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DEVELOPING AN INTEGRATED APPROACH TO BIOMASS ENERGY SYSTEMS IN THE UNITED STATES

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ABSTRACT

Biomass feedstocks could become the major renewable energy resource for power generation in the U.S.A. during the next two decades. Wood and agricultural residues sufficient to power 5000 to 10,000 MW of new capacity are available. Furthermore, 18 million ha of set-aside or under-utilized lands could be planted in energy crops.

Development of biomass production on this scale will result in a major shift in land use throughout rural America, with significant socio-economic implications and environmental effects. The National Biofuels Roundtable was formed in 1992 to develop consensus among representatives of government and industry, environmentalists, and researchers from universities and research institutes. The roundtable's principles will reflect the current understandings of landscape ecology and agricultural economics and will foster decreased dependence on agricultural subsidies.

Large-scale use of biomass will depend on establishment of reliable infrastructures which will link production of feedstock with its use in power generation. These infrastructures will: (1) provide crops planning and management, (2) supply equipment and materials, (3) handle maintenance and service, (4) carry out technology transfer and public education, and (5) secure financing.

Pilot projects involving thousands of acres of plantings for either existing or new generation facilities are being planned by the Electric Power Research Institute, the U.S. Department of Energy, and the U.S. Department of Agriculture. These pilots will define characteristics of production systems and infrastructures in different regions of the country, identify opportunities to decrease costs, and validate the principles being promulgated by the National Biofuels Roundtable.

KEYWORDS

Biomass sources; energy crop production; integrated systems; electricity production.

BACKGROUND

During January 1993 the Electric Power Research Institute (EPRI) issued a white paper entitled "Strategies for Achieving a Sustainable, Clean and Cost-Effective Biomass Resource" which projected the potential of biomass as feedstock for electric power production within the U.S. at 50,000 MW by the year 2010. This paper is a follow-up to that work and provides an initial overview of an implementation process.

THE BENEFITS ASSOCIATED WITH USING BIOMASS AS AN ENERGY RESOURCE

As a resource for power generation, biomass would displace significant amounts of fossil resources and thus help minimize increases in atmospheric carbon dioxide. As biomass feedstocks contain virtually no sulfur, and, because of their moisture content, combust at temperatures below those at which NOx is formed, their use will also offset SO_x and NO_x emissions associated with fossil fuel combustion. By providing a market for wood wastes and agricultural residues, biomass, used as fuel for energy production, will reduce open-field burning, landfill disposal of construction/demolition wastes and pallets, and forest fire hazards. There are limits to the availability and accessibility of wastes, however: wastes could provide at the very most 20% of this new renewable capacity. To serve as fuel for 50,000 MW, most of the biomass feedstock would need to be in the form of dedicated ligno-cellulosic energy crops - short rotation trees and grasses.

The projection of 50,000 MW of capacity is dependent upon the availability of 20 million ha of agricultural cropland and annual crop yields of at least 12 dry tons per ha. Production costs of these sustainable, dedicated resources are expected to be $2.35/MBtu for commercial-size operations within the near term. This mix of new crops for a whole new agricultural market would bring a boost of as much as $12 billion a year to U.S. farm sector incomes.

Along with these obvious pluses, large-scale development of biomass systems could also offer significant land-based environmental benefits. Foresight and planning, and the advice of competent soils scientists and landscape ecologists, could make it possible to remediate degraded lands, filter chemicals which threaten surface or ground waters, protect highly erodible soils, and even create some wildlife corridors and early-succession habitat.

THE NATIONAL BIOFUELS ROUNDTABLE

Recognizing the opportunities for valuable environmental improvements, EPRI and the National Audubon Society organized the National Biofuels Roundtable, directed toward developing principles, guidelines and strategies which will support environmentally sound, socially acceptable and economically viable biomass production. The Roundtable presently has 30 members, representing 24 organizations and at least as many areas of scientific and technical expertise. The meetings are run by a "conflict resolution facilitator" from Resolve: Center for Environmental Conflict Resolution. Decisions are made by consensus. Unresolved issues will be addressed in a separate chapter. The initial set of principles is expected to be aggregated in a synthesis document during February 1994 and will be published in *Biomass and Bioenergy* later in the year. These principles will be made available to the International Energy Agency's Bioenergy Programme VIII to be revised to fit its mandate.

As the principles to be promulgated by the Roundtable will have meaning only insofar as they are both used and shown to be effective, EPRI is presently collaborating with the Tennessee Valley Authority, Oak Ridge National Laboratory and the University of Tennessee to define methods for landscape design and for monitoring ecological changes. The existing land use, as well as the climate, soils and biodiversity data will be layered, along with regional resource assessments and feedstock costs, and spatially defined on Geographic Information System (GIS) maps. With hard data defining impacts on ecological health tied to a specific landbase, it will be possible to test the principles and to revise them over time.

REGIONAL PILOT PROJECTS

Now that the preplanning for biomass feedstock production is well along, the next step is to encourage commercialization. The crops improvement work which Oak Ridge National Laboratory has been managing for the past 15 years is bringing forth improved clones with increased productivity and greater resistance to disease and stresses. While crop yields are not 12 dry tons per ha per year in all parts of the country, in some regions they are as high as 28 dry tons, at least for 7 to 20 ha trial plantings. It is now time to learn how to grow these crops at a utility-scale; commercial biomass operation could be as small as a 20 to 25 MW power plant with feedstock sustainably produced on 6000 - 8000 ha. With that project size in mind, EPRI has been discussing co-sponsorship of scale-up pilot projects with the U.S.

Department of Energy's Biomass Feedstock Office (DOE) and several agencies within the U.S. Department of Agriculture (USDA). Inasmuch as commercialization of biomass production implies a market for the crops, an initial assumption is that energy crops pilot demonstrations will be integrated with the construction or a retrofit of a power generation facility.

One essential challenge is dealing with the reality that the production and conversion systems cannot be assembled one piece at a time. Rather, they must be envisioned and established as an integrated whole. In discussing the components of an integrated system, we shall consider each aspect independently and sequentially, but we emphasize that it is vital for the developer to maintain a total systems perspective.

LAND PLANNING AND DEVELOPMENT

During the past 18 months EPRI and DOE have been collaborating with the Tennessee Valley Authority (TVA) on creation of a GIS platform and methodology and a computer-based information system encompassing the 217 counties in the TVA service territory. The work is being done by the University of Tennessee and Oak Ridge National Lab's Biofuels Feedstock Development Program for the purpose of assisting TVA in estimating the costs of supplying wood fuel to any of its 12 coal-fired power plants. The GIS and linked network model are being used to assess the current and expected availability, the actual locations, and the cost of biomass resources. Along with the production and siting information, the developers of this modeling program are beginning to define factors which may affect supply and cost and to consider the probable socio-economic impacts of a conversion facility on the rural community. Work based on this sort of methodology would be a requisite for commercial projects and actually serve as the basis for defining coal co-firing priorities as well as siting a new greenfield facility.

Once a site is determined, it will be necessary to get commitments from those persons in the local agricultural community interested in producing this new crop for a new market. If the crop is not to be harvested for five or more years, the growers will need more than a long-term contract for purchase of the crops: they will undoubtedly want some upfront financial inducements. Perhaps many or most farmers will choose to contract out the land preparation and planting operations, but at this time we do not know this. In fact, negotiations with farmers and the contracts which result may very well turn out to be quite specific to a region and be influenced by the size of land holdings, the particular economics of federal land set-aside programs in the area, the crops selected - and the capital requirements for any new equipment.

CROPS PRODUCTION

Biotechnology is the scientific specialty which has already led to some significant improvements in several species of energy crops. Biotechnology can simply mean physical selection of high yielding and stress resistant clones and propagation of attractive hybrids, or it can mean deliberate introduction of a genetic characteristic. Over the past five decades, improvements in annual agricultural crops in the U.S.A. have resulted in about a 2% increase in productivities per year; thus we suggest that a conservative estimate of likely improvements in energy crop productivities will be 1.5% per year. Discussions between EPRI and U.S. Forest Service staff and Oak Ridge National Laboratory plant geneticists, regarding projections of yields of these crops in different regions of the country as well as any appropriate safety constraints which should be placed on genetic recombinant work, have been ongoing for about a year. A document summarizing the best current thinking on these topics will be published by EPRI by the end of 1994.

While even the short list of proposed energy crops numbers about ten species (see map), not all crops will be suitable for plantings in all parts of the country. Based on the information coming out of Oak Ridge-supported species trials and work which has been done in sustainable agriculture programs at various universities, decisions will need to be made regarding what to plant, and where. Also, because the suitability of any one species to successful growth in a particular location will not be known until it is tried, it will probably be desirable to plant several clones of each of two or three species. Plant spacings for trees are still being defined, though there seems to be some consensus that they will fall in the 8 feet by 8 feet to 10 feet by 10 feet range (or 3 m by 3 m). That will mean that there will be between 1600 and 2300 cuttings or seedlings needed for each hectare planted. In some parts of the country nurseries will need to be established. Once a nursery is in operation, however, it can produce between 250,000 and 450,000 plants per hectare per year. In other words, nursery stock requirements need to be planned for, and it may take some considerable investments, as well as time, to reach this level of operations. The difference in cost for cuttings, about 5–10 cents each, and seedlings, about 25–35 cents each, is not a negligible consideration. Some nurseries have tissue culture capability; however, stock produced that way is even more expensive.

Plant biologists in the paper industry, who have been growing short rotation crops for pulp for more than a decade, have emphasized that successes with these crops are not inevitable. There is a learning curve and still only a limited amount of experience. There have been losses of whole plantings, and this may reoccur. Some experimenters insist that a new grower should not consider putting in more than 3 ha the first year. On the other hand, others feel that the risk of failure is not that great, especially if initial land preparation is done during the previous year so that perennial weed species are appropriately managed. In any case, planting the crops must be followed by good maintenance. Weed control and appropriate fertilization will be vital to successful establishment.

ENVIRONMENTAL CONSIDERATIONS

As was indicated earlier, the principles being drawn up by the National Biofuels Roundtable are intended to be practical guidelines. They are expected to be used in designing plantings and defining regimens for culture. Roundtable members acknowledge that despite the serious contemplation and discussions which are going into definition of the principles, they will not emerge as ultimate doctrine. Thus, it will be important to test them in the context of several of the first large-scale biomass feedstock projects by actually monitoring, for instance, soils impacts and changes in wildlife patterns. When that information is in, it will be time to revisit the principles and revise them as needed.

The Roundtable's principles are not yet in place; however, we have been asked to present some ideas as to the sorts of concerns, both environmental and economic, which may be included in them. The items below reflect some ideas and are not agreed-upon principles.

- Siting and sizing of plantings must be appropriate.
- Cost-effective niche conversion opportunities should be identified.
- Local rural resources should be used optimally: Labor and Expertise, Capital Investments/Equipment, Tax Revenues and Benefits.
- Dependence on Federal supports should be decreased.
- Opportunities for ecological improvements should be valued: Habitat protection/creation, groundwater and surface water protection, soils remediation and protection
- Wastes and emissions should be monitored and controlled
- Crops should match native vegetation whenever feasible
- Both species and genetic diversity should be valued
- Spatial and temporal considerations should be incorporated in landscape planning
- Highly vulnerable or preserved areas must be protected.

INFRASTRUCTURE ESTABLISHMENT

Recognizing that electric utility personnel do not know much about farming and farmers do not know much about generating electricity, defining the interface between the production and conversion worlds will be a critical aspect of every project. With that in mind, EPRI has been seeking to put in place Memoranda of Understanding with both the U.S. Department of Energy and the U.S. Department of Agriculture to collaborate on ways to bridge this gap. The expectation is that there will be six or seven case studies and pilot plantings will be during the 1994–97 time frame. EPRI is currently seeking several utilities who agree to take on leadership roles in development of pilot projects.

Once there is a general outline for a specific integrated system, EPRI, DOE, and USDA staff will define a core group of experts to work with utility staff to identify key local leaders, who will be in the position to recruit resources—people, equipment, know-how, and funding. Working with local leaders, utility staff and the core support team will meet with state agencies, the Farm Bureau, the Cooperative Extension Service, Farm Management Cooperatives, Environmentalists, Sustainable Agriculture experts, and representatives of the financial community to explore the options for an infrastructure for the particular region.

This infrastructure must be conceived of as being primarily based on the people who live in the townships of rural America, and then secondarily on the necessary functions: management, funding, permitting, public education, farm sector education, risk sharing, etc. It is this group of local people who will work through the project operations, and the budget and the schedule. They will develop and implement an explicit program of continuing education and outreach.

EQUIPMENT AND MATERIALS

A recent appraisal of costs of production of biomass feedstocks shows that some components of the cost are mostly fixed. Land costs, taxes, and transportation fall in that category. There are other costs, however, which might be significantly decreased by directed research and development funding. Certainly, investments in higher yielding crops and techniques to produce less expensive cuttings or seedlings are important. Also, there should be ongoing work on planting technologies and alternatives to chemicals for weed control or protection from disease.

The largest component of biomass feedstock costs is that associated with harvesting. Unfortunately, no work has been done on improved harvesting technologies by any of the federal agencies for more than a decade. Development work on harvesting technologies is being supported in the Scandinavian and European Community countries, so we may be able to learn from the Europeans. In addition, there are suggestions that the paper and timber companies have been encouraging several equipment manufacturers to ensure that better and more suitable harvesting equipment for short rotation trees are ready to be marketed within a couple years when their current plantings must be cut.

FEEDSTOCK HANDLING EQUIPMENT AND CONVERSION TECHNOLOGIES

In the establishment of integrated "closed loop" biomass systems, notable improvements in the conversion efficiencies of the next generation of power plants and in the feedstock handling equipment installed at these plants are anticipated. DOE's Biomass Power Program, which is managed through the National Renewable Energy Laboratory, as well as EPRI, are supporting several generation technologies which hold real promise. Nevertheless, federal support for biomass programs has consistently favored the transportation fuels area over the power production area.

The high moisture content of energy crops—about 50%—inevitably results in conversion costs. Either a conversion facility must be designed to take into account the lower heating value of the feedstock, which will be between 13,750 and 17,000 Btu per kilowatt-hour, or the feedstock must be dried. In a coal plant that is retrofitted to handle co-firing, it appears that no more than 15% biomass feedstock can be mixed with coal with an average fleet heat rate of about 10,400 Btus per kilowatt-hour, without some derating of the capacity of the plant. Satisfactory feedstock drying techniques are being developed, again mainly by engineers in Finland and Sweden, from whom U.S. engineers can learn, and perhaps with whom collaborate.

Only one fully automated fuels handling system is in place within the U.S. to the author's knowledge. Again it is not that this presents such a great technical hurdle, rather it is an area which simply has not been accorded much attention or funding.

Fuels handling also implies fuels blending. It is recognized that utility boilers (or gasifiers) are not fully omniverous (accepting of all feedstocks), and alkali slagging continues to be problematic. The eutectics of sodium and potassium salts, which cause the slagging or sintering, is an area of important ongoing research in a project largely funded by the National Renewable Energy Laboratory, along with EPRI, Elkraft from Denmark, and a group of seven U.S. independent power producers. If recognition of a problem is half the way to realization of a solution, resolution of the slagging and hot gas clean-up issues will not be long in coming.

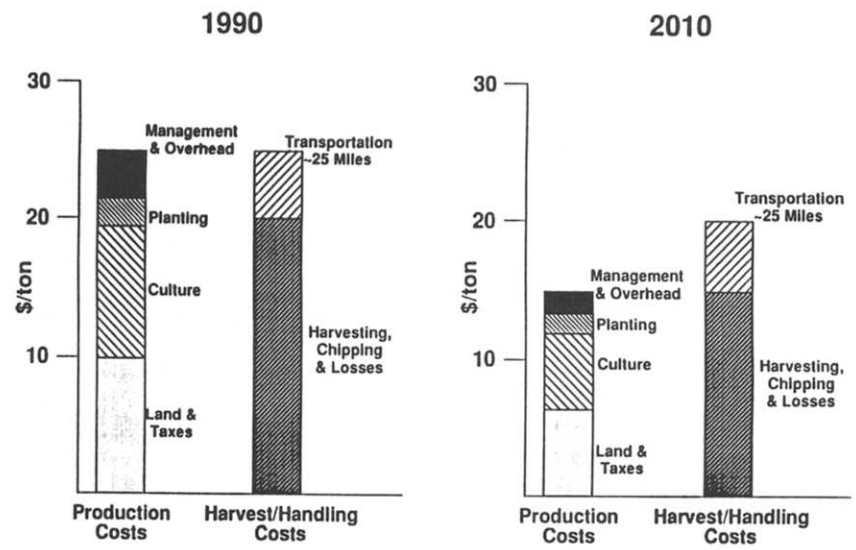
In summary, not all the questions about effectively using energy crops for electric power generation have answers, and not all the problems have been resolved. However, there is consensus that biomass feedstocks offer great promise as a renewable energy resource. EPRI's conclusion is that it makes good sense now to take some significant steps toward implementation of regional integrated pilot demonstrations. An objective of 50,000 MW installed by the year 2010 may be optimistic, but it is not unrealistic.

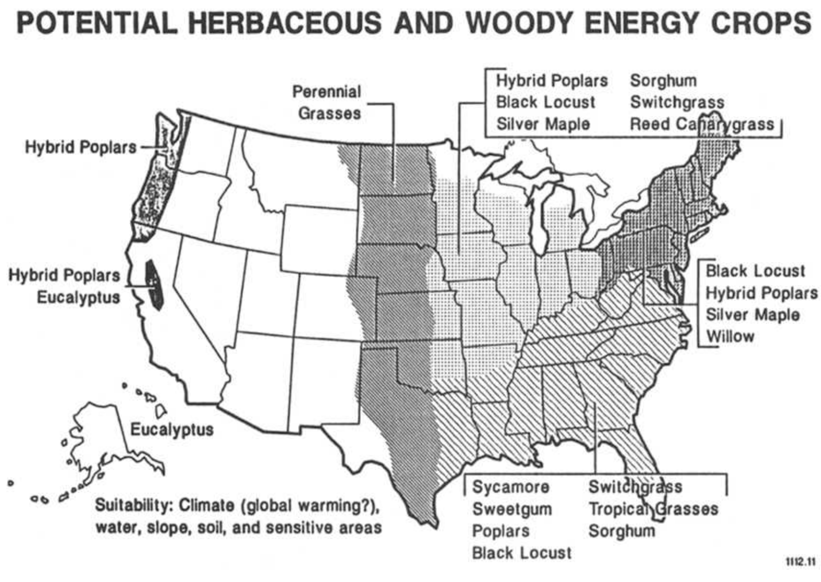
ACKNOWLEDGMENTS

Thanks to the many colleagues who have helped me come to understand biomass energy systems as offering a significant renewable energy resource, a means of providing important ecological benefits, and a major new market for agricultural communities.

Table 1. Integrated biomass regional pilot projects plan outline

Lands Planning	Resource Assessments **6 months**	Cost and Profit Evaluations **3 months**	Sites Selection **December 1993-1995**	Negotiations/ Contracting **12 months**	Land Preparation **12 months Spring 1997**	Initial Plantings **Fall 1994 -**
Crops Production	• Genetic Issues Appraisal • Species Selections **6 months**	Nursery Establishment **6 months**	Cuttings and Seedlings Propagation **24-36 months**	Crops Establishment **12-36 months**		
Environmental	Principles Development **6 months**	Landscape Modeling **18-24 months**	Principles Validation **ongoing**			
Infrastructure Establishment	• Host Utility Initiative • Identification of key leaders **3 months**	State and local agencies Farm Bureau Extension Service Sustainable agriculture **6 months**	Funding Permitting Public Education Farm Sector Education **18 months**	Continuing Education and Outreach **ongoing**		
Equipment	• Research on Planting Technologies • Harvesting Technologies/Methods **ongoing**					
Feedstock Handling Equipment	Design and Engineering Optimized for Specific Crops and Individual Facilities **ongoing**					


1990
2010
30
20
10
$/ton
Management & Overhead
Planting
Culture
Land & Taxes
Transportation ~25 Miles
Harvesting, Chipping & Losses
Production Costs
Harvest/Handling Costs


POTENTIAL HERBACEOUS AND WOODY ENERGY CROPS
Perennial Grasses
Hybrid Poplars Sorghum
Black Locust Switchgrass
Silver Maple Reed Canarygrass
Hybrid Poplars
Hybrid Poplars
Eucalyptus
Black Locust
Hybrid Poplars
Silver Maple
Willow
Eucalyptus
Sycamore Switchgrass
Sweetgum Tropical Grasses
Poplars Sorghum
Black Locust
Suitability: Climate (global warming?), water, slope, soil, and sensitive areas
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