CONF-970856--2

A NATIONAL RESEARCH & DEVELOPMENT STRATEGY FOR BIOMASS CROP FEEDSTOCKS

Lynn L. Wright and Janet H. Cushman

Environmental Sciences Division, Oak Ridge National Laboratory
P.O. Box 2008, Oak Ridge, TN 37831-6352

ABSTRACT

Planning was initiated in 1996 with the objective of reevaluating current biomass feedstock research and development strategies to: (1) assure that by 2005, one or more commercial lignocellulosic to ethanol projects will be able to acquire a dependable supply of biomass crop feedstocks; (2) assure that recently initiated demonstrations of crops to electricity will be successful and; (3) assure that the research base needed to support future biomass industry expansion is being developed. Multiple trends and analyses indicate that biomass energy research and development strategies must take into account the fact that competition for land will define the upper limits of available biomass energy crop supplies and will largely dictate the price of those supplies. Only crop production and utilization strategies which contribute profit to the farmer or landowner and to energy producers will be used commercially for biomass energy production. Strategies for developing biomass "energy" crop supplies must take into consideration all of the methods by which biomass crops will enter biomass energy markets. The lignocellulosic materials derived from crops can be available as primary residues or crop by-products; secondary residues or processing by-products; co-products (at both the crop production and processing stages); or, as dedicated energy crops. Basic research and development (R&D) leading to yield improvement continues to be recommended as a major long-term focus for dedicated energy crops. Many additional near term topics need attention, some of which are also applicable to by-products and co-products. Switchgrass R&D should be expanded and developed with greater collaboration of USDA and state extension groups. Woody crop research should continue with significant cost-share from industries developing the crops for other commercial products. Co-product options need more investigation.

KEYWORDS

Research; biomass energy; dedicated crops; biomass residues; by-products; co-products.

INTRODUCTION

A number of drivers are forcing reevaluation of biomass feedstock strategies in the U.S. as we approach the year 2000. Most suggest that only very lowcost biomass will be considered for energy. Oil, coal and natural gas prices have not increased as anticipated in the early 1980's and are projected to remain low for a number of years. The prospect of deregulation is forcing utilities to keep electricity prices low as possible, making investments in new or expensive technologies highly risky. Environmental drivers have not stimulated the development of national policies favorable to energy crops, though some states are experimenting with "green pricing" and renewable energy requirements. The federal ethanol tax credit is scheduled to expire by the year 2000, and may be ended earlier. At the same time other forces are at work which suggest that the U.S. should continue to develop biomass energy technologies and supply strategies. For example, changing agricultural policies that reduce federal control over crop production may make alternative crops a more viable option. Biomass energy still appears to be a major element of any U.S. strategy for significant, near-term reductions in greenhouse gas emissions. Established industries are interested in collaborative research on selected crops, offering a window of opportunity for greatly enhancing basic crop development and our understanding of the infrastructure necessary to supply significant levels of energy crops.

All U.S. Department of Energy programs involved in developing biomass energy technologies are developing road maps to chart a course from near-term cost-shared demonstrations to a mature and successful industry. The Alternatives Fuels Program expects to facilitate the commercial production of ethanol from biomass residues such as sugarcane bagasse and/or wood wastes by the year 2000 or earlier, and from switchgrass crops by the year 2005. In the long term, it is anticipated that ethanol will be produced from a variety of biomass residue and energy crop mixtures. The Biomass Power Program is facilitating the commercial production of electricity from several different combinations of residues and crops at 4-5 locations in the U.S. Similar efforts are ongoing in Europe (McCarthy et. al., 1996). The ongoing projects in U.S. and Europe illustrate the wide range of dedicated and residual feedstocks likely to contribute to the biomass energy industry of the future.

Related federal and private research programs in the U.S. are developing biomass crops for alternative uses such as paper, building supplies and bio-based chemicals. For example, the Department of Energy's Office of Industrial Technologies (OIT) Agenda 2020 (Forest Products Industry of the Future) program is supporting research on developing technologies to increase fiber production in environmentally sound ways in traditional forests and on cropland. With agricultural policies changing to give producers greater flexibility, farmers will want to grow the most profitable crops that meet environmental requirements. When the same crop is optimal for both fuel and fiber, research to optimize use of the land in environmentally sound ways will help both the farmers and all biomass using industries. Energy may not be the first or primary market for all such crops, but many biomass usage pathways can include energy production as a by-product or as final step in a multiple use chain (Overend, R. P., personal communication)

POTENTIAL BIOMASS FEEDSTOCK RESOURCES

Primary residues or by-products are the unprocessed portions of crops already being grown for well-defined markets (e.g. food, feed, and wood product markets). Primary residues are usually left in the field or forest (e.g., logging residues, corn stover, and wheat straw), though some are removed to control pests and diseases (e.g.. rice straw), or to facilitate site preparation (e.g.. tops and branches of plantation wood). Some clean, weed-free residues like wheat straw have limited existing markets as mulch and animal bedding, particularly where the crops are grown near population centers. However, there are large amounts of unused residues in major crop and forestry production areas of the U.S. Residues left in the field perform services such as erosion control and the maintenance of soil organic matter. Those not needed for environmental protection have potential new markets for energy, paper, and composite building materials.

Secondary residues or by-products are the residues from processing various agricultural and forest products. They differ from primary residues by being collected at some location. While quantity, quality, and availability vary greatly by site and process, quality is often relatively uniform at any one location. Examples include black liquor from pulping processes, sludges from paper mills, municipal solid wastes, municipal sewage sludges, wood and bark mill residues, and food processing residues. These by-products require disposal, with its associated costs, if not used. Both the convenience of a uniform, precollected feedstock and cost of disposal provide incentives for finding uses for secondary residues. Most of the biomass energy currently produced in the U.S. comes from secondary residues in forest products industries. Some materials such as urban forest and yard trimmings, and construction and demolition wastes, which are not process by-products, are nevertheless put into the secondary residue category because they are collected and require disposal.

Dedicated energy crops are crops grown specifically for energy end-uses such as liquid fuels, electricity or heat. Crops which have received serious consideration include annuals such as sorghum, wheat, and rye; thick-stemmed perennials such as "energy cane" and other tropical grasses, perennial thin-stemmed grasses, and short-rotation trees. The energy crops selected for development in the U.S. are native thin-stemmed perennial grasses and short-rotation trees. Energy crops are now being grown on experimental and demonstration scales. Such crops can provide multiple environmental services if appropriately grown, harvested, and deployed in the landscape. Environmental services such as carbon sequestration and soil stabilization may be a recognized (monetary) factor in the production of perennial energy crops in the future in the U.S. if agricultural and energy policies change.

Co-products crops are the potential fourth category of biomass resources. The distinction between by-products and co-products is basically an economic one. (Parker, 1995). When the production and sale of each of two (or more) products is essential to the viability of a production system, the products are co-products. Soybeans, produced for both oil and meal, are an example of the deliberate production of a crop for coproducts. As markets and technologies change, the designations of by-products and co-products are not necessarily fixed. What had been a by-product might become a co-product, or even the primary product. For example sugar cane bagasse is normally considered to be a residue or by-product. However, several projects are emerging worldwide to use the bagasse for producing electricity or ethanol. When sugar prices are low, the energy produced from bagasse could become a co-product, critical to the economic viability of the facility, .

A review of the potential price-supply relationships of some of the major sources of biomass in the U.S. shows that the amount of low cost biomass is very limited since most secondary by-product supplies are already being utilized. (Marie Walsh, personal communication). However, in the year 2015 up to 194 million dry tons of agricultural by-products plus about 100 million dry tons of energy crops could theoretically be available at prices between $27 and $35/dry ton - enough to support a substantial increase in biomass energy production. However, if food export markets increase demand, or other markets for the dedicated crops and agricultural by-products expand, then smaller amounts of these feedstocks would be available for energy and the prices will be higher. Significant amounts could still be available at reasonable prices, though the dispersed nature of biomass production will increase costs when very large quantities are needed at a single location (Graham). These analyses shows the importance of R&D strategies geared both toward dedicated crops and by-products.

STRATEGIES FOR BIOMASS RESOURCE DEVELOPMENT

Several implications of the biomass resource reevaluations should be significant considerations in strategic planning for biomass energy research and development. One is that the average per ton cost for feedstock will in most cases be less for smaller facilities than for very large facilities. Another is that conversion technologies which can use a mix of feedstocks will be able to acquire feedstocks at a lower average cost than those with very specific feedstock requirements. The availability of high-efficiency conversion technologies appears especially critical to the commercialization of energy crops and systems for collecting field residues. The most important implication for biomass resource development is that profitability to the farmer will determine the extent to which biomass energy supplies will come from dedicated crops, crop by-products, and co-products. This realization is reflected in the strategies presented below.

Dedicated Energy Crop Strategy

Increasing the profitability (to farmers) and the affordability (to energy producers) of high quality, uniform crops which can be produced in an environmentally sound manner is a top priority effort. This translates to increasing crop yields, decreasing production costs and risks, increasing positive environmental effects and reducing negative ones, and improving harvesting, storing, handling and transportation efficiencies. This strategy has been a keystone of the Biofuels Feedstock Development Program (BFDP) over the past several years. After years of species selection and crop management trials, the crop development tasks within the BFDP currently focus on the genetic improvement of one model perennial grass species, switchgrass, and two model short-rotation woody crops, poplars and willows. While all three are being developed as energy crops, in some locations other markets now exist for the poplars, which places them also in the by-product and co-product strategies mentioned below. Developing perennial grasses and tree crops is necessary to supply the resource base needed for significant expansions in the biomass energy industries (both power and liquid fuels). In the long run, additional crop species could increase feedstock supply by making energy crop production feasible on a wider range of sites; provide additional environmental benefits by increasing crop diversity; and reduce harvest and storage costs by increasing the length of the harvest season. Energy crop development is currently supported by both the Biomass Power Program and the Alternatives Fuels Development Program of DOE. The USDA Agricultural Research Service, the Forest Service, and universities have long been important cost-sharing partners in the selection and improvement of energy crops and crop production systems. More recently, the fiber industry has begun to play a significant role in evaluating short-rotation production techniques over a wide range of sites and contributing to advancing the science of woody crop biotechnology and genetic improvement.

R&D activities needed to improve dedicated biomass crop technology are the following.

1) Continue to integrate switchgrass research into "virtual crop development centers" in at least 5 regions of the U.S. Crop breeders selecting for higher yields, stress resistance, and desirable conversion trait qualities should be linked to projects performing basic research on yield-limiting factors, physiology, pathology, genetics, and breeding techniques. Variety screening and crop management studies should increasingly involve USDA and university facilities and scientists who work directly with farmers in extension and rural development programs.

2) Increase the number of large-scale plantings of switchgrass in order to develop dependable information on production economics and environmental impacts; to evaluate and improve harvesting, drying and storage technologies; and to develop expertise on feedstock scheduling and delivery systems. Include farmer participation in such scale-up R&D to understand farmer constraints, concerns, and conditions for participating in energy crop production.

3) Continue to support regional development centers for poplar in 4 regions of the U.S., and willow in one region. Link breeding centers selecting for higher yields, stress resistance, and desirable quality traits with basic studies on yield-limiting factors, management systems,

physiology, pathology, genetics, and advanced breeding techniques to form "virtual crop development centers". Continue to use the expertise and cost-share available from USDA Forest Service and university research facilities to establish and sustain the center infrastructure. Continue to link the centers with industries willing to cost-share the work and to test new varieties as they are generated.

4) Maintain research partnership with industries planting short-rotation woody crops on a commercial scale to gain knowledge of the operational issues and concerns, environmental issues and impacts, and woody crop economics.

5) Evaluate the potential variability in switchgrass and woody feedstock quality, its effect on commercial end-uses, and possibilities for controlling or modifying feedstock quality.

6) Evaluate alternative uses for energy crops, and their potential effect on prices.

7) Conduct full fuel cycle environmental and economic evaluations of biomass systems supplied with energy crops

Primary and Secondary By-Products Strategy

The dedicated energy crop strategy alone may or may not result in commercial biomass energy production. Under current conditions feedstock costs are so critical that a comprehensive program for developing biomass resources must include reducing costs by using wastes and residues, either alone or in combination with energy crops. This strategy includes developing more efficient ways of collecting and handling primary and secondary by-products for energy production and helping potential biomass energy producers determine the most cost-effective ways of using those materials. This has largely been the approach taken by DOE's Regional Biomass Energy Programs and is being used in the near-term by both the Biomass Power Program and the Alternative Fuels Development Program of DOE.

R&D activities needed to assist biomass energy development based on primary and secondary residues are summarized below.

1) National-, regional-, and local-level analyses of residue resources, production costs, and market prices.

2) Residue characterization and evaluation in current conversion systems.

3) Studies of effects of residue collection on forest and agricultural soils.

4) Full fuel cycle environmental and economic evaluations of biomass systems supplied with residues.

5) Evaluations of alternative uses for residues, and their potential effect on prices.

6) Materials handling R&D to improve the efficiency of collecting and storing residues.

7) Materials handling R&D to improve drying & feeding biomass residues into conversion systems.

Some of this R&D will also have benefits for energy systems based on energy crops, and for other, existing industries. One way to improve the utilization of residues/by-products for energy is to work with the existing industries that use biomass resources for other products (e.g. food and fiber). This is already happening through the BFDP's collaboration with the fiber industry in cooperatives and cost-shared research, and through efforts of the Biomass Power Program and the Industries of the Future Program to work with the pulp and paper industries to increase the efficiency of their biomass conversion technologies. With sufficient improvements, the pulp and paper industry could become energy self-sufficient and export electric power to the national grids.

A Co-product/New Markets Strategy

A third strategy is to develop a number of new products from traditional agricultural crops such as building materials, plastics, chemicals, etc. This has been the focus of the US Department of Agriculture and particularly the Alternative Agriculture Research and Commercialization program and the New Uses Council. Development of some new products could be done in such a way that energy becomes an important co-product that enables the economic viability of the integrated system. This differs from the by-product/existing market strategy primarily in that the markets for both the energy and co-product need simultaneous development. This approach presents some difficulties, including a difference in the size of the markets. With energy being a low-value product at present, it is assumed that the other product(s) will have higher value. However, most high value products remain that way by being a somewhat limited resource, which could limit the co-product strategy as a means of producing large amounts of biomass for energy. The co-product strategy is being evaluated by the Biomass Power Program in their Biomass Power for Rural Development project to produce energy from alfalfa stems and high-protein meal for livestock from the leaves. The co-product approach is complex, but one that could succeed under special conditions for some projects and therefore deserves further consideration by both DOE and USDA. In the long run, a mature biomass energy industry providing a dependable, well-defined market for residues could facilitate the introduction of many different new crops producing both a high-value product and a biomass residue.

There is a need for analysis of existing co-product and by-product crop opportunities and collaborative studies that will expand current co-product and by-product opportunities or lead to new co-product opportunities. This as an area where basic biological research on identification of genes responsible for the production of compounds of potential interest, and on the biochemistry and physiology of speciality compound production could be very important. While such work would not contribute to actual production of bioenergy within the next 15 years, it might lead to some very profitable new business venture over the long term. Exploration of this arena should be considered through some joint activities of several DOE and USDA programs.

SUMMARY

There are many pathways to expanding biomass resources for the production of energy, and many research needs associated each of those pathways. All relevant federal and state programs should be open to considering any or all of the pathways and in collaborating to facilitate development of the pathways. The Biofuels Feedstock Development Program managed by Oak Ridge National Laboratory is involved in collaborating with government and industry groups to facilitate the development of biomass resources as dedicated products, by-products and co-products.

REFERENCES

Graham, R. L., W. Liu, and M. Downing (1995). The Effect of Location and Facility Demand on the Marginal Cost of Delivered Wood Chips from Energy Crops: A Case Study of the State of Tennessee. In: *Second Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry, pp. 1324-1334.* National Renewable Energy Laboratory, Golden, Colorado.

McCarthy, S., M. Walsh, G. Gosse (1996). In: *The Future for Renewable Energy: Prospects and Directions*. Chapter 1. Biomass, pp 18-45. European Union Renewable Energy Centres Agency (EUTEC). James and James Publ., London.

Overend, R. P. Personal communication of paper in preparation for Biomass and Bioenergy as of February 1996. The paper contains an excellent diagram showing the relationships between biomass produced for energy, fiber, food and fodder and the various potential pathways of that biomass to bioenergy end uses. National Renewable Energy Laboratory. Golden, Co.

Parker, H. W. (1995). Process Design as a Research Tool, Today's Chemist at Work, Vol 4, No. 11, pp 26-30, The American Chemical Society.

Walsh, M. E. (1997). Personal communication of results of a recent analysis conducted jointly between Oak Ridge National Laboratory staff, National Renewable Energy Laboratory staff, Department of Energy staff and consultants.

Oak Ridge National Laboratory is managed by Lockheed Martin Energy Research Corp. for the U.S. Department of Energy under contract number DE-AC05-96OR22464.