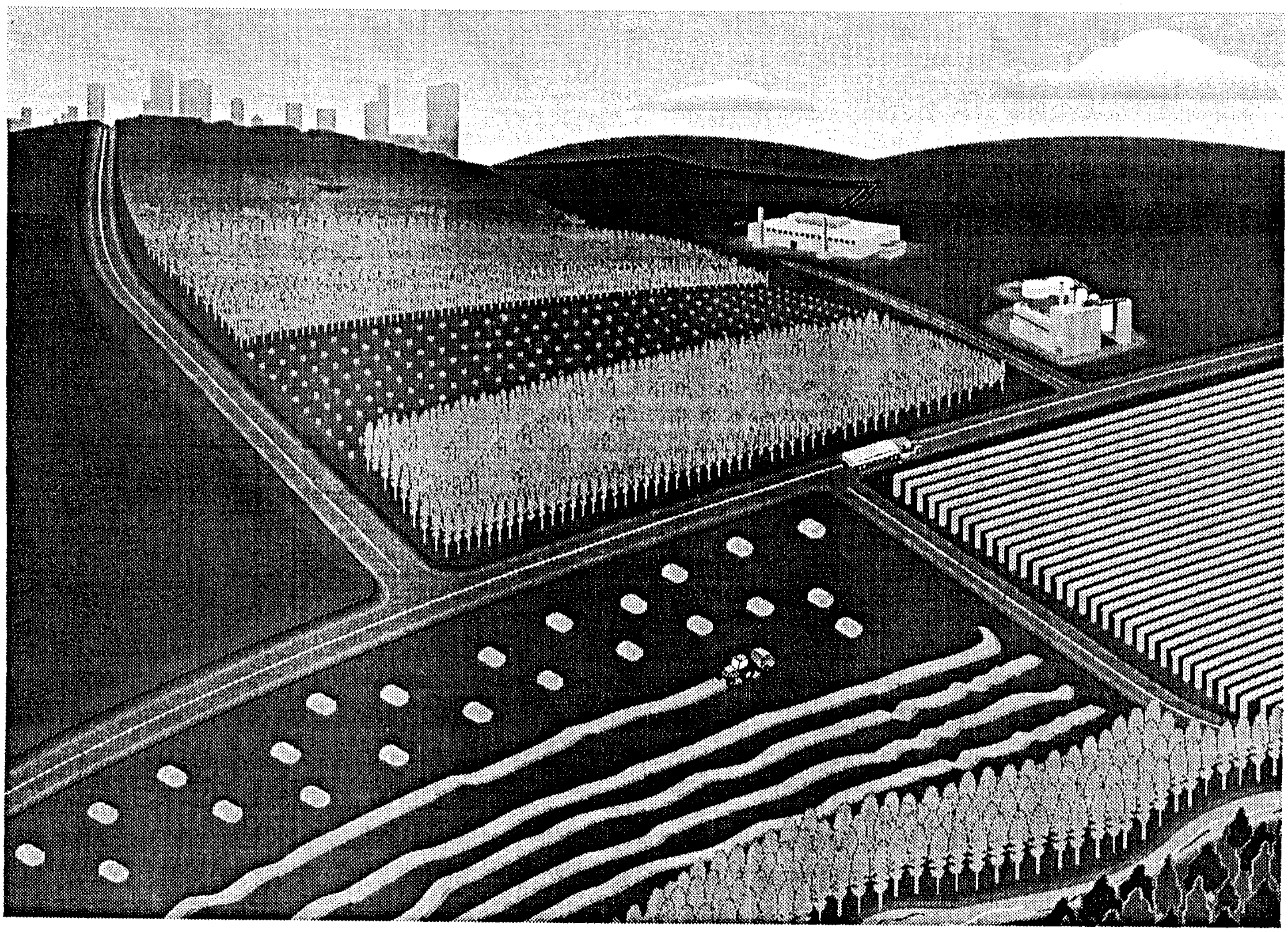
# Principles and Guidelines for the Development of Biomass Energy Systems





A Report from the
National Biofuels Roundtable
May, 1994

*Final Report*

# Contents

# Introduction

## Establishment of the National Biofuels[1] Roundtable

Interest in the development of biomass as a renewable energy resource has converged with concern about the environmental impacts of fossil-fuel use and with a desire to reduce the nation's dependence on imported fuels. If this convergence results in large-scale development of biomass for liquid fuels or electricity production, significant shifts in agricultural land use could result. Additional pressure could be placed on forests and other natural resources.

Recognizing that widespread adoption of biomass energy could raise complex environmental and economic issues, the Electric Power Research Institute (EPRI) and the National Audubon Society collaborated in the establishment of the National Biofuels Roundtable in the summer of 1992. The U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy provided additional support for this effort. From the onset, the Roundtable was committed to reaching consensus on guiding the development of a sustainable biomass energy resource.

This report proposes general principles for policymakers interested in promoting biomass energy development and guidelines for energy crop management. The report also identifies some of the barriers confronting commercialization of biomass energy and offers policy options to address these barriers. Finally, the report concludes with an Agenda for Resolution, which summarizes issues that the Roundtable discussed, but upon which it did not reach consensus.

Early support for the Roundtable was provided by the U.S. Department of Energy and the Tennessee Valley Authority. RESOLVE: the Center for Environmental Dispute Resolution was hired to facilitate the meetings. The Roundtable consists of 30 persons with expertise in social and natural sciences. They represent 24 different constituencies of industry, government, academia, and public interest/environmental groups.

The Roundtable's proactive efforts were based on the following premises:

- U.S. dependence on fossil fuels may place at risk the nation's security, economic prosperity, and perhaps the world's climate[2].
- To reduce these risks, the development of sustainable, domestic alternative energy resources, including biomass fuels, is desirable.
- The manner and timing of the transition to a sustainable energy economy will be determined by a complex interaction of political factors, market forces, environmental concerns, and societal preferences. Government has a critical role in fostering the vision and supporting the outcome.

The renewable energy resource that offers the greatest near-term promise of providing both transportation fuels and dispatchable electricity is energy crops. The Roundtable believes that if energy crops are included in the general mix of agricultural crops in a considered and informed way, environmental damage can be avoided; in fact, there could be significant environmental and ecological benefits achieved in tandem with the development of a fully sustainable energy resource.

### Energy Crops

For purposes of this report, the Roundtable defines energy crops as perennial herbaceous and woody crops. Trees and grasses selected for high yields and resistance to drought and pests show the most promise for long-term development. Trees include hybrid poplar, cottonwood, silver maple, black locust, sweetgum, eucalyptus, willow, and sycamore.

Trees are harvested on 5-to-15 year cycles. In most cases, tree planting requires such agricultural practices as fertilization, suppression of competition from weeds, and control of disease and insects. Harvesting trees requires specialized equipment that may be owned cooperatively by groups of energy crop farmers, provided by contract harvesters, or supplied by the conversion facility.

Herbaceous energy crops include such perennials as switchgrass, big bluestem, intermediate wheatgrass, a number of tropical grasses, and a few legumes. In most cases, traditional farming methods and equipment can be used to grow these crops for energy. Most can be harvested one or more times during the growing season and may be baled like hay. Some annual crops, including grasses, grains, and oilseeds are already part of the biomass energy market.

As the demand for energy crops increases, it seems likely that other herbaceous and tree crops will be identified or developed.

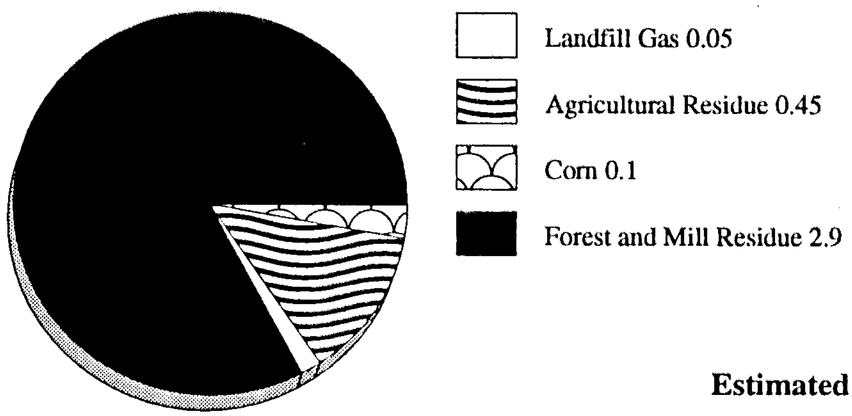
[1] A biofuel is any solid, liquid, or gaseous fuel derived from biomass. For purposes of this report, biomass is considered to be living or recently living plant materials, primarily lignocellulosic materials whose principal components include cellulose, hemicellulose, lignin, carbohydrates, and ash.

[2] The United States joined 153 other nations in signing the United Nations Framework Convention on Climate Change at the Rio de Janeiro "Earth Summit" in June of 1992. The Framework Convention, which was ratified by the United States Senate in October 1992, establishes the objective of stabilizing "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." The President's Climate Change Action Plan was announced in October 1993 with the specific goal of returning "...U.S. greenhouse gas emissions to 1990 levels by the year 2000 with cost effective domestic actions."

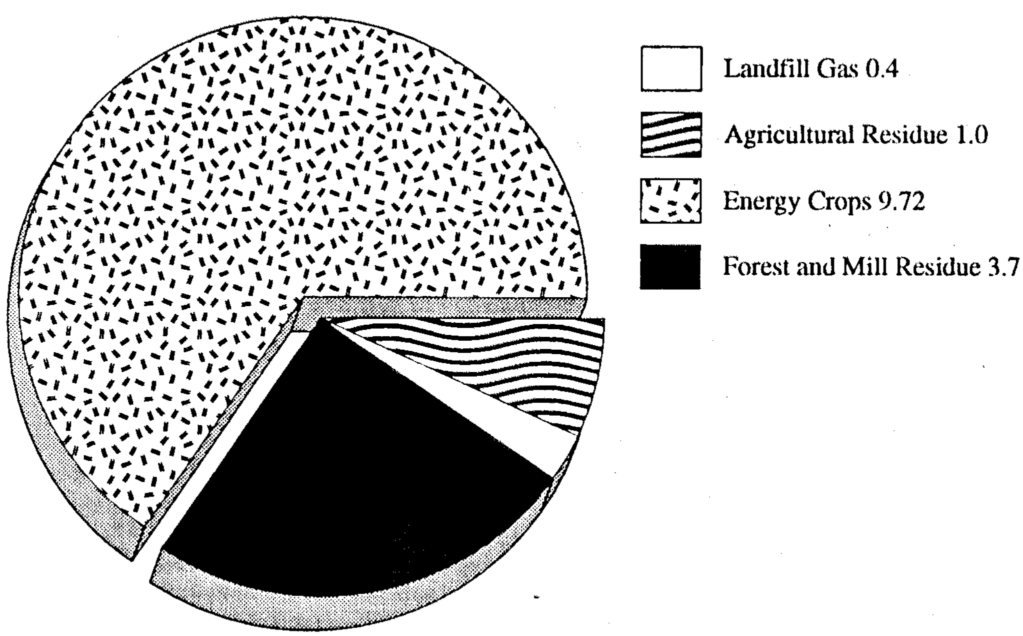
# Projected Change in Biomass Resources Utilization 1990 to 2030

Amounts in Quadrillion BTUs[3]

### Existing Biomass Resources (1990)




### Estimated Biomass Resources (2030)




[3] One quadrillion BTUs, or one quad, is the amount of energy contained in 45 million short tons of coal, 65 million short tons of oven-dried hardwood, 1 trillion cubic feet of dry natural gas, 170 million barrels of crude oil, 470,000 barrels of crude oil per day per year, 28 days of U.S. petroleum imports, 26 days of U.S. motor gasoline use, or 26 hours of world energy use in 1989.

## The Objective of the Roundtable

The objective of the Roundtable has been to assess energy crop production practices to define a set of principles and strategies for responsibly guiding the development of biomass energy systems. This report reflects the consensus of the members of the Roundtable; it also discusses topics for which consensus has not been achieved and the reasons for the lack of resolution of these issues.

### What is biomass energy?

Biomass energy is a form of solar energy. Green plants transform the energy in sunlight into chemical energy in a process known as photosynthesis. During photosynthesis, plants use light to change carbon dioxide and water into a variety of energy-rich carbohydrates, primarily sugars, cellulose, and starch. These compounds give rise to other energy-rich plant substances, including oils and protein.

Biomass energy can be used to make electricity, liquid transportation fuels, gaseous fuels, and a variety of useful chemicals, including those currently manufactured from petroleum. Because the energy in biomass is less concentrated than the energy in fossil fuels, new technologies are required to make this energy resource competitive with coal, oil, and natural gas. Superior energy crops and cost-effective conversion technologies are currently under development in government laboratories and in the private sector.

Of necessity, this report has a national, almost global viewpoint and reflects current knowledge and conceptual understanding; it is not intended to be viewed as final prescriptive doctrine. Its translation into good practices at local and regional levels will have to take account of the fact that geographical and ecosystem-specific factors will influence the measures to be adopted. This implies that biomass energy systems must be developed to be both environmentally and economically sustainable. Adoption of a particular environmental protection measure may make the costs of biomass fuels higher than those of competing energy resources. The Roundtable recognizes the importance of designing environmental protection strategies to be as cost effective as possible.

## Biomass Energy Systems

More than 7,000 MW of grid-connected biomass power capacity is presently installed and generating electricity from mill and wood-processing residues and from agriculture and forest residues. About 1 billion gallons of ethanol is produced from corn each year. Significantly more electricity and fuels may be produced from biomass in the future. Most of the additional feedstock needed to support this increased energy production is anticipated to be produced from crops grown on idle or under-used croplands. The U.S. Department of Agriculture projections made for the Second Resource Conservation Act Appraisal indicate that by the year 2030, cropland available for production of energy crops would be between 30 and 81 million hectares (74 and 200 million acres).[4] Currently there are more than 14 million hectares of cropland set aside in the Conservation Reserve Program. Much of this land would be available and suitable for energy crops.

While forest-harvesting residues and wood-processing wastes are insufficient to fuel a major expansion of biomass energy development, they are likely to continue in niche markets and serve as bridging feedstocks as dedicated crops mature. Forest thinnings, low-quality wood from damaged and diseased forests, and residual wood from plantations of short-rotation trees produced for fiber also may be used.

## Principles for Developing Biomass Energy

The underlying principles for the Roundtable's recommendations and strategies are as follows:

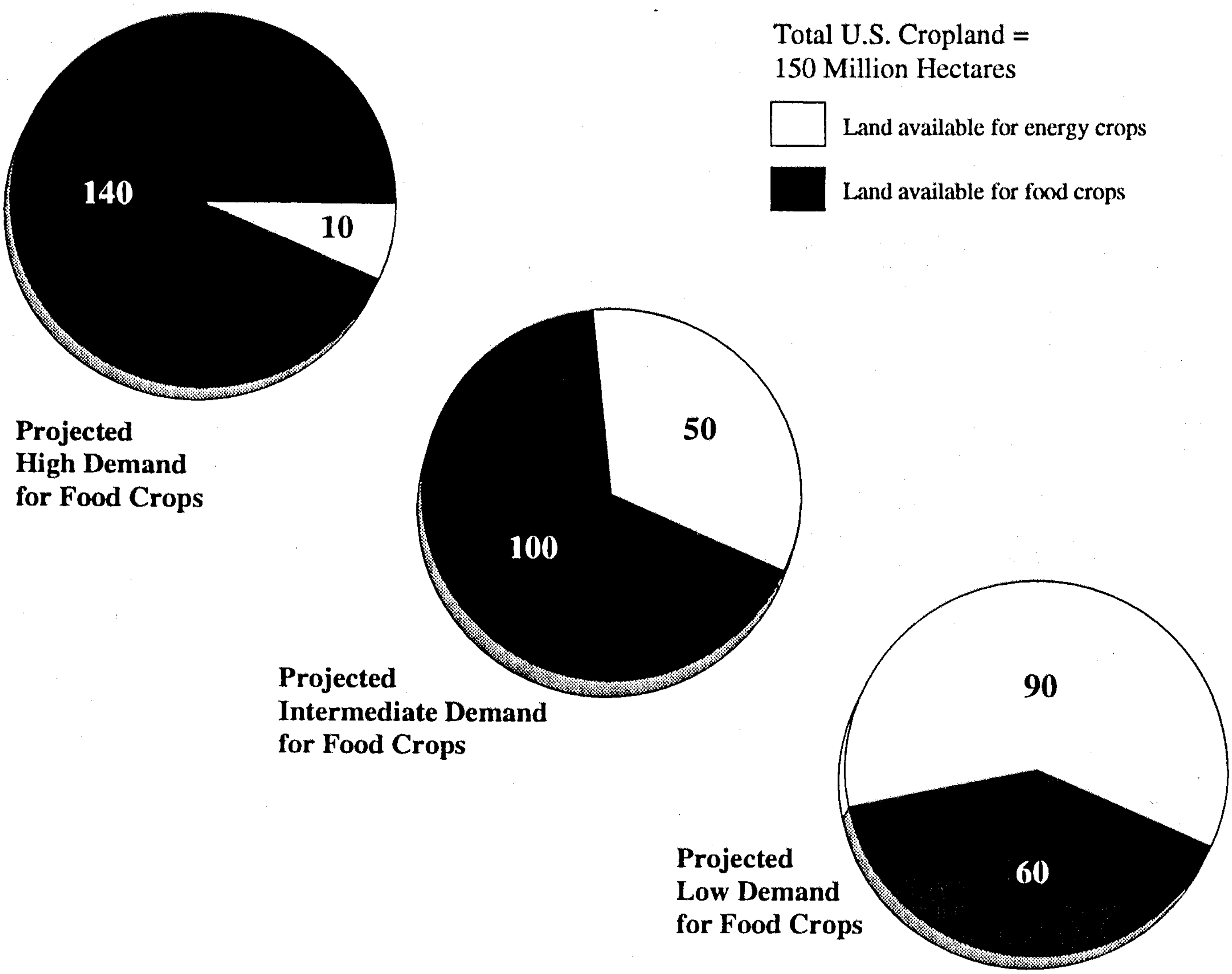
- Biomass energy system development must be guided by consistent decision criteria and should foster the multiple goals of environmental protection, economic revitalization, and energy security.
- Energy crop production practices and energy conversion technologies must be selected to ensure that the use of biofuels substantially reduces anthropogenic emissions that may contribute to global climate change. The use of biofuels should not exacerbate greenhouse gas emissions when compared with conventional fuels on a full-fuel cycle basis.
- The development and management of biomass resources should protect, and wherever possible ***enhance***, ecological integrity and biological diversity, while minimizing adverse impacts to land, air, and water.
- The development and management of biomass resources should contribute to the economic well-being of producers, local communities, and the nation as a whole.

[4] USDA. 1990. The Second RCA Appraisal: Soil, Water, and Related Resources on Nonfederal Land in the United States. Analysis of conditions and trends. Misc. Publication No. 1482. Chapter 12.

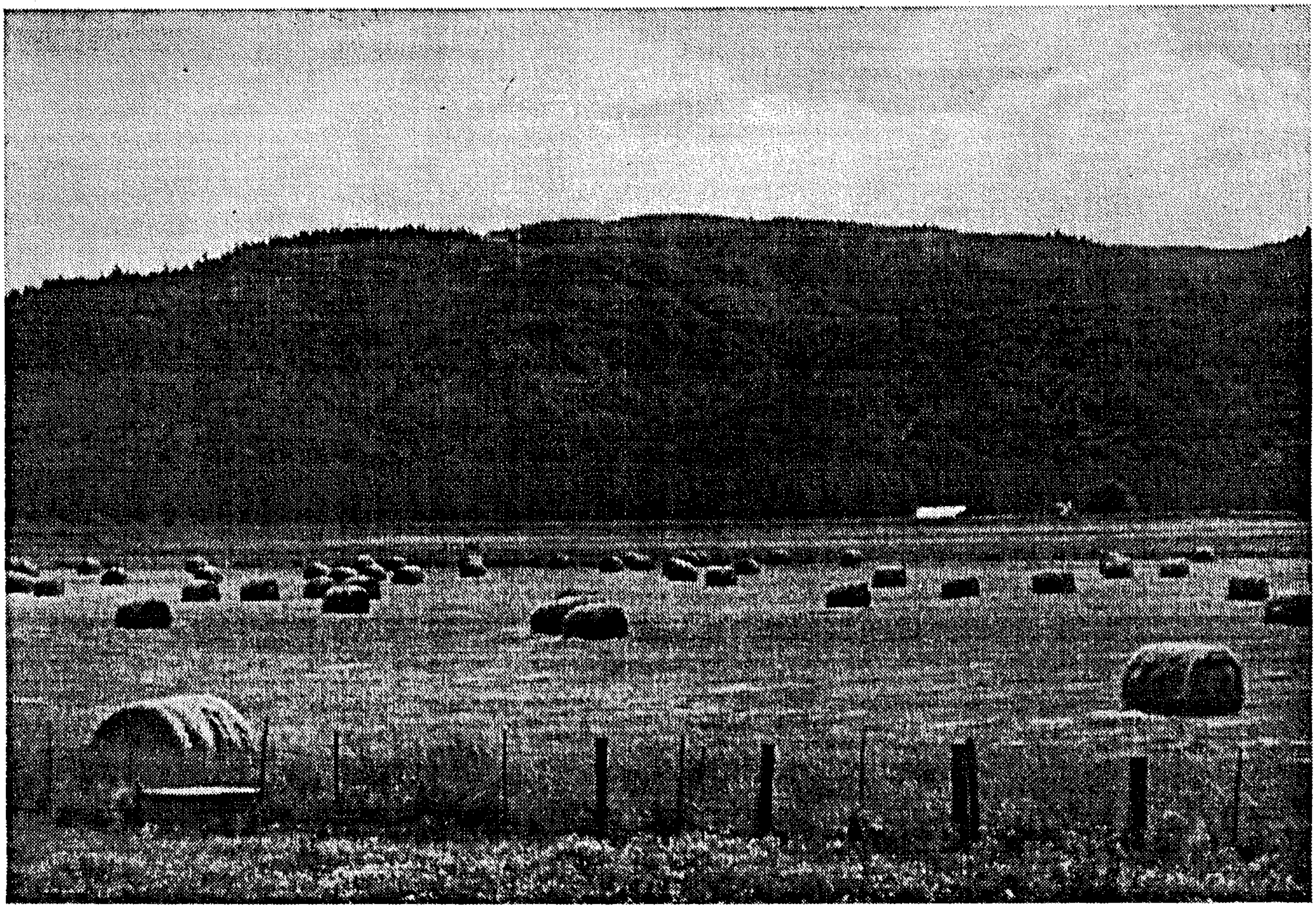
Figure 2

## Projected Land Available for Food and Energy Crops 1990 to 2030

Amounts in Million Hectares




SOURCE: Lynn L. Wright, ORNL



**Biomass resources should contribute to the economic well-being of producers, local communities, and the nation as a whole.**

- The use of biomass resources for energy purposes must rationalize trade-offs in terms of competing uses for the land and plants (whether for food, fiber, recreation, wildlife habitat, or other uses), while also recognizing the impacts and trade-offs implicit in the use of other energy resources.
- Long-term commitment, consistency of public support, and effective policy coordination are as important as year-to-year funding levels for biomass research and development.
- The formulation and implementation of biofuels policy should proceed, so far as possible, on a collaborative model that involves all stakeholders. Because of the diversity of stakeholders and interests involved, collaboration and agreement on common goals can be critical to ensure successful commercialization of a new technology like biomass production for fuels and electricity.

Biomass energy is already one of the most successful alternatives to the use of fossil fuels. Guided by the principles outlined above, stakeholders in the biomass energy industry can develop this resource, build a financially secure industry, and help to maintain a healthy environment for generations to come. It is appropriate to plan and monitor practices as conversion technologies, feedstock management systems, and market infrastructure are being developed.

# Biomass Energy: Environmental Considerations

The net environmental impacts of biomass energy systems will depend on the specifics of the biomass production and conversion technologies employed. With renewable biomass production and minimal fossil-fuel inputs, biomass energy systems can reduce emissions of both carbon dioxide and acid rain precursors. An increased demand for the production of biomass fuels could be met through crop land conversion or the conversion of existing forests, grasslands, and wetlands. Each of these has different potential impacts to the environment and different levels of perceived value. The substitution of perennial energy crops for annual row crops could provide substantial environmental benefits by improving habitat quality for resident wildlife, maintaining biodiversity, reducing soil erosion, and improving water quality[5]. Conversely, the over-harvesting of forests for fuel wood or the conversion of forests or wetlands to energy crops could seriously impact wildlife, soils, and water quality.

Some crops, including corn, wheat, soybeans, or other row crops, would be replaced by perennial grasses (e.g. switchgrass) or short rotation woody crops such as willow or hybrid poplar. The new energy crops would provide vegetative cover throughout the year, offering increased soil and watershed protection, as well as improved wildlife cover. Fewer applications of agricultural chemicals and reduced tillage could benefit local water quality. In addition, perennial crops may allow a farmer to enter a field fewer times over the course of a year, reducing energy costs and consumption and related emissions from machinery use.

### Climate Science

The science of global climate change continues to generate heated debate, in part because of its complexity and many uncertainties, and in part, because of its profound implications for the world's present energy economy. It is known that greenhouse gases, including water vapor, carbon dioxide, methane, and other trace gases, trap heat in the earth's atmosphere. Concentrations of some of these gases have been increasing. The debate centers on whether other feedback mechanisms and biotic interactions will offset (or exacerbate) a potential warming effect and if so, to what degree. Consequently, future climatic effects cannot be predicted with any certainty.

Nevertheless, ice core data do show an historic correlation between carbon dioxide concentrations and temperature. Few scientists dismiss the possibility that global warming could occur if carbon dioxide and other greenhouse gas concentrations continue to build up in the atmosphere. While there has been considerable debate about the consequences of such a build up, the most recent scientific assessment by the Intergovernmental Panel on Climate Change continues to estimate an increase in global average temperature ranging from 3 to 8 degrees F will likely result from a doubling of atmospheric carbon. Given the possible consequences of such a warming, many policymakers and scientists have recommended prudent measures to, at a minimum, reduce the risk of climate change. This rationale has provided the basis for national and international efforts to address climate change. It is likely to provide added impetus for sustainable biomass development.

The conversion of land to energy crops from existing perennial crops, pasture, or agricultural land in the earlier stages of disuse may result in fewer environmental benefits. Changes involving wildlife, chemical use, and soil stability will likely need careful monitoring to maintain existing environmental quality.

The conversion of existing forests, grasslands, or wetlands to energy crops could result in negative environmental effects. Woodlands harvested on long rotation cycles or woodlands not currently harvested provide wildlife habitat and protect soil and water. Short rotations of woody crops preclude forests from reaching maturity, which decreases the value of woody crops to interior forest wildlife species or species such as amphibians that have narrow habitat niches. Short rotations also increase the exposure of soils to erosive factors.

Given these concerns, the Roundtable recommends that biofuels be primarily produced on existing agricultural lands. Since the interactions between crops and the environment are complex, these relationships should be monitored closely as large-scale systems are developed. The environmental issues surrounding energy crop production are discussed in the remainder of this chapter and guidelines for crop management are presented in Chapter 3.

## Global Climate Change

The potential for global climate change is likely to have important implications for biomass energy development. The presence of certain heat-trapping gases in the atmosphere exerts a warming effect on the planet that is partially responsible for the earth's hospitable climate. Increased concentrations of these

[5] Statements in the text that most dedicated feedstocks are expected to be produced on retired cropland must be reconciled with statements elsewhere that biomass production will have its greatest environmental benefits when land currently in annual row crops is converted to energy crops. According to USDA program provisions, retired cropland (such as the CRP) is considered to be in its former crop use. However, other government policies (such as Conversion Compliance) and market conditions will determine how much retired land would, absent a biomass production option, return to its former use once program contracts expire. To the extent that retired parcels would not otherwise revert to annual crop production, the environmental benefits from converting them to perennial energy crops would be smaller.

gases as a result of human activities could amplify the existing greenhouse effect and lead to an increase in average global temperatures.

Carbon dioxide is an important greenhouse gas. Major anthropogenic sources of carbon emissions are fossil fuel combustion and the conversion of forests to other uses. Under the 1992 United Nations Framework Convention on Climate Change, the U.S. and other countries pledged to "...achieve...stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner."

As a renewable energy resource, biomass may offer significant opportunities to displace carbon emissions from fossil fuel combustion and thereby reduce the risk of future climate change. Although the burning or decay of plant material also releases carbon to the atmosphere, this carbon can be effectively "recycled" through photosynthesis as new energy crops are grown. The result, if energy crops are managed sustainably, can be a fuel cycle that contributes little or no net carbon to the earth's atmosphere.

Of course, fossil fuel inputs associated with harvesting, processing, and delivery of feedstocks, as well as with fertilizer and chemical use, can lead to net carbon emissions even for biomass-based energy production. These emissions can be significant for some biomass energy systems, including the current corn-to-ethanol process. To the extent that biomass systems increase long-term carbon sequestration through changes in soil composition and root structure, emissions from fossil fuels may be offset. It is critical, if biomass is to be considered a clean and sustainable resource for the long term, that efficiency be maximized and fossil inputs be minimized throughout the biomass fuel cycle.

## Carbon Cycle

Plants constitute a living reservoir of stored carbon. When plants are burned or decomposed, the carbon is released to the atmosphere. As long as the quantity of organic matter is fully replaced by new growth, however, there is no net increase in atmospheric carbon.

Biomass is in short-term equilibrium with the atmosphere as compared with fossil fuels. Fossil carbon stored in the ground is put back into the atmosphere eons after it was sequestered, thus increasing the atmospheric carbon dioxide burden. The carbon dioxide fixed by solar energy through photosynthesis is re-released after the crop is harvested and used for energy. Sometimes this is described as closed loop, or alternatively as a net-zero dioxide source. However, to the extent that fossil fuels are used in harvesting and transportation, it will not be a net-zero source.

In some instances, biomass may be sequestered in the soil (undergoing physical and chemical changes). In such cases, the loop will in fact sequester carbon and behave as a sink! Thus, the exposure of carbon-rich soil (as a result of certain harvesting and management practices) can release substantial quantities of carbon dioxide, which may not be recaptured in the plants or soil for long periods of time. This is why a short rotation energy crop may never fully recapture the carbon lost when a mature forest with high carbon storage capacity is harvested.

The net carbon benefits of a particular biomass energy system will depend both on the carbon emissions associated with the energy system it replaces and on resulting changes to the prior carbon inventory. The ability of a biomass system to displace fossil fuel carbon will depend on the productivity of the biomass system and on the efficiency of conversion technologies.

## Air Quality

Problems with urban air pollution and acid rain are also providing an impetus for the development of biomass energy systems. Federal legislation aimed at improving air quality has already led to improved emissions control at power plants and more stringent controls on automobile pollution. Renewable energy is specifically cited in the Clean Air Act Amendments of 1990 as being eligible for $SO_X$ offsets and credits.

Properly managed, biomass energy systems can mitigate some problems with air pollution. Compared to coal and oil, the majority of biomass fuels contain almost no sulfur, making them a candidate for offsetting power plant $SO_X$ emissions. However, the combustion of biomass (or biomass fuels) does produce some air pollutants, which may require emissions control devices. The control of $NO_X$ emissions, for instance, is as important for biomass fuels as it is for fossil fuels.

To the extent a biomass fuel cycle employs fossil fuels, it will generate additional air pollutants. The combustion of diesel and other petroleum-based fuels emit carbon dioxide, hydrocarbons, $SO_X$, $NO_X$, carbon monoxide, and particulates. Minimizing fossil-fuel inputs to biomass fuel cycles would help protect air quality.

## Typical Erosion Levels and Agricultural Chemical Use of Selected Food and Energy Crops

| Crop | Erosion $Mgha^{-1}yr^{-1}$ | Nitrogen $kgha^{-1}yr^{-1}$ | Phosphorus $kgha^{-1}yr^{-1}$ | Potassium $kgha^{-1}yr^{-1}$ | Herbicide $kgha^{-1}yr^{-1}$ |
|---|---|---|---|---|---|
| Corn | 21.8 | 135 | 60 | 80 | 3.06 |
| Soybeans | 7.1 | 10 | 35 | 70 | 1.83 |
| HECs* | 0.2 | 30 | 50 | 90 | 0.25 |
| SRWCs** | 2.0 | 60 | 30 | 80 | 0.39 |
| Pasture | 2.0 | 20 | 30 | 30 | 0.15 |

SOURCE: Lynn L. Wright and William G. Hohenstein (eds.), "Biomass Energy production in the United States: Opportunities and Constraints," *Biomass and Bioenergy*, in press 1994.

* Herbaceous energy crops

** Short-rotation woody crops

### Water Quality and Soils

The conversion of agricultural lands from their present use in row or grain crops to perennial and wood crops may generate significant improvements to soil structure, organic matter content, and water quality. The nature and extent of the improvements will depend upon the particular changes in crop and management approach. For example, perennial grasses and woody crops both develop a more extensive root systems than most annual crops. The root systems add organic matter to the soil,[6,7] slow erosion, and help in reducing soil compaction. By providing continuous vegetative cover for several years, perennial grasses protect the soil against wind and water erosion. This benefit is less clear compared to perennial hay crops and negative compared to most native habitats.

Soils in row-crop fields converted to short-rotation or perennial herbaceous energy crops accumulate approximately 2.4 megagrams (Mg) per hectare per year of organic matter over 10 to 20 years[8]. This figure suggests that soil properties such as structure, nutrient status, water holding capacity, and density (all of which depend upon soil organic matter content) will be improved over row crop use. Agricultural crop erosion models project that average erosion during the establishment of energy crops is within tolerable limits set by the Soil Conservation Service. Annual erosion rates for lands with perennial energy crops will probably be in the range of 0.2 to 3.0 Mg per hectare based on projections and very limited field data. However, without conservation measures during the crop establishment phase, erosion rates may parallel row crops at 10-20 Mg per hectare. Such high rates drop rapidly in the second and subsequent years when there is continuous cover. Studies on nitrate leaching confirm that fertilizers, applied to energy crops at rates that do not exceed soil nutrient requirements, do not leach into groundwater but are retained by the trees and soil. Only during the establishment phase are nutrients leached to the extent that EPA standards may not be met[9,10]. There is a need for research to optimize production practices during this critical phase.

The environmental advantages of shifting to energy crops depend on the prior land use and the energy crop chosen. Comparing row crops to perennial energy crops tends to maximize the environmental benefits of the shift to energy crops. In other cases, the environmental benefits associated with such a shift may be smaller or even negative.

[6] Ranney, J.W., L.L. Wright, and C.P. Mitchell, "Carbon storage and recycling in short-rotation wood crops," in *Proceedings of the International Energy Agency Executive Committee (Forest Energy)*, December 1990, Stockholm, Sweden. Copies available from Box 2008, MS 6352, Oak Ridge, TN 37831.

[7] Personal communication, Ed Hansen, United States Forest Service (from a 1993 unpublished study on soil carbon levels in tree plantations of varying age in the upper midwestern United States.)

[8] D. L. Gebhart, H.B. Johnson, H.S. Mayeaux, and H.W. Polley, "The CRP Increases Soil Organic Carbon," *Journal of Soil and Water Conservation*, in press.

[9] R.D. Perlack, J.W. Ranney, and L.L. Wright, "Environmental emissions and socioeconomic considerations in the production, storage, and transportation of biomass energy feedstocks," ORNL/TM-12030, 1992. Copies available from Box 2008, MS 6352, Oak Ridge, TN 37831.

[10] U.S. Congress, Office of Technology Assessment, *Potential Environmental Impacts of Bioenergy Crop Production*, Background Paper, OTA-BP-E-118, Washington, D.C., U.S. Government Printing Office, September 1993.

To the extent that energy crops require less fertilizers and pesticides than annual crops, the risk of groundwater and surface water contamination would be reduced. Fertilizer use with most energy crops is less than for corn or sorghum and approximates applications for wheat. These rates vary greatly between sites and different energy crops. Energy crops, because of their perennial nature, offer the opportunity to apply fertilizers at closely determined efficiency rates with respect to plant growth, site retention of the nutrients, and soil leachate quality. Soil scientists suggest that the application of fertilizer that results in greater plant growth in these crops actually results in increased soil organic matter since more roots and leaf litter are formed.

Most fast growing woody crops may require more water than some agricultural annual crops, but there may be regional exceptions. Even so, energy crops could be used to mitigate damage to riparian (adjacent to surface water) ecosystems resulting from adjacent intensive agricultural practices. Energy crops can be planted as run-off filters between conventional crops and riparian areas, capturing soil lost by erosion and absorbing nutrients and pesticides. These buffer zones may also provide wildlife corridors to connect fragmented habitats and increase the effective interior habitat of adjacent forests.

Pesticide application rates for energy crops are not yet defined. Herbaceous crops should require no more than most hay crops, which is a small amount compared to row crops. Short-rotation woody crops are expected to require somewhat more, but still on the average, relatively small amounts compared to row crops. Alternative methods to total weed control and chemical use are under consideration for economic reasons and for environmental protection. Unknown is the extent to which woody crops will need control of insects; to date this has been minimal, but pest outbreaks have to be anticipated. The type of pesticide along with the frequency and amount of its application are not expected to affect water quality in excess of EPA standards, but caution, vigilance, and careful selection and use of pesticides are necessary. It is routine practice to mix clones and use resistant or alternative species to lessen the likely impact of pests and diseases.

## Wildlife Habitat and Biodiversity

The conversion of cropland currently in annual row crops to perennial energy crops would generally benefit resident wildlife and maintain natural biodiversity. Some agricultural systems have been detrimental to resident wildlife species, by eliminating and fragmenting their habitat and by decreasing available cover and affecting food supplies. The change in habitat quality will depend on the specifics of the crop change and its arrangement in the landscape. For example, the conversion of row crops to native perennial grasses such as switchgrass or big bluestem is ideal for areas that were originally native grasslands. Perennial grasses would likely enhance grassland dependent species that experienced population decline when grassland habitats were fragmented by agricultural land use practices. Increased grassland acreage created under the Conservation Reserve Program of the 1985 Farm Bill has already resulted in increased populations and range expansions for grassland-dependent species such as the prairie chicken.

Similarly, grasslands developed for biofuel production could enhance neotropical migrant species adapted to grasslands. However, guidelines such as those provided in the subsequent chapter are needed to ensure that grassland habitats do not become "ecological sinks" that attract wildlife, only to have the habitat harvested at a crucial period. Destroying nests and young of the year during the spring reproductive period is not acceptable. Likewise, the indiscriminate planting of non-native plants could lead to undesirable ecological consequences, creating poorer habitat for resident wildlife than native species would provide.

The planting of woody crops in areas that were historically grasslands may further fragment remaining habitat for grassland species and can be perceived as either beneficial or harmful to wildlife. Increasing woody cover in a former grassland would benefit forest and edge dependent wildlife species at the expense of grassland dependent species. For example, woody cover in an agricultural landscape would benefit white-tailed deer, cottontail rabbits, and other species adapted to woody habitats. In such situations, the value of the changes would depend on regional wildlife management objectives. With foresight and planning, landowners should be able to enhance habitat for the desired mix of wildlife species, and at the same time generate acceptable levels of crop productivity.

The replacement of row crops with native woody energy crops — or hybrids with a native parent — in formerly forested regions may help increase populations of forest-dependent species. The habitat of forest dwellers has been (and continues to be) eliminated and fragmented by human activities. Woody crops could be sited to buffer and fill gaps between remaining forest fragments, reducing habitat fragmentation and increasing the availability of valuable forest-interior habitat. Furthermore, replacing soybeans or pasture crops in former bottom-land hardwood forests with native hardwood energy crops could help restore damaged riparian ecosystems.

Recent censuses of birds and small mammals in energy crop management systems has revealed substantial populations[11]. Birds found in short-rotation woody crops at the age of 5+ years consist of generalists and woodland species. Younger stands contain edge and generalist bird species but few field (grass habitat) species. Studies also suggest that short-rotation stands in predominately agricultural landscapes attract especially large numbers of a wide variety of wildlife. Older short-rotation hardwood stands appear to act more like native wood lots than other monocultures; younger short-rotation stands behave like early successional habitat; and it is not known whether these energy crops are sources or sinks for woodland wildlife populations. Studies on agricultural pest species in energy crops (e.g., cowbirds, blackbirds, raccoons) are not yet complete. Concern currently exists that displacing grain crops may deprive migratory birds of a food source during migration (e.g., corn along the Mississippi flyway).

Limited studies have examined the juxtaposition of short-rotation woody crops with other habitats, especially native forests, brush land, and cropland. Findings suggest that when energy crops are located next to forests, they effectively absorb the edge effect out of the forest itself and provide "forest interior" species more habitat[12]. Similarly, short-rotation stands may permit freer movement of some mid-size and large mammals and birds when the stands abut native forests. Thus, energy crops could act to connect native habitat for some species. Inclusion of native habitat and development of habitat corridors in connection with short-rotation wood energy crops would provide extremely important contributions to native wildlife biodiversity. However, the frequent disturbance of energy crops must be planned so as to minimize disruptions to habitat continuity within landscapes to provide sustainable benefits.

## Summary of Benefits and Costs of Different Biomass Resources

Increased use of biomass for energy could be based upon 1) expanding the current use of forest and agricultural residues, 2) using the existing forest base, and 3) converting croplands to dedicated energy crops[13]. The energy potential from the first resource is limited by the size of residue flows, while the second faces policy and market constraints. Cropland conversion thus constitutes the largest single source of potential energy crops.

Using any of these biomass resources has associated environmental benefits and costs. Many of these benefits and costs are summarized in Tables 1-3. In Table 1, the positive and negative attributes of the increased use of wood processing and agricultural wastes are listed. Table 2 depicts the impacts of using existing forests for energy[14]. Table 3 addresses the major area covered by the Roundtable deliberations on energy crops and the issues raised in this table are addressed in the succeeding chapter on guidelines. In each table, the benefit and cost categories are based on assumptions about how forest or agricultural resources would be used under the status quo. For example, Table 3 contemplates converting annual cropland to biomass; converting pasture to biomass would presumably have smaller environmental benefits.

[11] J.W. Ranney, "Principals and Issues of Biomass Energy Crops and the Environment," in *Proceedings of the 9th European Community Conference on Biomass and Bioenergy, Agriculture and Industry,* Florence, Italy, October, 1992.

[12] Personal communication, Wayne Hoffman, National Audubon Society, Taverner, Florida (based on bird census studies on industrial short-rotation plantations near Toronto, Canada, and Portland, Oregon.

[13] Dedicated energy crops are plants such as trees, grasses, algae, oil seeds, or annual crops such as grains grown specifically for energy use. This report focuses on lignocellulosic crops such as trees and grasses grown for energy. It does not address in detail plant products such as fats, starches, or sugars.

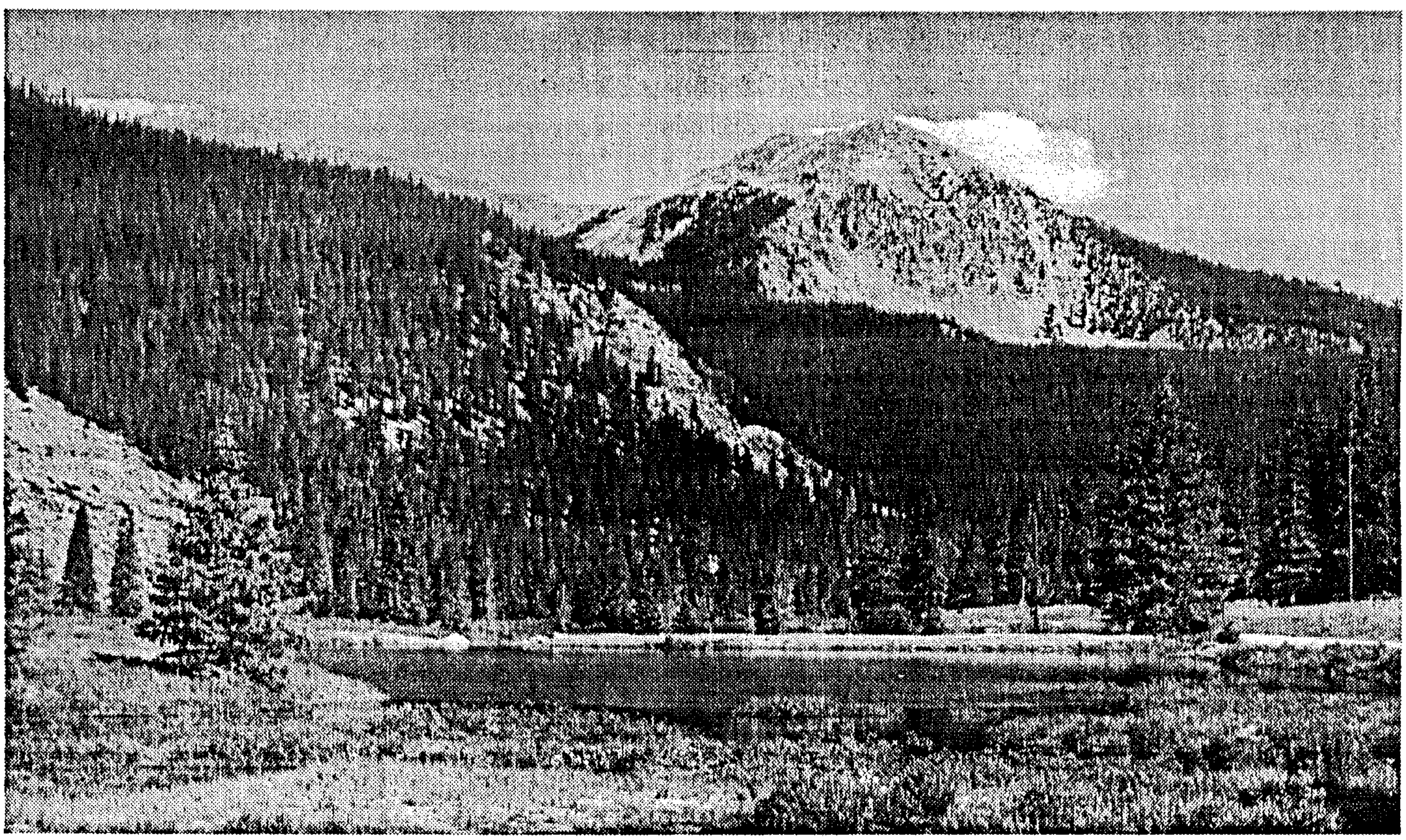
[14] The existing forest potential is already being realized to some degree in the Northeast. In Maine and Vermont, for example, energy use of forests is significant and is additionally used as a means to improve the quality of the forest for succeeding higher value timber harvests for use as saw logs and veneer.

## Table I.
## Potential Impacts from Increasing Use of Residues from Forest and Agricultural Harvesting and Processing

| Potential Benefits | Potential Negative Effects |
| --- | --- |
| • Serves as a bridge biomass source while energy crops are coming on-line<br>• Serves as a niche biomass source after energy crops come on-line<br>• Minimizes open field burning of crop residues and their attendant air quality concerns<br>• Reduces stress on landfills by providing an alternative use of woody and agricultural processing wastes and reduces emissions of methane from landfills<br>• Reduces potential negative water and air quality impacts due to run off or leaching from open buildup or dumping of residues<br>• Minimizes open burning of milling or processing residues and their attendant air quality concerns<br>• Provides economic and employment benefits by offering markets for residues and by minimizing disposal costs<br>• Reduces $SO_x$ emissions | • Reduces amounts of agricultural residues on cropland which may reduce soil organic matter and increase<br>– erosion<br>– sediment loadings<br>– soil compaction<br>which, in turn, lead to larger<br>– fertilizer requirements<br>– use of fossil fuels<br>• Reduces the amount of residue left on forest sites, which may increase<br>– erosion<br>– sediment loading<br>– soil compaction<br>and change<br>–wildlife habitat<br>–soil organic matter |

## Table II.
## Potential Impacts of Using Existing Forests

| Potential Benefits | Potential Negative Effects |
|---|---|
| • Serves as a bridge biomass source while energy crops are coming on-line | • Reduces site productivity |
| • Provides a market for low grade wood, forest products, and forest residues | • Reduces habitat diversity and availability |
| • Serves as a niche market after energy crops come on-line | • Increases soil erosion and sediment loadings to surface water and impairs water quality |
| • Increases the commercial value of stands by removing diseased and undesirable trees[15] | |
| • Reduces $SO_X$ emissions | |



[15] This potential benefit is discussed further in "When is harvesting forests for energy appropriate?" Appendix I, Agenda for Resolution, p 28.

## Table III.
## Potential Impacts of Converting Annual Cropland to Energy Crops

| Potential Benefits | Potential Negative Effects |
|---|---|
| • Reduces total quantity of agricultural chemicals applied which should reduce incidence of them in surface and ground waters | • Reduces ground and surface water levels in wetland areas (caused by evapo-transpiration from short-rotation woody crops) |
| • Reduces erosion and sediment loadings to surface water | • Harms wildlife populations if biomass harvesting destroys nests and young |
| • Reduces tillage operations which:<br>– reduces fossil fuel use<br>– reduces loss of soil organic carbon | • Puts wildlife at risk by changing the quantity and location of grain fields used by migrant species and resident wildlife. |
| • Sequesters soil carbon | |
| • Improves and/or increases wildlife habitat by augmenting area and connecting habitats | |
| • Increases biodiversity | |
| • As a buffer strip between water bodies and cropland, traps sediments, uses nutrients in sediments, and uses nutrients in subsurface flows to improve water quality | |
| • Provides a variety of habitats during early stages and maturing stages for forest and edge species, generalist species, and ground dwelling species | |
| • Serves as alternative use for surplus cropland | |
| • Reduces $SO_x$ emissions | |

# Managing Biomass Energy Systems for Environmental Benefits

Responsible land management is absolutely essential for a sustainable biomass energy industry. This chapter offers specific suggestions for developing and managing biomass energy resources. Site-specific, local and regional management issues are highlighted. Guidelines for managing biomass resources are presented. The Roundtable encourages farmers, local and state officials, utilities and other stakeholders to adopt these guidelines when implementing biomass energy systems.

> **Residues from Wood and Agricultural Processing**
>
> Because the Roundtable is focused primarily on energy crops, this document does not dwell on forest and agricultural co-products or residues. Nevertheless, processing residues are expected to play an important role in the evolution of the biomass energy industry. Virtually all the existing biomass energy systems are based on processing residues. Since we anticipate there will be an ongoing need for processing forest and agricultural products, these residues represent an indefinite supply of biomass feedstocks. Moreover, processing residues will continue to be the major feedstock resource for biomass conversion system research and development activities during the next few years. Thus processing residues will serve as a bridge for the biomass industry from current residue-based generating facilities to future energy systems based primarily on energy crops.

## Forest and Agricultural Residues

Biomass resources, primarily residues and co-products from forestry and agriculture, have been used for energy production for many years. The Public Utilities Regulatory Policies Act of 1978 (PURPA) encouraged the use of domestic and renewable resources such as biomass for electrical generation. These resources had the potential to decrease U.S. dependence on imported petroleum supplies and reduce emissions of $SO_X$ as compared to coal and oil. As a result of PURPA, biomass-fired, grid-connected electrical generation in the United States grew from 200 MW in 1979 to about 7,000 MW in 1992.

The primary feedstock for most of this biomass-based energy production has been woody residues and co-products from forest-products processing facilities such as sawmills, plywood plants, pulp and paper mills, and secondary wood-products manufacturing companies. In recent years, increased use of forests and agricultural harvesting residues have been considered, since a significant amount of residues remain unused that could generate electricity or be converted to fuels.

There are possible benefits from the increased use of forest and agricultural harvesting residues for energy production. Currently, such residues are left or burned on site. However, there could also be negative impacts from excessive removal of residues, which could increase the rate of soil loss and reduce soil fertility by reducing the quantity of organic material and micro-nutrients returned to the soil. Plans to use residues will need to take these concerns into account.

*GUIDELINES*
*Residues*

1) The use of forests and agricultural harvesting residues should be fully consistent with sustainable production and harvesting practices.

2) When harvesting forest residues, sufficient material (foliage, twigs and small branches) should be left on the forest floor to ensure adequate nutrient cycling, preserve soil structure and control erosion. Sufficient larger debris should be left to provide adequate wildlife habitat.

3) When harvesting agricultural residues, sufficient material should be left on the field to reduce runoff, increase infiltration, preserve soil structure, and control erosion.

4) Where appropriate, ash and processing residues from biomass conversion facilities should be returned to the land as soil amendments[16].

[16] For example, ash from biomass-fired boilers contains minerals beneficial for crop production. Composted processing residues or other composted biomass resources can be used to increase soil humus content and fertility. Land application of these materials contributes to biomass use and is considered essential for truly sustainable production.

## Forests

There is considerable interest in developing forest-based biomass energy systems in forested regions of the United States, particularly in the Northeast. It is likely that there will be an increased demand generally for fuel wood from forests while energy plantations mature. However, since the Roundtable was unable to reach consensus regarding likely impacts, acceptable harvesting levels or policy recommendations, these issues are not addressed here. Alternative perspectives are presented in Appendix I, Agenda for Resolution. Even so, there was general agreement that the following guidelines should be followed whenever forests are harvested.

*GUIDELINES*

*Forests (Forest harvesting is an unresolved issue. See Appendix I, p. 28)*

5) Harvesting forests for energy must follow ecologically sound management plans and use best management practices.

6) Regeneration of forests should be ensured. Harvesting activities should incorporate regeneration or replanting practices that will maintain indigenous biodiversity levels.

7) Forest harvesting should incorporate practices for preventing or minimizing damage to soils and water quality[17].

8) Disturbance of wetlands and streams should be minimized.

9) Sensitive ecological, natural and cultural features should be located in advance and protected by buffer zones as appropriate[18].

10) Sufficient large standing trees that are dead or dying (snags) should be left to provide habitat for cavity nesting species. Similarly, sufficient large debris should be left to provide adequate wildlife habitat.

11) Negative visual impacts should be minimized by the use of aesthetic best management practices, such as buffer zones and selective harvesting.

**Forest harvesting should minimize disturbance of wetlands and streams, protect sensitive areas with buffer zones, and leave sufficient debris to provide wildlife habitat.**

[17] Such practices include road siting and design to minimize erosion, streamside buffers, infrequent entry, equipment with low pressure tires, dedicated skidding trails, and cable or helicopter logging in steep slopes. Sufficient residues should be left on site to control erosion.

[18] Examples of such features include karst topography, endangered and threatened species and their habitats, and sites of historical or anthropological interest.

## Energy Crops: *Landscape and Regional Issues*

A transition to energy crop production will change land use and vegetative cover. If these changes are significant, it will be crucial to consider their aggregate socioeconomic and environmental effects, both positive and negative, from a variety of viewpoints. Innovative approaches are needed to consider, monitor, and guide these broad-scale effects toward desired ends. This calls for an understanding of how biomass supply systems for energy interact with their surroundings.

Issues of concern, such as job creation, biodiversity, or nonpoint source water pollution, each have geographic scales at which they can best be described. Depending on the issue, the geographic scale may be a hillside, a community, a watershed, the biomass procurement area for a biomass conversion facility, an ecoregion, or a state(s). The important point is that cumulative effects on ecosystems and socioeconomic systems be recognized. Guidelines can be developed beyond site-specific applications that accrue to greater benefits for people and their environment. These guidelines should strive for the sustainable functioning of ecosystems, especially with the introduction of new crops.

The prospect of regional-scale guidelines across multiple land ownerships raises serious concerns about property rights and cost equity in meeting guidelines. Guidelines alone will not determine the decisions of individual landowners. Partnerships, such as those between landowners and state stewardship programs, or between environmental groups and developers of biomass energy conversion facilities, are essential for implementing useful guidelines. The guidelines can provide a mechanism for the sum of the landowner decisions to be positive. A variety of strategies can be used to implement regional guidelines: education, incentives, cost-sharing, or development of local guidelines. Strategies should foster partnerships among producers, consumers, and society.

Land use changes could bring cumulative environmental benefits or damage at the landscape level, depending upon how they occur. Some of the possible landscape-level changes include: habitat fragmentation or consolidation, changes in the size and distribution of wildlife populations, changes in soil erosion and siltation, and changes in biodiversity. According to Perlack et al., the feedstock requirements of conversion facilities would not likely demand that more than 11% of any landscape be used for energy crop production[19].

### Landscape Planning Concepts

From an ecological perspective, a region is the sum of its parts: the hydrology, the climate, the land use patterns, plant and animal life, existing social and economic infrastructure, and the values of those who live there. The assessment of potential, cumulative ecological impacts often occurs from a "top-down" perspective in space and time. At the regional scale, evaluation of the impact of biofuels development should consider climate, evapotranspiration, competing land uses, and biogeochemical cycles such as cycling of carbon and nutrients. At the landscape scale, additional concerns include agricultural policy impacts, landforms and topography, existing and historic natural vegetation, air and water quality patterns, soil, and biodiversity. Dominant social and economic concerns include geographical, collaborative, or competitive relationships among utilities, agricultural producers, and forest product industries.

Adoption of a holistic and hierarchial perspective will lead to the recognition that some regions and landscapes are better suited to biofuels development than others. Once such a perspective is gained, local siting strategies fall into place, along with a realistic estimate of the source and size of the biofuels resource. This approach may lead to implementation of comprehensive, regional environmental assessments, which provide the context for evaluating future local developments. By channeling more resources and expertise into regional assessments, decision-making may be both more timely, cost-effective, and of higher quality.

[19] The extent of energy crop deployment cannot yet be accurately predicted. Speculation is that 5 to 15% of land around a biofuel conversion facility may be the maximum land area affected (R.D. Perlack, J.W. Ranney, and L.L. Wright, *op. cit.*, 1992). For example, Oak Ridge National Laboratory has calculated the amount of land required for two types of biomass conversion facilities. Both calculations assume a yield of 11 $Mg ha^{-1} yr^{-1}$ (5 dry tons $acre^{-1} yr^{-1}$) delivered to a biomass conversion facility. An ethanol plant processing 1800 dry Mg/day (2000 dry tons/day), which operates 330 days/year, would require 11% of the land within a 42-km (25-mile) radius of the facility. Similarly, a 100 $MW_e$ electric power plant with a 70% capacity factor, at a heat rate of 10,000 Btu/kWh, would require 6% of the land within the same radius.

Less than 11% of the available cropland should meet most supply needs. At this penetration level, energy crops would be the third or fourth most important crops in most regions. Higher percentages could occur locally. The point is that energy crops could be significant but will probably not dominate agricultural land use or involve overwhelming land use changes.

At present, the size of proposed conversion facilities is limited by the available feedstock supply. The problem is compounded by the fact that grower returns per hectare for energy crops are less than those for many regular commodity and specialty crops. If this continues to be the case, changes for most landscapes will be moderate. The effects will depend on which crops are replaced by energy crops, and how those energy crops are managed. On the other hand, changes in agricultural policies and crop markets could make energy crops much more attractive to growers. The need to produce adequate supplies of food, feed, or fiber crops may limit the extent of such land conversion, however. Changing circumstances could lead to more general and extensive landscape changes.

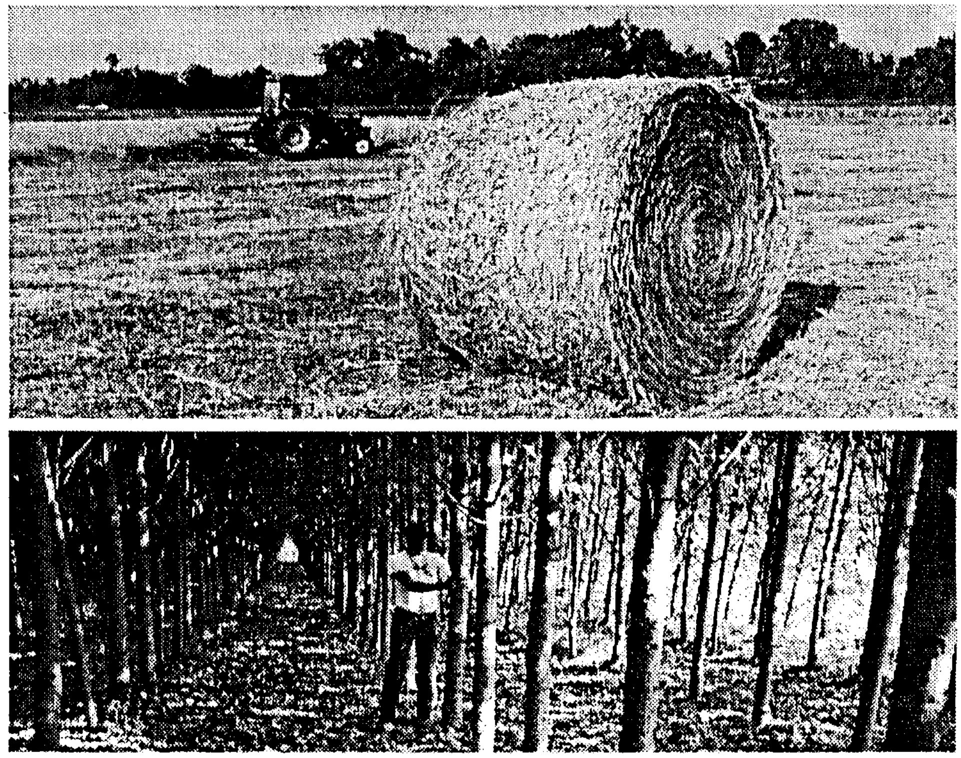
Developing general principles at the regional scale has been difficult since available information is limited and fragmentary. Nevertheless, there are opportunities to improve ecosystem functions at the regional scale and to test and refine guidelines over time. To the extent that agricultural lands are converted for energy crop production, the guidelines set forth below should help direct such changes in beneficial directions.

*GUIDELINES*

*Habitat*

12) Match native ecosystem cover types as much as possible (e.g., perennial grasses in prairie regions and trees in woodland regions). In addition, emulate natural vegetation patterns and functions when establishing energy crops on agricultural land.

13) Locate, plant, and harvest tracts of energy crops in ways that help improve pathways for animals to move between habitats and across landscapes in any particular year[20].



**Energy crops should be considered agricultural crops since they require agricultural production practices.**

14) Employ energy crops in ways that minimize the fragmentation of desirable habitats and improve overall habitat quality of the landscape for native species[21].

*Environment*

15) Where possible, solve additional environmental concerns when establishing energy crops[22].

16) Use management practices that protect land, especially marginal land, from environmental degradation or help diminish degradation caused by human use.

17) Incorporate aesthetic and cultural values when planning at the regional level[23].

18) At the watershed scale and in agricultural landscapes, use energy crops as stream-side filters to control nonpoint source water pollution effects.

19) At the landscape scale, energy crop management should encourage genetic and species diversity of energy crop plantings.

*Policy*

20) Ensure that, when energy crops are under consideration for classification and regulatory use, they be considered agricultural crops since they require agricultural production practices.

21) Use landscape-scale planning as a basis for encouraging individual land use decisions that aggregate to a positive landscape effect.

[20] Energy crop producers can facilitate wildlife movement across the landscape. If some energy crop plantings continue to mature during the time others are being harvested, suitable habitat will be available at all times. Growers can also use energy crop production to assist the survival of a limited number of species.

[21] Examples of such enhancement include use of woody biomass plantings to close forest gaps, creation of wooded corridors linking forest tracts and the establishment of buffers for forest fragments and corridors of otherwise marginal size.

[22] For example, sewage sludge could be applied as fertilizer to energy crop fields. Energy crops could also be planted as buffers around stream banks to capture nutrient runoff from adjacent agricultural fields.

[23] For example, planners could agree to keep selected rural areas green and productive or to maintain them in viable farming operations.

## Sustainable Agriculture

Sustainable agriculture is an overarching, interconnected framework of technologies and practices that lead to agricultural production systems that are economically sound, socially acceptable, and environmentally benign. It is inherently site specific. The goals of sustainable agriculture include the control of wind and water erosion of soil, protection of ground and surface water quality, protection of air quality, reduction of the use of all types of pesticides through integrated pest management and biological control, management of fertilizer inputs, and the improvement of quality of life and rural communities. Sustainable agriculture recognizes, however, that off-farm inputs such as fertilizers or pesticides may be required, but has as one of its goals, their minimization. The site specific nature of sustainable agriculture is dependent upon effective management in order to make the most efficient use of each field or farm.

## Energy Crops: *Site-Specific Issues*

As noted, portions of the future agricultural landscape may be devoted to production of energy crops. Concerted economic and political forces could soon cause rapid movement toward large-scale energy crop production systems. In fact, such trends are already happening for fiber production.

The list of guidelines that follows has grown out of deliberations in which we have sought to foresee and avoid potential adverse on-site impacts on the sustainability of biomass production systems. The guidelines were developed to apply to current cropland or former cropland. They do not apply to other categories of land. The principles are general enough, we hope, to be applicable for a wide range of possible crops and geographic settings.

Our list of guidelines attempts to draw attention to factors that should be considered in developing an environmentally sound and sustainable energy-cropping system. We promote practices that conserve or improve soil, water and biotic resources. We have attempted wherever possible to suggest principles that might ameliorate existing human-made problems.

*GUIDELINES*

*Site Selection*

22) Sites should primarily be cropland. Avoid critical habitat sites that might be negatively affected.

23) Evaluate sites with respect to the anticipated management practices for the potential energy crop or crops[24].

*Species Selection (Using non-native species as energy crops is an unresolved issue. See Appendix I, p. 29)*

24) Match energy crop species to sites.

25) Produce a mix of crops, where sites and markets allow, to diversify the landscape and spread risk.

26) Rotate crops or species to reduce nutrient depletion or build up of pests.

27) In species selection, consider the ability of crops to sequester significant amounts of carbon through roots and other material left on site.

28) Give preference to native species and hybrid species in the same genus.

*Genetics*

29) Since the production environment is dynamic, continued genetic selection and improvement will be required to sustain diversity and enhance pest resistance and productivity and ensure the retention of the genetic pool.

*Site Preparation*

30) Recognize that site preparation requirements vary by crop, site and subsequent management requirements.

31) Use conservation tillage practices where applicable.

*Harvesting Strategies*

32) Consider short- and long-term site quality (i.e. organic matter content, soil structure, soil erosion, nutrient content, compaction) in harvest planning.

33) Focus on harvesting strategies as an area for potential cost reduction[25].

34) Coordinate harvesting strategies with handling, storage, product quality and market requirements.

35) Implement harvesting strategies based upon site-specific and seasonal considerations affecting conversion facility operations. In addition, consider the relationship of harvesting schedules to soil compaction, erosion, water quality and windows of opportunity for site preparation for the next crop.

36) Schedule harvests dependent upon crop, habitat considerations in relation to other sites. For example, schedule sequential harvests for portions of large blocks of biomass feedstock plantings to maintain a continuous range of stand ages for habitat.

[24] Important factors include erodability, water quality, habitat diversity, and productivity.

[25] Harvesting energy crops is commonly the single most costly aspect of production and represents one of the areas for potential cost reduction through further research and development.

*Habitat*

37) Introduce short-rotation woody crops or perennial crops to agricultural landscapes dominated by annual crops to increase habitat diversity.

38) Consider habitat values within the production areas when making crop selection, cultural, operational, and timing decisions.

39) Consider micro sites, such as excessively wet areas where it would be hard to establish a crop, for other uses, including wildlife habitat, other crops, natural areas, or wildlife food plots.

40) Schedule field operations to minimize disturbance during critical periods of animals' life cycles (e.g., nesting, winter cover, etc.)

*Water Quality*

41) Cultural practices in aggregate should not negatively impact water quality relative to current practices.

42) Energy crops should be managed to increase soil organic matter content.

*Soil Nutrition and Amendments*

43) Add supplemental nutrients only as required to meet plant uptake requirements.

44) Encourage perennial energy crops that enhance nutrient cycling and retention of nutrients on site.

45) Consider sludge, ash and other residues from biomass use and conversion processes for land application to help return nutrients and organic matter to the soil[26].

46) Consider energy crops for land application of biodegradable wastes. Toxic contaminants should be eliminated at their source and kept out of the biomass feedstock loop.

*Buffer Zones*

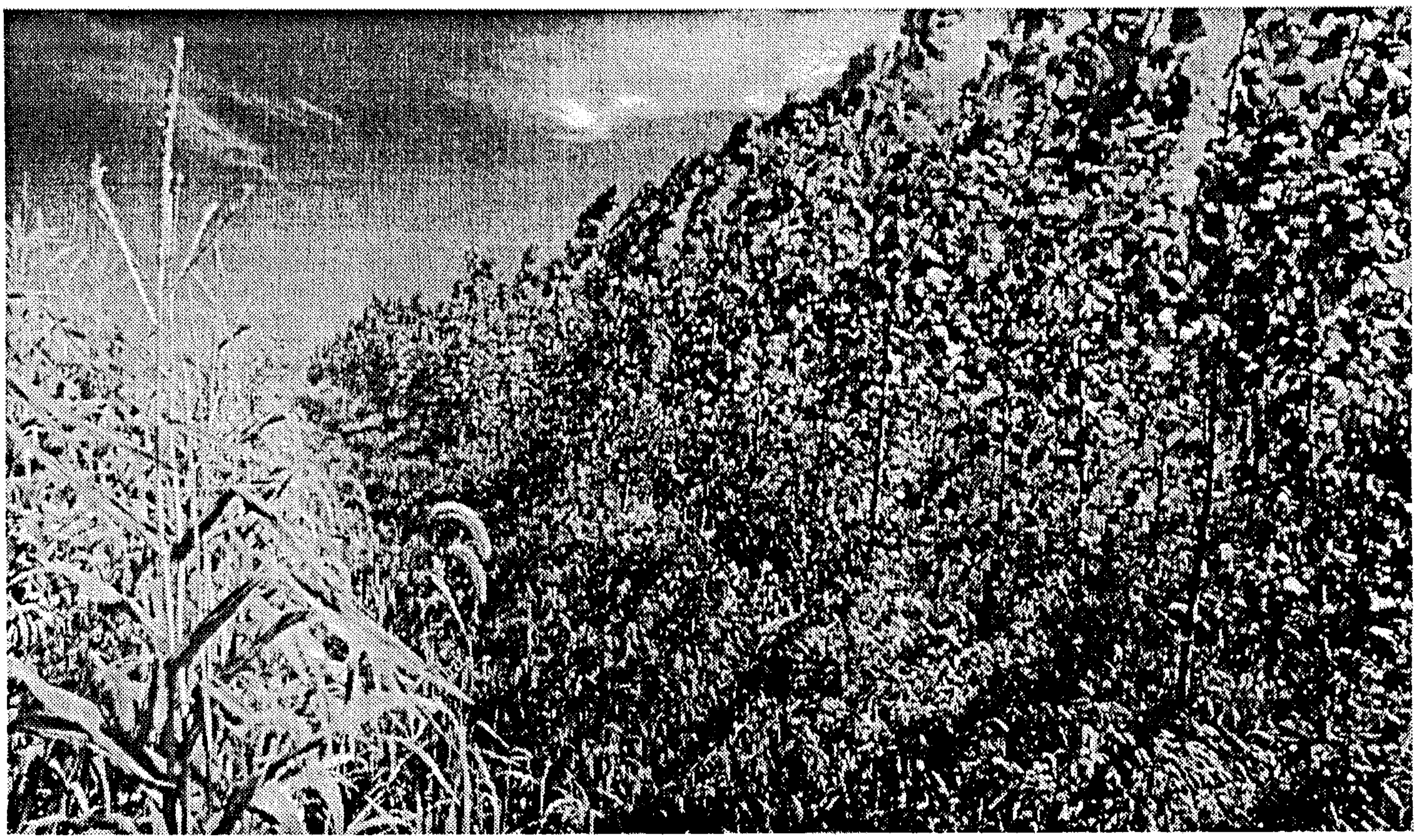
47) Delineate buffer zones for the protection of water quality and wildlife habitat as part of the management plan.

48) Consider buffers for wildlife corridors as an integral part of the landscape.

49) Establish vegetation in buffer zones at the same time or before the rest of a site is planted.

50) Enhance local species diversity and provide ground cover with buffer zones[27].

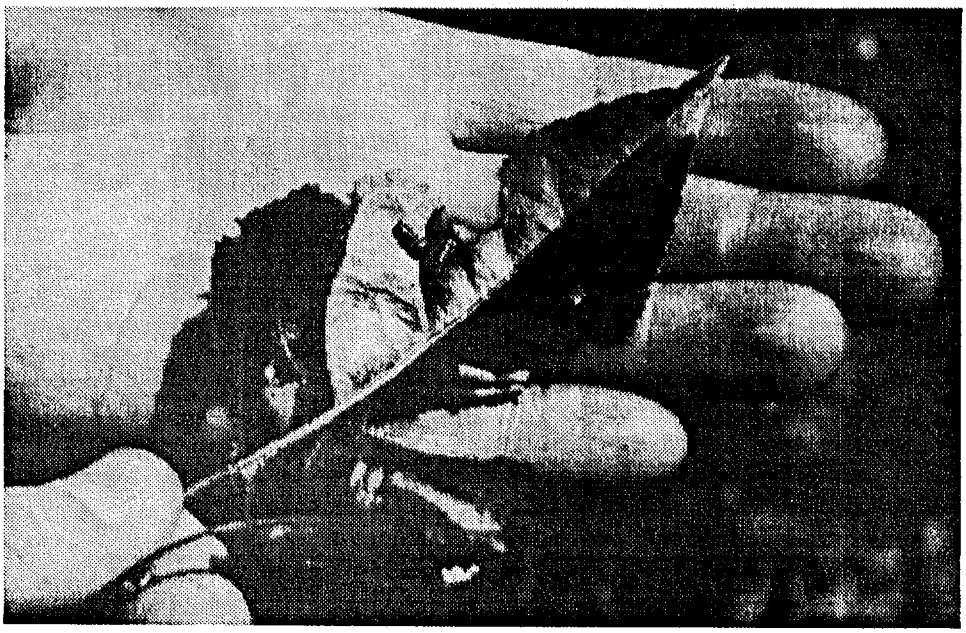
51) In general, minimize the use of fertilizers, pesticides, or nutrient amendments in buffer zones.



**Farmers can use buffer zones to protect water quality, wildlife habitat and migration routes, and to enhance local species diversity.**

[26] Materials that contain hazardous levels of toxic metals and organic compounds should not be used.

[27] Buffer zones may be planted with a variety of native species chosen to avoid species known to be hosts for unwanted insects or diseases.



**Energy-crop producers should use integrated pest management practices such as natural predators, biological control agents, mechanical weed control, crop selection, grazing, and pesticides.**

## Integrated Pest Management

Pest control is essential in any integrated cropping system if it is to be sustainable. Integrated Pest Management refers to pest management strategies that are fully integrated into the whole farm system. It has as its principle goal the control of pests with the minimal use of pesticides through the use of biological control, host resistance, and cultural control. Cultural controls involve such things as tillage practices, time of planting, trap crops, cover crops for beneficials (organisms that suppress pests), and the natural antagonistic effect of certain plants on pest or other plants. Pesticides play a key role in the IPM arsenal. However, their use is limited to situations where pest pressures, as determined by monitoring or experience, dictate their use. Biological controls rely on natural enemies and predators to control pests. Extreme caution must be used if pesticides are used in the system. Integrated pest management is site specific and management intensive. It is a key component in all sustainable agricultural systems.

*Pest Control*

52) Minimize total chemical-pesticide inputs by using integrated pest management practices[28]. In addition, use preventative management techniques (e.g. crop rotation, tillage practices, time of planting, etc.) to minimize future occurrence of pest outbreaks.

53) Monitor pest population and pest damage. Use economic thresholds for damage to determine which pest management strategies should be undertaken.

54) Use selective pesticides to protect the balancing aspects of beneficials such as natural predators or biological control agents.

55) Consider alternatives to chemical pest control, including but not limited to mechanical weed control, crop selection for resistant hybrids and clones, planting density, cover cropping, companion planting and grazing.

56) Use pesticides in compliance with label instructions.

57) Care should be taken to prevent the drift or movement of pesticides from the target zone by using ground application of pesticides with low mobility and low volatility.

58) Control competing vegetation to optimize yields, thereby reducing the total acreage required.

59) Consider herbicides, which are critical for the successful establishment of many crops, as part of an integrated management decision process.

60) Consider using herbicides to minimize negative site impacts such as soil compaction, erosion, and habitat degradation resulting from other weed control strategies.

61) Weigh the applications, rates, and timing of chemical pest control against other alternatives.

62) Use breeding and selection for developing pest resistance in energy crops to minimize pesticide use.

*Aesthetics*

63) Aesthetic considerations should be part of the planning process to ensure long-term acceptance of a new industry.

64) Consider planting patterns other than precisely aligned rows to improve the aesthetics.

[28] Expanded research in this area, including weed ecology and the use of beneficial species, is needed.

# The Economics and Policy of Biomass Energy

The National Biofuels Roundtable believes that a complex interaction of political factors, market forces, environmental considerations, and societal values could lead the nation to a sustainable energy economy. Biomass energy systems are likely to play a key role in such a sustainable energy economy. EPRI and others regard the biomass resource as being the most promising contributor to the nation's renewable energy portfolio over the near term.

Economics is a critical factor in determining the future of the U.S. biomass energy industry. In a simplistic sense, farmers will plant energy crops only when they can make a profit from them. Biomass will be used as an energy resource when it makes good business sense. Thus, the biomass energy industry must be profitable and competitive within both the energy and agricultural sectors of the economy to significantly impact the nation's reliance on fossil fuels. This situation is complicated by the fact that large segments of the farm sector and much of the electrical utility industry are currently facing severe economic strain, which make them risk averse[29].

This chapter discusses some of the economic forces that are shaping the transition to using energy crops and offers a variety of policy options for overcoming barriers to creating a profitable and sustainable biomass energy industry.

## Market Issues

Using low-cost, wood waste materials, electric power can presently be produced at a cost of $0.035 to $0.06/kWh in most parts of the country. These materials, as well as other low-cost waste feedstocks such as corn stover and waste paper, could also be used to produce ethanol at $0.80 - $1.10 per gallon, if infrastructure requirements are met. However, if biomass is to become a large scale energy resource, the costs of producing energy crops must be reduced. In addition, more efficient conversion technologies will be needed to make electricity production from biomass competitive with that from natural gas. Similarly, if ethanol and other liquid biomass fuels are to become competitive, advances in crop production and conversion technologies will be necessary. In the near term, economic and political pressures to responsibly manage wastes and residues should continue to facilitate the adoption of biomass energy. However, investments in large-scale energy crop production are not likely to take place until there are markets for the crops. The appearance of these markets will in turn be dependent on the assurance of a reliable and reasonably priced feedstock: the proverbial chicken and egg.

Currently production costs for dedicated energy crops are higher than coal or natural gas prices. There are financial risks associated with new and unproven systems. The genetic improvement of crops and the development of improved harvesting technologies could result in a notable decrease in the cost of production, however. The near-term need is to develop a portfolio of varieties, hybrids and new crops that will be cost competitive with other energy alternatives.

### The Potential Benefits of Biomass Energy

A vigorous biomass energy industry could bring important economic benefits to the nation. Reliance on domestic energy resources will increase our national and economic security. Since energy crops are bulky to transport, a biomass energy industry is likely to be dispersed near sources of supply as energy crops are introduced. New biomass industries could improve rural economies, creating net new jobs as a result of adding value locally, increasing the tax base and property values, and maintaining or even improving rural infrastructure.

Because transportation of energy crops by truck is expensive and makes a negative contribution to the overall energy balance, conversion facilities supplied by road transport should be sited within a radius of between 50 and 100 kilometers (31.5 and 63 miles) of crop production, according to EPRI. Continued research and development is also needed to bring down the cost of new conversion technologies.

Once costs are low enough to make energy crops profitable, energy crops could occupy up to 11 percent of agricultural land in some regions, making them a strong secondary crop. As such, they may compete with major commodity crops, including food and fiber crops, for water in arid regions, farm machinery, or cropland.

[29] In particular, both regulatory and economic changes are resulting in new capacity being installed by independent power producers rather than traditionally vertically integrated utilities. See for example C. Flavin and N. Lenssen, "Reshaping the Power Industry," in *State of the World 1994: A World Watch Institute Report on Progress Toward a Sustainable Society,* W.W. Norton & Company, New York, London, 1994, pp 61-80.

Introducing energy crops into U.S. agriculture is a significant challenge that goes beyond the introduction of new crops. Conversion facility managers will have to develop methods to procure feedstocks on an on-going basis. Assuring their supply will require them to develop close working relationships with energy crop producers, forest managers, timber harvesters, residue and waste suppliers, and agricultural advisors.

Stakeholders throughout a region would profit from working together with others in their industry to organize their respective activities to ensure stable markets for the producers of feedstocks. Collaborative endeavors can help the biomass industry overcome a number of barriers that now stand in the way of biomass energy development.

## Policy and Regulatory Framework

Together with market forces; energy policy, environmental regulations, tax incentives and agricultural policy will influence the development of the biomass energy industry. The Clean Air Act Amendments of 1990, the Energy Policy Act of 1992, other environmental legislation and regulations, and agricultural policies will all play a role in the development of biomass energy systems.

The Clean Air Act Amendments of 1990 are already providing an impetus for the development of biofuels and biomass power. By limiting sulfur emissions from coal-fired power plants, the amendments are encouraging electrical generators to look at co-firing biomass with coal. The amendments also favor increased use of oxygenated fuels and fuel additives, which can be derived from biomass.

Several other laws have been passed to encourage the development of alternative fuels. The 1988 Alternative Motor Fuels Act promotes alternative transportation fuel through incentives and subsidies. The 1992 Energy Policy Act provides for income tax deductions to purchasers of new vehicles that burn fuels containing at least 85 percent alcohol. The act also provides a production credit for "closed-loop" biomass systems. As it currently stands, this incentive applies only to energy crops grown exclusively for generating electricity.

Federal agricultural programs have a significant effect on crop choices made by farmers. Programs that support or increase the price of existing crops make energy crops less attractive to producers. Other federal programs are designed to encourage farmers to set-aside lands which have been planted in row crops. The Conservation Reserve Program is one important example. Lands enrolled in the CRP program begin coming out of the program in 1995 and, given budgetary pressures, the program will not likely be included in its present form in the new Farm Bill. Efforts are already underway at the U.S. Department of Agriculture to evaluate energy crops as an alternative to set-asides for controlling soil erosion and chemical runoff.

A variety of state and local policy, regulatory, and public opinion issues are also likely to affect the development, siting, and permitting of biomass energy systems. These include:

- Energy policies and the role envisioned for biomass in the future energy mix;
- Forestry policies and the types of forest management objectives, harvesting practices, and preservation goals established in the policies;
- Land use and agricultural policies and potential impacts on farmland, forest land, wetlands, and open space;
- Utility regulatory policies and the availability of incentives for electrical generators that invest in and/or purchase power from biomass energy systems;
- Air emissions, ash emissions, water quality, and other environmental regulations that pertain to biomass energy systems; and
- Overall public opinion and perceptions about whether biomass energy systems are environmentally acceptable, sustainable, and have a net positive impact on local communities.

The successful development of biomass energy facilities requires a comprehensive understanding of the relevant policies, regulations, and public opinion in the state where a facility may be located. An important strategy is to work with state and local stakeholders early in the planning process for a new facility. Together, stakeholders can identify and address concerns to ensure the facility is appropriate for the local community. Barriers to the development of biomass energy will not be overcome unless key stakeholders can identify their common interests and not see each other as opponents.

## Public- and Private-Sector Options for Developing Economical Biomass Energy Systems

The Roundtable has identified 10 barriers that it believes should be considered, in whole or in part, if a major expansion of biomass energy is to occur within the 2030 time frame. The Roundtable has identified the following options for developing biomass energy systems, but has not endorsed any of the options included in this section. The Roundtable believes that these options should be considered only if the principles and guidelines presented in other sections are closely followed.

**I. The lack of understanding of biomass energy resources and technologies by the public and key stakeholder groups inhibits interest and investment in biomass energy.**

*Options*

A) Launch an information campaign to inform the public about biomass energy.

1) Provide funding for a major educational initiative for schools on biomass energy. (e.g. DOE, USDA, and others)
2) Coordinate efforts to inform the media, in particular science writers and editors, about biomass energy.
3) As part of these efforts, provide speakers, educational materials, pamphlets, documentary news clips, and in-depth articles about biomass energy.

B) Support a program to train extension agents to educate farmers and other growers regarding the best methods for growing productive energy crops using environmentally sustainable methods. (e.g. USDA, land-grant colleges and universities)

C) Sponsor conferences on biomass energy for state legislators, environmental and utility regulators, and other stakeholders. (e.g. DOE and others)

D) Demonstrate biomass energy systems incorporating Roundtable principles to rural farming and forestry communities. (e.g. DOE, EPRI, and cost-share partners)

**II. Uncertainty regarding the availability of biomass resources and the performance and economics of biomass energy systems inhibits private investment in research, development, demonstration, and commercialization activities.**

*Options*

A) Increase incentives for private research, development, and demonstration efforts. These incentives could include, but are not limited to, cost-sharing, joint ventures, cooperative research and development agreements, and tax relief. (e.g. federal and state governments)

B) Undertake cost-shared studies of the infrastructure required to support energy farming. Studies should consider energy crop harvesting, procurement, storage, transport, and preparation. (e.g. private-public partnerships)

C) Use predictive tools, such as economic models and regional Geographical Information Systems, for addressing system uncertainties. (e.g DOE, USDA, EPRI, and others)

D) Fund federal biomass energy research, development, and demonstration in line with national goals of economic and national security, environmental quality and economic growth. (e.g. DOE and USDA)

1) Fund research for the production of electricity, chemicals, and fuels from biomass at levels commensurate with their potential to improve national security, economic growth, and environmental quality. (e.g. DOE)
2) Coordinate collaborative research and development efforts on energy crop production amongst DOE, USDA, the private sector, and the land-grant colleges. (e.g. DOE, USDA, and others)
3) Identify emerging applications of biomass energy technologies to transfer to the private sector. (e.g. DOE, USDA)

**III. Shifting from existing crops to energy crops is a higher risk for landowners because of planting a new crop and uncertain demand.**

*Options*

A) Investigate innovative financial mechanisms such as public procurements or guarantees — if these mechanisms include adequate safeguards — to reduce risks to farmers and minimize public costs. (e.g. DOE and USDA)

B) Encourage DOE and USDA to cooperate in reducing biomass-energy-system risk and to coordinate their efforts with land-grant colleges and the private sector.

C) Encourage conversion facilities to contract for energy crops in advance. For multi-year harvest cycles, contracts could include annual payments. (e.g. private sector)

D) Encourage landowners to reduce risk by planting multi-use crops, i.e. trees suitable for both fiber and energy or grasses suitable for both animal feed and energy. (e.g. landowners, private companies)

**IV. Utilities are uncertain about the performance and economics of biomass energy systems and are averse to exposing themselves to disallowance of cost recovery by state public utility commissions.**

*Options*

A) Create "safe-harbor[30]" rules for individual electrical generators implementing biomass energy pilot projects. (e.g. state public utility commissions)

B) Provide DOE and EPRI funding to share the risk of pilot projects. (e.g. DOE and EPRI)

**V. Utility generation planning and power purchase procedures do not fully account for some of the benefits of biomass energy systems. These benefits include fuel diversity and the reduction of greenhouse gas emissions.**

*Options*

A) Require competitive set-asides for biomass as part of new capacity acquisitions. (e.g. state public utility commissions)

B) Require integrated resource planning that incorporates considerations of environmental and social impacts and portfolio diversity. (e.g. state public utility commissions)

C) Develop competitive bidding processes for acquiring generating capacity that fully incorporate the range of values from biomass resources. (e.g. federal or state agencies)

D) Improve power producers' financial returns for investing in biomass by creating rate or other incentives.

**VI. Low energy costs for fossil fuels do not reflect their true cost to society in terms of environmental degradation, health impacts, and costs to protect foreign supplies.**

*Options*

A) Move toward a taxation system that reflects the environmental and social costs of different energy sources. (e.g. federal and state revenue agencies)

B) Develop full-fuel cycle analyses,[31] including primary and secondary social and environmental costs of energy use for all energy technologies. (e.g. DOE, USDA, and others)

**VII. The potential environmental risks of large-scale dedicated biomass production could limit support by environmental groups and generate local opposition to projects.**

*Options*

A) Create a working group of state and local stakeholders before a project is fully developed and before a site is selected. The group's purpose would be to learn specific stakeholder concerns and to incorporate them in project planning processes.

B) Improve existing state and local regulatory processes to promote public participation in biomass demonstration projects. (e.g. state and local regulatory agencies)

C) Support research that is needed for reliably predicting the environmental impacts of biomass energy systems and steering the technology in environmentally sustainable directions. Areas of needed research include wildlife habitat, air and water quality, and other environmental effects. (e.g. federal and state agencies, private sector, and environmental organizations)

D) To ensure sound land-use practices, planning and management practices should be carried out in ways that take into account the cumulative effects and the integrity of ecosystems across an entire landscape.[32]

E) Develop sustainable agriculture protocols, including the creative use of mixed plantings.[33]

**VIII. Existing and emerging financial and regulatory mechanisms within the electric utility industry and federal agricultural policies inhibit private incentives to invest in biomass energy.**

*Options*

A) Many existing subsidies not only constitute a formidable barrier to biomass development, they also distort both energy and agricultural markets and, in many cases, promote environmentally damaging practices. Removal of such subsidies is preferable to creation of new subsidies to offset their impact. If new subsidies are deemed necessary for emerging biomass energy technologies, they should be carefully designed to overcome a specific market barrier, set at the minimum level sufficient to achieve their commercialization objective, and phased out once that objective has been achieved.

[30] Safe-harbor rules are established by state public utility commissions to partly protect utilities that wish to gain experience with new technologies. By establishing up front the cost recovery boundaries for well-conceived, and well-managed pilot projects, safe-harbor rules offer a means of limiting overall investment to levels that protect ratepayer interests while encouraging utility research, development, and demonstrations.

[31] Full fuel cycle analysis looks at the energy system—in this case from the seedling to the electron and tracks all inputs and outputs for each of the discrete steps in the chain, e.g. land preparation, seedling production, planting, cultivation and tending, harvesting, transportation, fuel or feedstock preparation and the conversion process. At each stage a balance of energy and materials is measured or estimated and the whole assembled so that impacts and benefits per unit output can be estimated.

[32] Land-use practices affect ecological systems throughout a region. They cut across jurisdictional boundaries and may compromise private ownership rights.

[33] Protocols for land-use planning and management that will foster sustainable agricultural systems increasingly necessitate an evaluation of the aggregate impacts of plant selection, tillage, chemicals use, and harvesting practices over an entire landscape and throughout an extended time frame. Mapping tools, such as Geographical Information Systems, aerial photography, and visual modeling should be used to foster development of innovative, ecologically beneficial approaches to biomass feedstock production.

B) Create a Biomass Title in the 1995 Farm Bill to give energy crops the same recognition as other crops and to expand their production. Include a program that encourages landowners to plant and harvest perennial energy crops on cropland that would otherwise be used for annual crops. National Biofuels Roundtable guidelines should be followed and appropriate emphasis should be given to areas such as highly erodible land, flood plains, and ecologically sensitive lands. Encourage research and experimentation to investigate the environmental consequences of using such lands for energy crop production. (e.g. USDA, DOE and Congress)

C) Revise the closed-loop biomass provisions of the National Energy Policy Act to extend the period of eligibility sufficiently to allow eligible biomass fuel cycles to be fully tested and markets to be stimulated. (e.g. Congress)

**IX. Inconsistencies among federal, state, and local environmental policies and regulations limit the development of biomass energy systems. This problem is compounded by a lack of familiarity with the environmental impacts of biomass energy systems.**

*Options*

A) Identify and review major federal energy, environmental, and agricultural policies and regulations that affect biomass energy systems. Identify inconsistencies and develop strategies for addressing the inconsistencies. (e.g. EPA, TVA, USDA, DOE, DOI)

B) Create a regulatory assistance service that provides up-to-date technical information on the environmental impacts of biomass energy systems to federal, state, and local regulators. The service should be an inter-agency effort among DOE, EPA, FERC, USDA, and non-governmental organizations. It should include low- or no-cost databases on environmental impacts such as air and ash emissions.

C) Research, test, and identify environmentally-acceptable end uses for ash produced by biomass energy systems. Develop federal and state definitions for beneficial uses and conduct RD&D on new end uses, products, and applications.

**X. In deciding what biomass crops to grow, land parcels to devote to biomass energy crops, and management practices to use, the economic incentives faced by landowners may conflict with environmental sustainability.**

*Options*[34]

A) Utilities and other purchasers should include provisions in purchase contracts with feedstock producers requiring that energy crops be produced using best management practices.

B) Make eligibility for the federal biomass production tax credit and any other economic incentives for biomass production contingent upon a federal, state, or recognized private certifier verifying that feedstocks are produced following best management practices appropriate to the region.

C) Provide cost-sharing for biomass energy projects that promote habitat improvement and increased biodiversity.

[34] The options listed below presume that the biomass resource management guidelines presented earlier in this document have been adapted by local public and private stakeholders to those feedstocks and conversion technologies appropriate for their regions.

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[35] Roundtable members participated in discussions as individuals, not as representatives of their organizations. The organizations listed in this section were included solely as a means of reaching these individuals.

# Appendex I: Agenda for Resolution

In Roundtable discussions, participants were unable to reach consensus on policy recommendations for three issues:

- harvesting of forests for energy;
- using non-native plant species for energy production; and
- changing the requirements of the biomass production tax credit.

Rather than allow these issues to interfere with development of its recommendations, the Roundtable decided to include a brief description of each issue and leave the resolution of all three issues for the future. The Roundtable hopes that this appendix will provide the reader with advance notice that these, or similar issues, may arise in consideration of regional or local biomass energy projects.

## When is Harvesting Forests for Energy Appropriate?

One potential source for biomass energy is wood harvested from forests. During Roundtable discussions, several issues were raised regarding the use of wood harvested from forests for energy.

The first issue raised was whether forests should be a source for biomass energy. At the root of this question are different values regarding the appropriate function of forests and different perspectives regarding what is sound stewardship of a forest. Even if there were agreement on what is "sound management" or "wise stewardship," increased market or political pressures on demand for wood energy could distort what is perceived as good forest management. The underlying concern was that forests may be over harvested to the detriment of long-term sustainability of forest ecosystems.

Some people believed forests should be used for their highest value. It follows that commercial forests should be managed to enhance productivity to achieve optimum yields of wood and other renewable products. From this perspective, harvesting can add value to a forest. For example, forests can be managed to maintain desired species composition such as an oak-hickory forest or to mimic natural disturbances. However, harvesting should follow carefully planned procedures to assure high forest site productivity and preserve the plant and animal life indigenous to the forest.

When and how to harvest forests was another issue raised. Some suggested that these matters ought to be decided on a site-specific basis. However, there was a debate about what the forest should look like, what makes a "healthy" forest, how a forest should be managed, and what priorities should be used to guide future forest management policies.

For instance, there is growing interest in whether harvesting for biomass feedstocks might contribute to restoration of diseased or degraded forests. There are both public and private forest lands that were extensively cut early in the century. Normal succession processes have not occurred in these locations because of fire suppression or drought. Air emission problems may constrain the use of controlled burns as a tool for forest rehabilitation. Research projects are expected to be undertaken over the next several years to assess the potential of differing harvest regimens in restoring both the commercial and ecological values of severely degraded forests.

In contrast, others argued that the aesthetic and intrinsic value of remaining forests, including the habitat they provide for native wildlife and their role in preserving biodiversity, outweigh economic considerations. From this perspective, the prospect of significantly increased forest harvesting to meet energy demands raised serious concerns. In particular, some Roundtable members argued that public lands should not be considered as a source for energy feedstocks.

A related issue was that if a supply of wood for energy is not provided from domestic forests, demand could move harvesting to other countries. For some, this raised an ethical issue.