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Great Lakes Regional Biomass Energy Program

BIOMASS, BIOENERGY, AND CARBON MANAGEMENT

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ABSTRACT

Biomass is a significant contributor to the United States economy – agriculture, forest and paper products, food and related products account for 5% of our GDP. While the forest products industry self generates some of their energy, other sectors are importers. Bioenergy can contribute to economic development and to the environment. Examples of bioenergy routes suggest that atmospheric carbon can be cycled through biofuels in carefully designed systems for sustainability. Significant potential exists for these options. Research and development of integrated biomass production and conversion systems, as currently being performed in the Biomass for Rural Development program, can help verify the potential energy, economic, and environmental benefits and advance biomass and bioenergy into the 21st century.

Keywords: life cycle, biomass, bioenergy, environment, carbon dioxide, emissions, energy, electricity, coal-fired power plant, Biomass for Rural Development Program

BIOMASS AND BIOENERGY[1,2]

Biomass is the result of storing sun light as chemical energy in plants. Through photosynthesis, sunlight transforms carbon dioxide from the atmosphere and water into complex plant polymers over short periods of time. Our use of this resource for energy cycles the carbon dioxide from the atmosphere. Our use of this resource as a material or durable product keeps the carbon dioxide stored. Biomass are plant materials – such as wood and its wastes, herbaceous and aquatic plants, agriculture crops and its residues, industrial and processing wastes, and the organic portion of municipal wastes.

Certainly, biomass is the most complex renewable resource by its very diverse nature. It has a variety of uses including conventional – food and feed as well as renewable fibers

used by the pulp and paper industries, materials produced by the wood products industry – and energy. To compare the scales of these various uses of biomass as a first order of magnitude, all cereals worldwide have the energy equivalent of 31.3 EJ while all the merchantable boles represent 14.3 EJ. Fuel wood and charcoal used primarily in developing countries for cooking and heating are estimated at 15.3 EJ. Just the usable portion of the current biomass applications worldwide amounts to 60.9 EJ, a very large number indeed or 2/3 of the United States' energy consumption. [1 quad = 1.055 EJ]

For comparison with these worldwide figures, in the United States, the grains in energy equivalent units account for 5.6 EJ, while the merchantable boles are equivalent to 3.4 EJ and the industrial self-generated energy used in the processing is 1.7 EJ. Overall, the pulp and paper industry is 56% energy self-sufficient while wood products manufacturing is 74% energy self-sufficient. Residential energy use is only 0.7 EJ. The use of wastes for energy amounts to 0.5 EJ and the use of biomass for electricity account for 0.9 EJ. The ethanol produced from corn is equivalent to 0.08 EJ. Biomass is the only renewable resource capable of producing liquid fuels, oxygenates or hydrocarbons, through a variety of processes. So, when taken together, biomass and bioenergy account for 4% of the primary energy in the United States.

In the last two decades, biomass power has become the second largest renewable source of electricity after hydropower. Similar to hydropower and geothermal energy, biomass plants provide baseload power to utilities. Biomass power plants are also fully dispatchable—they operate on demand whenever electricity is required. If biomass is cultivated and harvested properly, it is a renewable resource that can be used to generate electricity on demand, with little net contribution to global carbon dioxide. About 350 biomass (not municipal waste) power plants with a combined rated capacity of 7000 MW feed electricity into the nation's power lines, while another 650 enterprises generate electricity with biomass for their own use as cogenerators. Biomass power was the industry created by the Public Utilities Regulatory Policy Act (PURPA). It generated 66,000 jobs with an investment of $15 billion. The industry created was based primarily in the use of biomass residues with condensed steam technologies that are about 20% efficient. PURPA's avoided costs paid for and built an environmental infrastructure that collected biomass residues and avoided landfill use. In addition to significant economic development afforded by this option and environmental benefits, how much can the biomass industry contribute to carbon management?

ROLE OF BIOMASS AND BIOENERGY IN CARBON MANAGEMENT

With the atmospheric concentration of CO_2 increasing, an extensive international literature is evolving advancing the understanding of the balance of carbon C pools and fluxes in standing forests and the use of forests for products and the role of bioenergy.[3] Several C management strategies exist. One strategy for mitigating the accumulation of CO_2 in the atmosphere is the collection and storage of C in growing trees, i.e., reforestation or afforestation, which is currently considered by the Kyoto protocol, and accepted by many environmental groups. Another strategy is afforestation or

reforestation with harvest of the standing stock and use to produce a mixture of short and long lived products, displace fossil fuels, and provide energy for processing. Another possibility is the displacement of fossil-fuel combustion through the use of renewable biomass fuels, i.e., by cycling C through biomass fuels. The last two strategies provide ways to remove atmospheric carbon and generate economic activity while the first strategy provides a sink for as long as the biomass accumulates (order of 100 years).

Many trade-offs between the various strategies have been discussed because the amount of land potentially available for growing trees is limited.[4] Durable wood products provide some storage of C and all biomass products displace alternate products and services that have different levels of embodied energy. Solar energy and the photosynthetic process can provide a feasible route to remove CO_2 from the atmosphere. Collection of solar energy for this purpose relies on a large area of plant collectors. There are several options on how the C can be most advantageously stored or cycled once collected.

Marland and Schlamadinger[5] compared two options and highlight the need for increased efficiency at each step of the way -- plant production, harvest, transport, processing into final products, and use. The whole cycle is important and its efficiency and sustainability are key drivers. When sustainably-produced forest products are used inefficiently to displace fossil fuels, the greater C benefit is achieved through reforestation and protection of standing forests, and increasing the rate of stand growth yields little gain. However, when forest products are used efficiently to displace fossil fuels, a sustainable harvest produces the greater net C benefits, and the benefit increases rapidly with increasing productivity.[5]

The success of any mitigation strategy based on forest or land management will depend on a number of variables. It will be highly site specific, depend on the initial status of the land, physical environment (e.g., climate), the productivity that can be expected, the efficiency with which harvested forest is used, and the time perspective of use of land for that application. Some of these factors can be manipulated as part of a mitigation project and some are imposed on a project by the economy in which it operates. The more fully one understands the system of C impacts, the easier it is to take advantage of the opportunities available.

Integrated life cycle analysis is one key tool for the assessment of biomass systems. A considerable effort in analyzing the entire life cycle for biomass energy was completed recently.[6] A life cycle analysis (LCA) identifies, evaluates, and helps minimize the environmental impacts of a process. Material and energy balances quantify the emissions, resource depletion, and energy consumption of all processes involved. The process starts with the transformation of raw materials into building blocks, such as cement and steel for building the power plant, natural gas and other starting materials for fertilizers, and petroleum for diesel. It also considers the final disposal of all products and by-products at the end of their service life. There are three components of an LCA. 1) Inventory to quantify the energy and material requirements, air and water emissions, and solid waste from all process stages. 2) Impact assessment to examine the environmental and human health effects associated with the emissions and waste products quantified in the

inventory stage. 3) Improvement assessment to propose ways to minimize environmental drawbacks.

This life cycle analytical effort looks at the entire cycle from nearly the seedlings to the emissions from the production of the plant biomass, construction of the power plant, and emissions from operations at all phases over the 37 years of construction, operation and decomissioning.[6] It concluded that biomass electricity might indeed contribute significantly to U.S. energy supplies while minimizing environmental consequences. Compared to regular annual crop farming the use of short rotation poplar wood requires much less fertilizers, herbicides, and water. The biomass electricity system analyzed is nearly closed from a carbon cycling point of view. Assuming zero accumulation of carbon in the soils, 95% of the carbon cycles in this cycle. In sites that have the ability to uptake carbon in the soils, the cycle becomes a net sequestration option as determined by sensitivity analysis. The net energy ratio is 16: 1. Sixteen times more "green" energy is produced per unit of fossil fuel consumed.

Life cycle analysis in the forest products industry and the role of life-cycle analysis related to the wood products industry has been recently reviewed. [7]

BIOMASS AND BIOENERGY, CARBON MANAGEMENT AND RURAL DEVELOPMENT

Boman and Turnbull[8] evaluated four biomass energy systems that were investigated as a result of the "Economic Development through Biomass Systems Integration" activities of the United States Department of Energy and the Electric Power Research Institute. These studies addressed dedicated feedstock supply systems (DFSS) in the context of production of energy alone or energy and other products. Based on the reports from the evaluation of these systems, these researchers[8] from Vattenfall and EPRI conducted the full fuel cycle studies including emissions of carbon dioxide from four of the studies. The following table shows the studies and the carbon impact.

The main conclusions from that study were that the biomass systems did not require more external energy input than the coal-based systems; on the contrary, often they required less external energy. The potential for reduction of greenhouse gas emissions through the offset of coal by biomass was found to be significant.

More recently, an analysis was conducted of the case of integrated gasification combined cycle opportunities in the forest products industry.[9] This study concluded that with accelerated development of the technologies of biomass and black liquor gasification and implementation, the planned replacement of capital stock with next generation technologies (instead of improved conventional technologies) could offset a 10 million metric tons of carbon by 2010. It could make the forest products sector a net exporter of electricity. Under some conditions, cofiring with coal could offset 15 million metric tons of carbon also by 2010.[10] Just two technological avenues in biomass power and

combined heat and power production could offset 25 million of today's carbon emissions of 1634 million metric tons.

Study Performer/Location	Objective	Carbon Impact[8]
Northern States Power/Minnesota	Alfalfa stems as a biomass feedstock for an integrated gasification combined cycle electricity production	-95 kgC/Gje
Empire State Power Consortium/New York	Willow hybrids for cofiring with coal	-9 kgC/GJe (at 10% cofiring) -90 kgC/GJe (100% biomass)
Weyerhaeuser/New Bern Advanced Biomass to Energy Project/North Carolina	Integrated Gasification Combined Cycle integrated with pulp mill residues	-100 kgC/Gje
Kansas Electric Utilities Research Program/Kansas	Fast pyrolysis of different herbaceous and woody crops for 3-4 MWe baseload	-120kgC/Gje

This talk introduces the session papers addressing the continuation of the studies initiated in the Economic Development Through Biomass Systems Integration mentioned above, which have continued through a Request for Proposals issued by DOE for Biomass for Rural Development projects with participation of the US Department of Agriculture. The status of the projects will be highlighted. As these projects proceed, their data validate the potential of these integrated biomass production and conversion options to provide economic development for rural America and a host of environmental benefits including carbon offsets. They also highlight both technical and non-technical challenges that face project developers. These projects are examples of research and development of integrated systems and are complex and multidisciplinary. They rely on partnerships between various entities in the private sector (growers, seed producers, technology developers, financing community, utilities, engineering and construction companies, to name a few), federal (multiple agencies), state and local governments, and academia. These partnerships will propel the "NEW BIOMASS" systems, a term coined by the Shell International[11] to differentiate the low efficiency biomass usage which is practiced throughout the world but particularly in developing countries from these high efficiency concepts.

Several independent scenarios of world energy evolution indicate that by 2050, biomass has the potential to contribute 25-50% of the present global energy. Shell International Petroleum Co. scenario calculations (1994-96) indicate certain conditions in which new biomass sources could contribute 45-50%. These careful evaluations have been followed by the creation of Shell International Renewables (1997) with investments in biomass forestry and biomass power generation.[12] The second assessment report of the

Intergovernmental Panel on Climate Change (1997) identified biomass as a major contributor (25-45%) by 2050. Ecologically driven scenarios of the World Energy Council (1996) come to similar conclusions.[13] The President's Committee of Advisors on Science and Technology report on Federal Energy Research and Development for the Challenges of the 21st Century (1997) recognizes that biomass is one major contributor to global energy and many other environmental, social, and economic benefits.[14]

Recently a transnational company capable of implementing these technologies in many countries entered photovoltaic energy as an area of business, short rotation forestry and biomass electricity. The company is interested both in the large-scale activities and in the small scale which would allow them to implement Sun Stations.[15] In this concept, short rotation forestry plantations are established near a village. The village has a biomass power small station to supply electricity to grid connected homes. Just like a gas station, the sun station model could be easily duplicated worldwide and serviced from a centralized or decentralized structure. Photovoltaic energy provides electricity to the homes distant from the center of the village and backup energy for critical operations. As a company like Shell operates in more than 130 countries, it is easy to see how this powerful concept could dominate many rural areas in the future while providing a high quality of life to a rural population. Coupled forest products and these renewable-energy self-sufficient towns – the "sun towns" could develop throughout the world.

All of these developments bode well for the national and international development of NEW BIOMASS – high efficiency production and conversion systems, as a key supplier of energy needs of the 21st century along with essential services that biomass provides in food, feed, and fiber.

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