# COMMITTEE ON SCIENCE AND TECHNOLOGY
# SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
# U.S. HOUSE OF REPRESENTATIVES

## *Biomass for Thermal Energy and Electricity: A Research and Development Portfolio for the Future*

**Wednesday, October 21, 2009**
**2:00 p.m. - 4:00 p.m.**
**2318 Rayburn House Office Building**

## PURPOSE

On Wednesday, October 21 the Subcommittee on Energy and Environment will hold a hearing entitled "*Biomass for Thermal Energy and Electricity: A Research and Development Portfolio for the Future."* The purpose of the hearing is to explore the role of the Federal Government and industry in developing technologies related to the conversion of biomass for thermal energy and electricity.

Biomass includes any organic matter that is available on a renewable basis, including agricultural crops, agricultural wastes and residues, wood and wood wastes and residues, animal wastes, municipal wastes, and aquatic organisms. Biomass has received considerable attention for its ability to be converted into liquid transportation fuels, but it can also produce biopower or thermal energy (heat), power (electricity) and biobased products. Biomass feedstocks are vital as the country moves toward a more diverse portfolio of energy sources, especially in the Southeast and Northwest of the country where there is a significant quantity of these renewable resources.

## WITNESSES

- **Mr. Scott M. Klara, PE** - Director, Strategic Center for Coal - National Energy Technology Laboratory
- **Dr. Don J. Stevens** - Senior Program Manager - Pacific Northwest National Laboratory
- **Mr. Eric Spomer** - President - Catalyst Renewables Corporation
- **Dr. Robert T. Burns** - Professor, Agricultural & Biosystems Engineering - Iowa State University
- **Mr. Joseph J. James** - President Agri-Tech Producers, LLC (ATP)

## Background

Biomass is mankind's oldest source of energy. Since the time of the first nomadic hunter-gatherer societies, wood has been burned for cooking and heating. As few as five generations ago, 90 percent of our energy was supplied by the combustion of wood. Today, biomass provides about 10 percent of the world's primary energy supplies. Over the last century, the convenience and low cost of fossil fuels has allowed an emerging industrial society to meet its vast energy needs. However, decreasing availability of fossil fuel resources and simultaneous increases in demand, along with concerns over climate change, have given rise to renewed interest in biomass as an energy resource.

In the United States renewable energy—water, wind, solar, geothermal, and biomass—currently accounts for approximately 10 percent of total energy production.[1] Of the renewable energy consumed in the country the largest portion, 53 percent, comes from biomass (this includes liquid transportation fuels). The U.S. Departments of Agriculture and Energy estimate that, by 2030, 1.3 billion tons of biomass could be available for energy production (including electricity from biomass, and fuels from corn and cellulose). Through improvements of existing technologies and development of new technologies biomass could meet its potential as a major resource of renewable energy production.

In the last decade, most legislative efforts concerning biomass have focused on promoting its use for the production of liquid transportation fuels. Comparatively little has been done to advance biomass for electricity generation and thermal energy, or "biopower."

## Continued RD&D for Cost-Effective and Increased Energy Efficiency in Biopower Generation

A variety of conversion technologies are used for biopower, many of which are capable of being integrated into the existing energy generation infrastructure. Technologies such as direct-fired systems (stoker boilers, fluidized bed boilers and co-firing), gasification systems (fixed bed gasifiers and fluidized bed gasifiers) and anaerobic digestion are in various stages of development, and some have already seen limited deployment in the energy sector. However, while efforts to deploy these technologies have been met with some success, there are still a number of technical barriers before these technologies reach their full potential.

Efforts to promote biopower have largely focused on wood, wood residues, and milling waste. The pulp and paper industry has become a major producer of renewable energy in the United States. The industry uses "black liquor," a byproduct of the pulping process, as well as "hog fuel" or other wood wastes as its feedstock to produce energy. Generally most of this energy is used onsite to power various industrial processes. In 2008, the pulp and paper industry generated 38 billion Kilowatt-hours, or more than two-thirds of all electricity generated from biomass.[2]

[1] EIA, Monthly Energy Review, September 2008.
[2] Energy Information Administration/ Renewable Energy Consumption and Electricity Preliminary Statistics, 2008 http://www.eia.doe.gov/fuelrenewable.html.

In a September 2009 report the Washington State Department of Ecology assessed the current energy profile of the state's pulp and paper industry and explored the potential for increasing the industry's biopower production. The Department found that while the state's pulp and paper mills already produce a substantial amount of biopower, they typically do so with outdated and inefficient boilers and ancillary equipment. With older equipment, the mills produce considerably less power than they could with new boilers, evaporators, and turbines. Factoring for capitol costs and increased biomass demands, the report found the benefits of implementing existing state-of-the-art technologies to be compelling. It was found that the total electrical power from Washington mills could be increased from 220 MW to 520 MW with new boilers. Although this study identified key technologies that could be implemented immediately, it called for more research on gasification technologies which may be a viable replacement for existing boilers. Additionally, pulp and paper mills may be great demonstration facilities for integrated biorefineries which produce fuels, power and products. This currently is being researched through the DOE.

Most of today's biopower plants are direct-fired systems, typically producing less than 50MW of electrical output. The biomass fuel is burned in a boiler to produce high pressure steam that is used to power a steam turbine-driven power generator. In many applications, steam is extracted from the turbine at medium pressures and temperatures and is used for process heat or space heating. While these systems are generally very efficient and have superior emissions profiles over many conventional technologies, increased research is needed to drive down capital costs, especially in back-end air pollution control devices.

Another technology of interest is co-firing, a near-term low-cost option for efficiently and cleanly converting biomass to electricity by adding it as a partial substitute fuel in existing coal-fired boilers. Biomass co-firing in modern, large-scale coal power plants is efficient, cost-effective and requires moderate additional investment. By blending suitable biomass into coal boilers for simultaneous combustion, co-firing reduces the amount of coal used by as much as 20 percent. Little or no loss in overall boiler efficiency can be achieved if appropriate designs and operational changes occur.[3] According to the International Energy Association, in the short term co-firing is expected to be the most efficient use of biomass for power generation worldwide. As electricity from coal represents 40 percent of worldwide electricity, each percentage point replaced by biomass represents some 8 GW of installed capacity, and approximately 60 Mt of $CO_2$ per year avoided.[4]

Additionally, significant global market potential has been identified for small modular biomass systems in distributed, on-site electric power generation. These systems typically use locally available biomass fuels such as wood, crop waste, animal manure and landfill gas to supply electricity from 5 kilowatts to 5 megawatts per system to rural homes and businesses. Systems include combined heat and power systems for industrial applications, gasification and advanced combustion for utility scale power generation. [5] Several prototype systems were developed in the

[3] Federal Energy Management Program (DoE): *Biomass Cofiring in Coal-fired Boilers* http://www1.eere.energy.gov/femp/pdfs/fta_biomass_cofiring.pdf.
[4] IEA: Biomass for Power Generation and CHP. January 2007.
[5] National Renewable Energy Laboratory: *Small Modular Biomass Systems* *www.**nrel**.gov/docs/fy03osti/33257.pdf*.

early part of this decade, but continued research is required to optimize integration of these systems with existing infrastructure and to overcome a variety of other design issues.

## Closing the Technology Gap for Biopower Technologies

In addition to the numerous conversion technologies used to generate electricity from biomass, there are several technologies that could convert biomass into a gaseous energy product to replace natural gas and other energy resources (often described as "renewable natural gas.") Such products can be used in existing natural gas pipe lines, industrial processes, home heating, or any number of other situations where natural gas is normally used. Gasification, pyrolysis, and anaerobic digestion are all conversion technologies that exist in some form in today's market, but are generally not used to make renewable natural gas. Both gasification and pyrolysis are thermochemical conversion processes, whereas anaerobic digestion involves the natural decomposition of organic matter to produce methane.[6]

The thermochemical process of gasification begins with the decomposition of feedstocks such as wood and forest products, followed by the partial oxidation or reforming of the fuel with a gasifying agent- usually air, oxygen, or steam- to yield raw synthesis gas, or syngas. These gases are more easily utilized for power generation and often result in improved efficiency and environmental performance compared with the direct combustion of biomass. The gasification process is further optimized when operating at very high pressures, and process improvement and development is needed to make high-pressure feed systems commercially available.[7]

Nexterra Systems, based in Vancouver, Canada, has been at the industry forefront in developing biomass gasification systems. They have some operations in the United States, including a cogeneration plant designed to power the University of South Carolina that consists of 3 gasifiers that convert wood biomass to syngas. In August they received $7.7M in funding from the BC Bioenergy Network (BCBN), Sustainable Development Technology Canada (SDTC), the National Research Council Canada Industrial Research Assistance Program (NRC-IRAP), and Ethanol BC. This funding will be used to support Nexterra's recently announced program to commercialize a new high efficiency biomass power system in collaboration with GE Jenbacher and GE Energy.

Pyrolysis is a thermochemical process similar to gasification. Typical pyrolysis processes occur in environments with virtually no oxygen. Fast pyrolysis is being commercially developed by organizations such as Ensyn Technologies and DynaMotive, a corporation also based in Vancouver, Canada and with sites in the United States.[8] DynaMotive has developed fast pyrolysis technologies that utilize non-food biomass to produce a renewable liquid fuel, BioOil, as well as several other products. These technologies operate in oxygen-free environments at

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[6] National Renewable Energy Laboratory. "Learning About Renewable Energy and Energy Efficiency: Biopower". July 25, 2008, http://www.nrel.gov/learning/re_biopower.html.

[7] National Renewable Energy Laboratory. "An Overview of Biomass Gasification". July 25, 2008. http://www.nrel.gov/biomass/pdfs/overview_biomass_gasification.pdf.

[8] U.S. Department of Energy- Energy Efficiency and Renewable Energy. Biomass Program. "Pyrolysis and Other Thermal Processing". October 13, 2005. http://www1.eere.energy.gov/biomass/printable_versions/pyrolysis.html.

moderate temperatures, thus improving overall efficiency.[9] Despite limited deployment of this technology, development of new methods to control the pyrolytic pathways of bio-oil intermediates is needed in order to increase product yield.

Anaerobic digestion involves the breakdown of organic matter through natural biological processes and is most commonly used on manure and municipal wastes. This breakdown produces a "biogas" that consists of methane, carbon dioxide, and trace levels of other gases.[10] There are approximately 135 anaerobic digesters in the United States, 125 of which are used for generating electric or thermal energy. Electric generation projects account for almost 307,000 MWh generated annually, while boiler projects, pipeline injection, and other energy projects account for an additional 52,500 MWh equivalent per year.

The Pacific Gas and Electric Company (PG&E) in California is partnering with dairies, industry, and municipal waste processing facilities in projects to transport biomethane to consumers through their natural gas pipeline. Additionally, in 2008 PG&E began to cultivate the next generation of biogas technologies through its biomethanation research project. This recently launched project explores emerging biomethanation technologies and processes that may increase conversion efficiency, expand the range of usable feedstocks and improve the quality of biomethane products. Although anaerobic digestion is considered carbon-neutral, the process does result in the formation of nitrogen oxides. Flue gas from electricity generation using biogas must be treated before being released into the atmosphere. There are two key technologies employed for this purpose: Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR). Both technologies have the capability to reduce nitrogen oxide emissions, but require considerable more development to optimize cost and ease of installment.[11]

Thermochemical conversion processes also require the cleaning of syngas before it can be used for energy generation. Syngas clean-up and conditioning has the greatest impact on the cost of syngas and is a barrier to the commercialization of thermochemical conversion technologies.[12] Gas Technology Institute (GTI) has taken action in developing cleaning technologies to be used in biomass gasification. Their projects focus on cost-effective contaminant removal to ensure that syngas after gasification meets standards for downstream applications, such as turbine generation. Many of their other gas-cleaning projects are sponsored by the U.S. Department of Energy and focus on coal gasification and IGCC power plants. In order for thermochemical conversion processes to be commercialized to the extent where they can be utilized by small agricultural and forestry communities, the same focus needs to be placed on biomass gasification and pyrolysis clean-up.

[9] Dynamotive Energy Systems. "Fast Pyrolysis". Copyright 2009©http://www.dynamotive.com/technology/fast_pyrolysis/

[10] U.S. Department of Energy, Energy Efficiency and Renewable Energy. "Energy Savers: Methane (Biogas) from Anaerobic Digesters". December 30, 2008. <http://www.energysavers.gov/your_workplace/farms_ranches/index.cfm/mytopic=30003>

[11] U.S. Environmental Protection Agency. "Air Pollution Control Fact Sheet". EPA-452/F-03-031. http://www.epa.gov/ttn/catc/dir1/fsncr.pdf

[12] U.S. Department of Energy. Energy Efficiency and Renewable Energy. "Biomass Program: Syngas Clean-up and Conditioning". http://www1.eere.energy.gov/biomass/pdfs/syngas_cleanup.pdf

## Cross-Cutting Issues

Advancing biopower technologies requires research and development in a number of areas, including enhanced basic and applied research, technologies for collection and conversion of biomass, identification of biomass resources, cost analyses for the available biomass, and commercialization of emerging methods and technologies. Significant research breakthroughs are needed in a number of key areas including advances in plant science to improve the cost-effectiveness of converting biomass to fuel, power, and products. Some of biggest challenges remain in the areas of feedstock handling, densification and residue collection, where current inefficiencies make this resource costly to harvest. Furthermore, RD&D using Geographical Information Systems (GIS) will help the U.S. more accurately identify biomass availability, especially forest biomass.

Pellet fuel biomass systems utilize biomass by-products or small diameter, low-value trees, and process them into pencil-sized pellets that are uniform in size, shape, moisture content, density and energy content. The moisture content of biomass pellets is substantially lower (4 to 8 percent water) than raw biomass (30 to 60 percent water). Less moisture means higher BTU value and easier handling, especially in freezing situations, than with green raw biomass materials. The density of pellet fuel is substantially higher than raw biomass: 40-45 lbs. per cubic foot vs. 15-30 lbs. per cubic foot in raw material form. This means that more fuel can be transported in a given truck space and more energy can be stored on site. Biomass pellets are more easily and predictably handled as well. Their uniform shape and size allows for a smaller and simpler feed system that reduces costs. This high density and uniform shape can be stored in standard silos, transported in rail cars and delivered in truck containers. Pellet fuel is made up of refined and densified biomass that allows for remarkable consistency and burn efficiency at a fraction of the particulate emissions of raw biomass. While, this is clearly a great improvement over raw biomass, the production of biomass pellets costs more. Research on mobile pelletizers has been discussed as a way to reduce the cost of transporting biomass, but little has been done to explore the actual technology and the difficulty of drying the feedstock on site.

## Additional RD&D Support for Biopower

The National Science Foundation (NSF) initiated efforts in bioenergy and subsequently transferred those efforts to DOE in the late 1970s. Biofuels and biomass energy systems were the focus of most early projects. In 1991, the DOE created the Biopower Program with the stated goal of contributing 600 gigawatts of new electricity generating capacity globally within 10 years. According to the IEA in 2007 the global biomass electric generating capacity was approximately 47 GW. In 2002, the Biomass Program was formed to consolidate the biofuels, bioproducts, and biopower research efforts across DOE into one comprehensive RD&D effort. From the 1970s to the present, approximately $3.5 billion (including $800 million in ARRA funds) has been invested in a variety of RD&D programs covering biofuels (particularly ethanol), biopower, feedstocks, municipal wastes, and a variety of biobased products, including forest products and agricultural processing industries. A reinvigorated Biopower Program at DOE could help close the more than 500 gigawatt gap between the stated goal of the original Biopower Program and the actual global biomass electricity generation.