BIOMASS FOR THERMAL ENERGY AND ELECTRICITY: A RESEARCH AND DEVELOPMENT PORTFOLIO FOR THE FUTURE

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

OCTOBER 21, 2009

Serial No. 111–56

Printed for the use of the Committee on Science and Technology

Available via the World Wide Web: http://www.science.house.gov

U.S. GOVERNMENT PRINTING OFFICE

52–860PDF WASHINGTON : 2010

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
Fax: (202) 512–2104 Mail: Stop IDCC, Washington, DC 20402–0001

COMMITTEE ON SCIENCE AND TECHNOLOGY

HON. BART GORDON, Tennessee, *Chair*

JERRY F. COSTELLO, Illinois
EDDIE BERNICE JOHNSON, Texas
LYNN C. WOOLSEY, California
DAVID WU, Oregon
BRIAN BAIRD, Washington
BRAD MILLER, North Carolina
DANIEL LIPINSKI, Illinois
GABRIELLE GIFFORDS, Arizona
DONNA F. EDWARDS, Maryland
MARCIA L. FUDGE, Ohio
BEN R. LUJÁN, New Mexico
PAUL D. TONKO, New York
PARKER GRIFFITH, Alabama
STEVEN R. ROTHMAN, New Jersey
JIM MATHESON, Utah
LINCOLN DAVIS, Tennessee
BEN CHANDLER, Kentucky
RUSS CARNAHAN, Missouri
BARON P. HILL, Indiana
HARRY E. MITCHELL, Arizona
CHARLES A. WILSON, Ohio
KATHLEEN DAHLKEMPER, Pennsylvania
ALAN GRAYSON, Florida
SUZANNE M. KOSMAS, Florida
GARY C. PETERS, Michigan
VACANCY

RALPH M. HALL, Texas
F. JAMES SENSENBRENNER JR., Wisconsin
LAMAR S. SMITH, Texas
DANA ROHRABACHER, California
ROSCOE G. BARTLETT, Maryland
VERNON J. EHLERS, Michigan
FRANK D. LUCAS, Oklahoma
JUDY BIGGERT, Illinois
W. TODD AKIN, Missouri
RANDY NEUGEBAUER, Texas
BOB INGLIS, South Carolina
MICHAEL T. MCCAUL, Texas
MARIO DIAZ-BALART, Florida
BRIAN P. BILBRAY, California
ADRIAN SMITH, Nebraska
PAUL C. BROUN, Georgia
PETE OLSON, Texas

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

HON. BRIAN BAIRD, Washington, *Chair*

JERRY F. COSTELLO, Illinois
EDDIE BERNICE JOHNSON, Texas
LYNN C. WOOLSEY, California
DANIEL LIPINSKI, Illinois
GABRIELLE GIFFORDS, Arizona
DONNA F. EDWARDS, Maryland
BEN R. LUJÁN, New Mexico
PAUL D. TONKO, New York
JIM MATHESON, Utah
LINCOLN DAVIS, Tennessee
BEN CHANDLER, Kentucky
BART GORDON, Tennessee

BOB INGLIS, South Carolina
ROSCOE G. BARTLETT, Maryland
VERNON J. EHLERS, Michigan
JUDY BIGGERT, Illinois
W. TODD AKIN, Missouri
RANDY NEUGEBAUER, Texas
MARIO DIAZ-BALART, Florida
RALPH M. HALL, Texas

CHRIS KING *Democratic Staff Director*
SHIMERE WILLIAMS *Democratic Professional Staff Member*
ELAINE PAULIONIS PHELEN *Democratic Professional Staff Member*
ADAM ROSENBERG *Democratic Professional Staff Member*
JETTA WONG *Democratic Professional Staff Member*
ELIZABETH CHAPEL *Republican Professional Staff Member*
TARA ROTHSCHILD *Republican Professional Staff Member*
JANE WISE *Research Assistant*

C O N T E N T S

October 21, 2009

Appendix: Answers to Post-Hearing Questions

BIOMASS FOR THERMAL ENERGY AND ELECTRICITY: A RESEARCH AND DEVELOPMENT PORTFOLIO FOR THE FUTURE

WEDNESDAY, OCTOBER 21, 2009

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 2:00 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Brian Baird [Chairman of the Subcommittee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

RALPH M. HALL, TEXAS
RANKING MEMBER

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE AND TECHNOLOGY

SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515–6301
(202) 225–6375
http://science.house.gov

Committee on Science and Technology
Subcommittee on Energy and Environment

Hearing on

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

Witness List

Dr. Don J. Stevens
Senior Program Manager
Pacific Northwest National Laboratory
U.S. Department of Energy

Mr. Joseph J. James
President
Agri-Tech Producers, LLC

Mr. Scott M. Klara
Director
Strategic Center for Coal
National Energy Technology Laboratory
U.S. Department of Energy

Mr. Eric Spomer
President
Catalyst Renewables Corp

Dr. Robert T. Burns
Professor
Agricultural & Biosystems Engineering
Iowa State University

HEARING CHARTER

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE AND TECHNOLOGY
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 bio-based 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

[1] EIA, *Monthly Energy Review,* September 2008.

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 on-site 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]

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 capital 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 50 MW 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]

---

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

[3] Federal Energy Management Program (DOE): Biomass Co-firing 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.

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 five kilowatts to five 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 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 co-generation plant designed to power the University of South Carolina that consists of three 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 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

[5] National Renewable Energy Laboratory: Small Modular Biomass Systems *www.nrel.gov/docs/fy03osti/33257.pdf*

[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*

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

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.

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 (four to eight 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 im-

[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*

provement 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 bio-based 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.

Chairman BAIRD. Our hearing will come to order. I want to welcome everyone to our hearing on Biomass for Thermal Energy and Electricity: A Research and Development Portfolio for the Future.

Before we begin to discuss the topic of today's hearing, I want to particularly recognize some special guests in our subcommittee today. Members of both the Liberian and Haitian Parliaments are here as guests of Representative David Price from North Carolina as part of a week-long seminar on committee operations. I understand there are fellow committee chairs here among our guests, and we are very honored that you are here. It is particularly appropriate we have international governments community with us today as biopower, of course, is very much linked to the global issues of climate change and energy security. Members of Parliament include the Speaker of the House of the Haitian Chamber of Deputies; the President of the Haitian Senate; the Chair of the Haitian Committee on Justice; and the Chair of the Haitian Committee on the Budget. The Chair of the Liberian Committee on Natural Resources, Energy and the Environment is also here with us along with other Members of Parliament and dignitaries.

Excellencies, thank you all for joining us. We welcome you here. We also know that our committee hearings can go somewhat timely. If you have other engagements, we will not take it personally if you have to go to another meeting, but we are very grateful to have your presence here, and we are honored.

Did you wish to offer any comments before we start, Bob?

Mr. INGLIS. Just to also add our welcome on this side. We are very grateful that you are here and hope that it is a good visit and a productive visit.

Chairman BAIRD. Thank you very much. With that, we will proceed with our discussion of today's hearing. We will today examine a number of different technologies utilized to convert biomass feedstocks into biopower, and discuss the federal role in the development of these technologies.

While more widely known as a feedstock for liquid transportation fuels, biomass can also be used to generate heat and electricity, a field otherwise known as biopower.

Biomass includes, of course, any organic matter that is available on a renewable basis, including agricultural crops, wastes and residues, wood and wood wastes and residues, animal wastes, municipal wastes, and aquatic organisms. But of course, if these things are used for energy, they are not waste after all, are they? They are raw materials from which we can generate power.

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 are significant quantities of these renewable resources.

For example, a 2005 report published by the Washington State Department of Ecology and Washington State University found that our state, my own, has the potential for annual production of over 1,769 megawatts of electrical power from biomass. This is roughly 50 percent of Washington State's annual residential electrical consumption.

Furthermore, in my home district we have abundant amounts of forest biomass. When this resource is harvested in conjunction with a sustainable forest management plan, important restoration goals can be achieved, such as wildfire mitigation, watershed protection, wildlife habitat restoration and reduced insect infestation, and we can generate valuable power as a result as well and reduce our CO_2 output.

To realize these benefits, new research needs to be funded. Enhanced basic and applied research and commercialization of a diversity of conversion technologies needs to be advanced.

In 2002 the Bush Administration consolidated liquid transportation fuels, bioproducts and biopower research efforts across DOE into the Biomass Program, and since then the large majority of the research has focused on liquid transportation fuels, primarily ethanol.

However, given the decreasing availability of fossil fuel resources and simultaneous increases in demand, along with concerns over lethal overheating of the Earth and ocean acidification, a responsible 21st century energy policy will include a renewed commitment to biopower technologies.

While the development of liquid transportation fuels from biomass is a critical research area, I am interested in hearing from our witnesses about increasing biopower research efforts in the federal research portfolio and the steps we need to overcome barriers to new biopower technologies.

My apologies to the translator with our guests. I speak awfully fast. Good luck.

With that I would like to thank this excellent panel of witnesses for appearing before the Subcommittee this afternoon.

I yield to our distinguished Ranking Member, Mr. Inglis, for his opening statement.

[The prepared statement of Chairman Baird follows:]

PREPARED STATEMENT OF CHAIRMAN BRIAN BAIRD

In today's hearing we will examine a number of different technologies utilized to convert biomass feedstocks into biopower, and discuss the federal role in the development of these technologies.

While more widely known as a feedstock for liquid transportation fuels, biomass can also be used to generate heat and electricity—a field otherwise known as "Biopower."

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 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 are significant quantities of these renewable resources.

For example, a 2005 report published by the Washington State Department of Ecology and Washington State University found that my state has the potential for annual production of over 1,769 MW of electrical power from biomass. This equates to roughly 50 percent of Washington State's annual residential electrical consumption.

Furthermore, in my district we have abundant amounts of forest biomass. When this resource is harvested in conjunction with a sustainable forest management plan important restoration goals can be achieved, such as wildfire mitigation, watershed protection, wildlife habitat restoration and reduced insect infestation.

To realize these benefits new research needs to be funded. Enhanced basic and applied research and commercialization of a diversity of conversion technologies needs to be advanced.

In 2002 the Bush Administration consolidated liquid transportation fuels, bioproducts, and biopower research efforts across DOE into the Biomass Program, and since then the large majority of the research has focused on liquid transportation fuels, mostly ethanol.

However, given the decreasing availability of fossil fuel resources and simultaneous increases in demand, along with concerns over lethal overheating of the Earth and ocean acidification, a responsible 21st century energy portfolio will include a renewed commitment to biopower technologies.

While the development of liquid transportation fuels from biomass is a critical research area, I am interested in hearing from our witnesses about increasing biopower research efforts in the federal research portfolio, and the steps we need to take to overcome barriers to new biopower technologies.

With that I'd like to thank this excellent panel of witnesses for appearing before the Subcommittee this afternoon, and I yield to our distinguished Ranking Member, Mr. Inglis.

Mr. INGLIS. Thank you, Mr. Chairman, and thank you for holding this hearing today. For the last 10 years or so we have primarily been looking toward biomass as a replacement for petroleum-based transportation fuels. The result has been a substantial interest in converting food crops to fuel with small emphasis being placed on developing cellulosic ethanol.

Environmental and cost concerns are cultivating interest in other types of biomasses of fuel for base load electricity and thermal power.

Some biomass can be and is already being used in conventional generation technology. Paper mills generate power from milling waste, and woody biomass can be mixed with coal in co-fired in modern and large-scale power plants.

More research and technological innovation can expand the reach of renewable biomass fuels in our energy sector.

The subject of today's hearing represents a step in that direction. Developments in renewable natural gas, biorefineries, biomass transportation, and other technologies will help increase the efficiency of biomass energy, and a diversity of organic materials can be used for energy generation.

I am looking forward to hearing about the state of the industry today and where we should direct federal research and development resources to overcome remaining technological hurdles.

I also want to admit to a parochial interest in biopower. Two South Carolina universities, including Furman in the upstate and USC, have launched already bioenergy pilot projects. Our robust forest industry stands to gain jobs and a larger market. As we will hear from Mr. James, biomass energy is already creating jobs back home.

Thank you, Mr. Chairman, for holding this hearing. I look forward to hearing from the witnesses and yield back the balance of my time.

[The prepared statement of Mr. Inglis follows:]

PREPARED STATEMENT OF REPRESENTATIVE BOB INGLIS

Good morning and thank you for holding this hearing, Mr. Chairman.

For about the past 10 years, we've primarily been looking toward biomass as a replacement for petroleum-based transportation fuels. The result has been a substantial interest in converting food crops to fuel, with a smaller emphasis placed on developing cellulosic ethanol.

Environmental and cost concerns are cultivating interest in other types of biomass as a fuel for base load electricity and thermal power. Some biomass can be and is already being used in conventional generation technology; paper mills generate power from milling waste, and woody biomass can be mixed with coal and co-fired in modern, large-scale power plants. More research and technological innovation can expand the reach of renewable biomass fuels in our energy sector.

The subject of today's hearing represents a step in that direction. Developments in renewable natural gas, bio-refineries, biomass transportation, and other technologies will help increase the efficiency of biomass energy and the diversity of organic materials that can be used for energy generation. I'm looking forward to hearing about the state of the industry today and where we should direct federal R&D resources to overcome remaining technological hurdles.

I also want to admit a parochial interest in biopower. Two South Carolina universities, including Furman in the Upstate, have launched already bio-energy pilot projects, our robust forestry industry stands to gain jobs and a larger market, and as we'll hear from Mr. James, biomass energy is already creating jobs back home.

Thank you again, Mr. Chairman, for holding this hearing. I look forward to hearing from the witnesses and I yield back the balance of my time.

Chairman BAIRD. If there are other Members who wish to submit additional opening statements, your statements will be added to the record at this point.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good afternoon. Thank you, Mr. Chairman, for holding today's hearing to receive testimony on the research and development (R&D) of new technology to improve the use of biomass for thermal energy and electricity.

Biomass is unique among renewable energy sources because of its abundant supply and long history as a source of energy. Nearly every state in the U.S. has a source of biomass fuel through agricultural waste, wood and wood waste products, or animal and municipal waste. Further, individuals and industries have used biomass as an energy source for centuries. These characteristics make biomass an effective and efficient source of renewable energy available in the U.S. today. However, additional R&D is necessary to modernize existing techniques for using traditional forms of biomass, such as wood, and to develop ways to use new forms, like municipal waste.

In particular, I am interested to learn how biomass can be used in conjunction with abundant and inexpensive domestic energy sources such as coal. Co-firing coal and biomass fuel has proven to be an efficient means of producing abundant energy while reducing greenhouse gas emissions. Illinois has an abundant coal and agricultural products, and co-firing could provide a cost-effective way to produce clean energy while extending the supply of coal. I would like to hear from our witnesses, especially Mr. Klara of the Strategic Center for Coal, how the existing technology for co-firing coal and biomass can be improved and utilized to demonstrate its widespread use.

Finally, I would like to hear from our witness how Congress and the public and private sector can work together to support biomass R&D.

I welcome our panel of witnesses, and I look forward to their testimony. Thank you again, Mr. Chairman.

Chairman BAIRD. At this point, it is my pleasure to introduce our witnesses at this time. Dr. Don J. Stevens is a Senior Program Manager at Pacific Northwest National Laboratory, PNNL. Mr. Scott M. Klara is the Director of the Strategic Center for Coal at DOE's National Energy Technology Laboratory. Mr. Eric Spomer is the President of Catalyst Renewables Corporation. Dr. Robert Burns is a Professor of Agricultural and Biosystems Engineering at Iowa State University, and I will again yield to my friend and Ranking Member, Mr. Inglis, to introduce our last witness.

Mr. INGLIS. Thank you, Mr. Chairman, for the opportunity to introduce Mr. Joseph James who is a terrific example of alternative energy industry that is creating new jobs in South Carolina. Mr. James has over 35 years of experience in economic development devoted to achieving equity for disadvantaged people in communities. Since 2004 his career has taken on a new focus aiming to create jobs and revitalize rural African-American communities in South Carolina through opportunities in the emerging biomass and bioenergy fields. In recognition of his pioneering work, he was awarded the 2008 Purpose Prize. He also is a bioenergy entrepreneur. He is the founding member and Vice President of the Board of South Carolina Biomass Council and a member of the Southeast Agricultural Forest Energy Resources Alliance. He is the President of Agri-Tech Producers which is developing and commercializing biomass technology in South Carolina through partnerships with North Carolina State University and Kusters Zima Corporation in Spartanburg.

Looking forward to hearing from him about this innovative torrefaction technology that Agri-Tech Producers is bringing to the market, and we thank him for being here.

Chairman BAIRD. Thank you, Mr. Inglis. It is obvious we not only have professional interests as Members, Chair and Ranking Member of this Committee, we have personal interest as we represent districts with great potential. Our colleague, Dr. Bartlett, as you may discover when he offers his questions, is one of the real leaders in walking the talk of renewable energy. He has probably the lowest carbon footprint of any Member of Congress in his residence, and I admire that greatly. So he brings great expertise.

With that, we will begin. As the witnesses know, we have five minutes for a testimony followed by questions from the panel, and we invite you to begin. We will begin now with Dr. Stevens. Thanks again to all of you for your presence.

STATEMENT OF DR. DON J. STEVENS, SENIOR PROGRAM MANAGER, BIOMASS ENERGY & ENVIRONMENT DIRECTORATE, PACIFIC NORTHWEST NATIONAL LABORATORY, U.S. DEPARTMENT OF ENERGY

Dr. STEVENS. Thank you very much, Mr. Chairman, and the Members of the Committee. I very much appreciate this opportunity to be here today at a time when our nation is moving forward with a sense of purpose and urgency toward a more sustainable energy future, and biomass is certainly part of that future.

As a nation, we have approximately 1.3 billion tons potentially available on an annual basis for a variety of energy purposes. As you indicated, those resources come from woody biomass, from agricultural residues, from dedicated energy crops, and others, all of which vary significantly on a regional basis. We can use that for a variety of purposes, biofuels, or for the topic of today, biopower.

Several technology options exist to convert biomass to biopower including direct combustion, gasification, and pyrolysis, which I am talking about today.

So what is pyrolysis and why is it important? Well, biomass pyrolysis is simply the process of heating biomass in the absence of air to produce a combination of liquids, solids and gaseous products, and we can control the relative amounts of those by selecting the process conditions accordingly.

Today I will focus on so-called "fast pyrolysis" which produces a liquid product referred to as "bio-oil." That bio-oil has several important characteristics that are beneficial for power generation. Most importantly, the bio-oil can be used in high-efficiency electric generation systems, systems that can't directly use solid biomass. With stabilization and upgrading, the bio-oil can be used in industrial turbines, combined cycle systems, or potentially solid oxide fuel cells. These have electric generation efficiencies of 30 to 40 or more percent compared to a simple wood-fired boiler system with efficiencies of 15 to 25 percent. And since we have a finite amount of biomass in our nation, it is important to use that efficiently to meet our national energy needs.

Both nationally and internationally at present, there is significant interest in using pyrolysis. Technologies to produce bio-oil are in the near-commercial stage of development, and there are several large-scale development units with capacities ranging from about five to about 200 tons per day in operation to produce bio-oil on a demonstration basis. However, at present, no fully integrated commercial bio-oil to energy facilities exist.

The primary technical barrier at this time is the need for stabilization and upgrading. Stabilization is necessary so the bio-oil can be stored and used for periods of several months, and additional upgrading is needed to meet equipment specifications for high-technology conversion systems. The upgrading, among other things, chemically neutralizes the bio-oil and removes mineral salts.

There are quite a few national and international research programs currently focused on removing these technical barriers for the utilization of biomass. Pacific Northwest National Lab, for example, is working with many partners, including industry, Department of Energy, USDA, and other national labs and universities to improve bio-oil stabilization and upgrading. And we are also looking at the use of catalysts to improve the initial quality of the bio-oil as it is formed to reduce the need for downstream stabilization and upgrading.

In addition, we are working in collaboration with a range of international groups to understand just how much stabilization and upgrading is needed for various applications for bio-oil. PNNL leads the International Energy Agency's Pyrolysis Task, and we are also working with groups in Canada, Finland and Asia on other pyrolysis issues.

As a result of this work, we are making significant progress in overcoming the technical barriers for using bio-oil.

In summary, I would like to conclude by noting that pyrolysis offers flexible options to meet our national and regional energy needs. The bio-oil gives us the opportunity to more efficiently produce the electricity, and national and international programs are assisting industry by resolving the existing technical barriers.

Thank you.

[The prepared statement of Dr. Stevens follows:]

PREPARED STATEMENT OF DON J. STEVENS

Introduction

Chairman Baird and distinguished Members of this subcommittee, thank you for providing me an opportunity to testify today regarding biomass pyrolysis and its potential for contributing to our nation's energy needs.

My name is Don Stevens, and I am a Senior Program Manager in the Energy & Environment Directorate at Pacific Northwest National Laboratory (PNNL). In this role I am responsible for developing PNNL's technical approach to sustainable production of biopower and biofuels. I have over 30 years of research and development experience in the area of biomass power and fuels, and much of that work has focused on the use of pyrolysis and gasification. During this time, I have worked with the U.S. Department of Energy's Office of the Biomass Program as well as a variety of other U.S. and international clients, including the International Energy Agency's Implementing Agreement on Bioenergy.

Today I will provide information on biomass pyrolysis and its potential for contributing to our national needs for sustainable energy. I will:

- explain why biomass pyrolysis offers potential advantages for producing both biopower and "drop-in" biofuels from biomass
- address the current state of development for the technology
- describe technical barriers that, if overcome, could speed technology deployment
- describe national and international research efforts that are addressing these technical barriers.

The Importance of Biomass Pyrolysis

Over the past three or four years, biomass pyrolysis has attracted increasing attention as a technology with the potential to more effectively utilize biomass resources. Pyrolysis provides a flexible pathway to convert solid biomass to a liquid intermediate. Following stabilization and upgrading, the resulting product can be used to fuel higher-efficiency electric power generation technologies such as gas turbines or integrated combined cycle systems. With additional upgrading, the bio-oil can potentially be used in highly efficient fuel cells or can be refined to liquid transportation fuels. *Biomass pyrolysis thus provides a continuum of options for efficiently producing electricity or fuels to meet a variety of our national needs.*

The production of bio-oil as an intermediate has several potential benefits. Liquid intermediates have higher bulk energy densities than the solid biomass and can be transported at lower cost. Liquid intermediates are more readily fed into advanced biomass conversion technologies than solids, and they are more readily fed, with other fuels, into to co-firing facilities. The liquid intermediates are particularly important because they are compatible with advanced conversion technologies such as industrial turbines, which more efficiently utilize our biomass resources. These high-efficiency systems are a priority because they can achieve the highest impact from our limited biomass resources. Biomass is also the only source of renewable liquid fuels to displace petroleum, and the bio-oil liquid intermediate is a promising opportunity for producing renewable "drop-in" gasoline and diesel transportation fuels.

The impact of using pyrolysis to increase utilization efficiency is shown in Figure 1. The raw bio-oil, as produced, can be combusted in conventional steam boilers with current biomass-to-electricity generation efficiencies typically ranging from about 15 percent to 25 percent depending on scale and other factors. Following moderate stabilization and upgrading, the bio-oil can potentially be combusted in industrial turbines which have electrical efficiencies of about 30 percent, or in combined cycle gas/steam turbines that have efficiencies of 35 percent or more. Additional stabilization and upgrading would potentially permit the pyrolysis product to be used in advanced solid oxide fuel cells with electric generation efficiencies of 40 percent or more. These ranges are approximate. The same type of upgrading needed for fuel cell use would also be relevant to producing liquid transportation fuels. This range of opportunities provides flexibility in meeting national and regional energy needs.

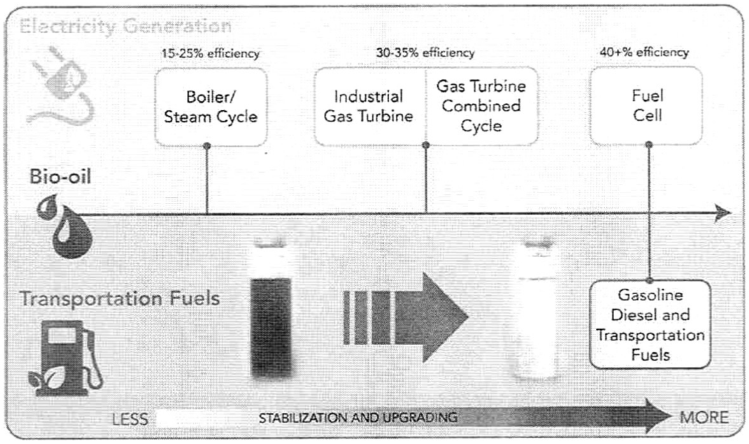


Figure 1. Pyrolysis provides a pathway to higher efficiency utilization of biomass.

Overview of Pyrolysis and Bio-oil

Biomass consists of a complex arrangement of natural, oxygen-containing polymers, including cellulose, hemicelluloses, and lignin, which have fairly low energy density. A challenge exists in converting these constituents into a state that can be shipped inexpensively to large-scale central processing facilities and used efficiently in high technology conversion systems. Pyrolysis, which is defined as the heating of biomass in the absence of air, is one option for converting biomass to a liquid intermediate. Pyrolysis processes generate a liquid bio-oil along with gas and solid (biochar) by-products, and the relative portions of each can be controlled by the processing conditions. While pyrolysis has been used historically to produce charcoal, most current efforts are focused on advanced processes that maximize the yield of bio-oil.

Fast Pyrolysis

At present, fast pyrolysis is the most developed pyrolysis technology for producing liquid bio-oil. In fast pyrolysis, the biomass is reacted at moderately high temperatures (450–550 °C), for very short times (less than one second). This produces bio-oil with physical properties superficially similar to #4 fuel oil, but different chemically. The bio-oil is less stable and more acidic than petroleum oil, and also may contain small percentages of inorganic mineral salts from the biomass. These characteristics make the raw product unsuitable for longer-term storage, for use in higher-efficiency electric generation systems, or for use as a liquid transportation fuel. However, the oil can be stabilized and upgraded using processes such as hydrotreating to produce stable fuels for advanced technologies such as industrial gas turbines for power generation. Depending on the extent of upgrading, the refined bio-oil can also potentially be used in advanced fuel cells or even gasoline- and diesel-range hydrocarbons for transportation fuels. The overall process is depicted in Figure 2.

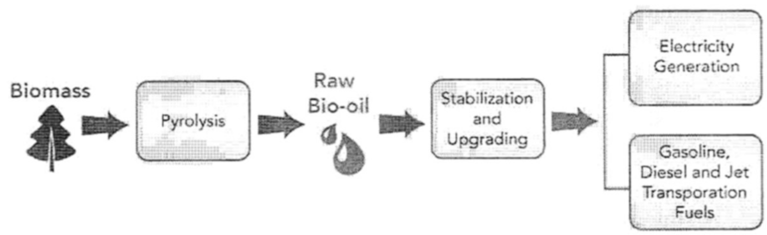


Figure 2. Biomass Pyrolysis Pathway

Distributed Pyrolysis and Refining

Pyrolysis technology provides a means by which biomass can be collected and initially converted near its source. Fast pyrolysis units can be located near biomass resources where the biomass would be converted to the higher energy density bio-oil. The resulting bio-oil can be collected from multiple facilities and transported to larger-scale central facilities for stabilization or end-use (Figure 3), taking into account economies of scale to help reduce costs. This provides an effective way to decouple the biomass resource from the eventual conversion and potentially can reduce the costs of collecting and transporting biomass.

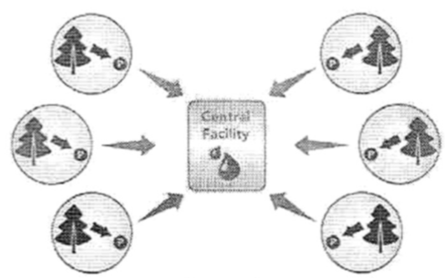


Figure 3. Distributed Pyrolysis

Related Pyrolysis Technologies

In addition to fast pyrolysis, other pyrolysis technologies of value exist. Hydrothermal liquefaction has also been examined to convert feedstocks such as wet biomass to bio-oil. This technique liquefies wet biomass streams at temperatures of about 350 °C and high pressures (200 atm) to produce a bio-oil with less oxygen than fast pyrolysis. This approach could be useful in cases where the biomass resource has high moisture content, such as the residual biomass from algae production.

Pyrolysis is also used to produce solids. The oil yield from biomass decreases while the solid (biochar) content increases to about a 30 percent yield. The biochar is being examined as a method to remove atmospheric carbon (via plant growth) for storage in soil. As a soil amendment, biochar not only acts as a carbon pool, but it has been shown to reduce fertilizer requirements while enhancing crop yields and reducing phosphorous and nitrogen chemical runoff in some soils in certain geographical regions.[1]

Summary of the Current Biomass Pyrolysis Industry

Presently, the use of fast pyrolysis to produce liquid bio-oil intermediates for energy uses is at the near-commercial stage. Smaller-scale fast pyrolysis technologies

[1] J. Lehmann and S. Joseph. 2009. “Biochar for environmental management: An introduction.” Chpt. 1 in J. Lehmann and S. Joseph (eds.) *Biochar for Environmental Management: Science and Technology.* Earthscan Publishers, London, UK.

are used by companies in the United States, Europe, and elsewhere to produce "liquid smoke," which is processed into a food flavoring and additive. Larger-scale fast pyrolysis demonstration facilities are being built or operated in the United States, Canada, Europe, and Asia with companies such as Ensyn, Dynamotive, BTG, Renewable Oil International, and others. These demonstration units have capacities ranging from about five to 200 tons/day of biomass feed, and they will produce bio-oil that could potentially be used in energy applications. At present, there are no integrated, fully commercial facilities where the bio-oil is converted to either electricity or transportation fuels.

Conventional, slow-pyrolysis continues to be used to produce commercial charcoal for cooking and industrial purposes throughout the world. The efficiency of these processes varies widely depending on the type of process used. The charcoal is frequently sold as "lump" charcoal or briquetted to provide consistency in the product. Commercial charcoal may also contain carbon from other sources such as coal or residual petroleum.

Biochar is produced using the same slow pyrolysis technologies as those for charcoal, but additives common to commercial charcoal are omitted. Several smaller companies have recently been established to produce biochar using slow pyrolysis technologies, but at present there is an uncertain market for the product. The value of biochar, to the producer or the user, has yet to be quantified.

Technology Barriers

Although the capability to produce pyrolysis bio-oils exists, there are currently no integrated, pyrolysis-based facilities commercially producing either electricity or transportation fuel, as noted previously. Technical barriers impede the deployment of these technologies.

Stabilization and Upgrading:

The primary technical barrier for biomass pyrolysis is related to the characteristics of the bio-oil. At a molecular level, the raw bio-oil contains 30–35 percent oxygen by weight, with that oxygen coming from the biomass feedstock. The crude product is less stable than petroleum and will begin to change at room temperature over a period of several weeks or months, or more rapidly upon heating to even moderate temperatures. The product slowly becomes more viscous, and may separate into multiple phases. The oxygen content makes the raw bio-oil mildly acidic, and that can potentially lead to corrosion of tanks used for transportation and storage. The bio-oil also may contain small quantities of inorganic mineral salts that were part of the original biomass. When the bio-oil is subsequently burned, the salts can volatilize and then condense on cooler locations downstream, potentially creating deposits that reduce system performance or can cause significant damage in systems such as gas turbines with high rotation speeds.

Effective, low-cost stabilization and upgrading of the bio-oil is needed to help biomass pyrolysis more rapidly enter the market. Stabilization and upgrading processes improve the quality of the oil by removing oxygen, reducing the acidity, and removing mineral salts from the intermediate.

The extent of upgrading required will depend on the end-use for the bio-oil. In electric generation systems, raw bio-oil can potentially be used in simple boiler/steam systems, but stabilization is needed to ensure the bio-oil can be stored for reasonable periods of time at a variety of different temperatures. Additional upgrading is needed for more advanced conversion technologies, such as advanced boiler systems, industrial gas turbines, or combined cycle systems. The upgrading would reduce the acidity of the bio-oil and remove mineral content to be fully compatible with these advanced systems. The advanced systems provide higher electric generation efficiencies that better utilize the biomass resource. As is found with refining petroleum, additional upgrading would be required to provide a fuel for advanced fuel cells or for transportation fuels. The upgrading would remove small amounts of sulfur from the product and further reduce its oxygen content. Similarly, the more extensive upgrading is also needed to produce "drop-in" gasoline, diesel, and jet fuels for transportation fuels. The need for stabilization and upgrading can be viewed as a continuum where stabilization is desirable for even the simplest conversion technology, and additional upgrading is required to produce a fuel that can be used in advanced technologies, either for electric generation or for transportation fuels.

Improving the Bio-oil Quality:

The need for stabilization and upgrading of the bio-oil could potentially be reduced if a higher quality bio-oil could be produced. Current fast pyrolysis systems have been optimized to produce high liquid yields, and there is limited ability to change the properties of the bio-oil. Modified systems, such as those using catalysts during the pyrolysis process, could produce bio-oil that would also require less upgrading. The catalysts would enhance the rate of chemical reactions that remove oxygen from the biomass, thus providing an intermediate with lower oxygen content. Other processing techniques can also potentially be applied to bio-oil improvement. Improvement of the original bio-oil quality is needed for either electricity generation or for producing transportation fuels.

Expanding Bio-oil Standards:

For bio-oil to enter the marketplace, standards are needed to define its characteristics and qualities. Working within the International Energy Agency's Bioenergy Agreement, PNNL recently helped establish the first standard for use of bio-oil as a burner fuel, ASTM Standard D–7544–09. This standard provides definition of the qualities the intermediate must have for use in boilers. Additional standards are needed to quantify the qualities necessary for higher efficiency uses of the bio-oil.

Improving Utilization of Byproducts:

Pyrolysis creates a combination of liquid, gaseous, and solid (char) products. The liquid will primarily be used for energy purposes, but it also contains precursors to higher-value chemicals. Better extraction and utilization of these precursors for chemical products can potentially increase the economic rate of return for the pyrolysis-based conversion facility (biorefinery). The bio-oil is a complex mixture of many individual components, and there is a need to better characterize the intermediate and better understand the processing involved in generating chemical byproducts.

In addition to liquids, pyrolysis also produces solid char. The term *biochar* has been applied to the use of that material as a soil amendment. The impact of biochar is only partially understood at this time. While biochar can produce significant yield improvements in some soils, it has very little effect on others. This arises both from the variability of soils as well as the variability of biochar produced by different pyrolysis approaches. Improved understanding of the characteristics of the biochar and how those influence plant growth are needed. That information will provide a better quantification of the value of biochar to the farmer. In addition, work is needed to understand the sustainability impacts of biochar. For example, it is not presently clear whether there would be greater carbon savings to pyrolyze biomass and put biochar in the ground, or to alternatively convert that same biomass to liquid transportation fuels, thus displacing petroleum fuel emissions. Additional information on the total "value" of biochar is needed before effective markets can be established.

Industry Acceptance of Bio-oil:

Bio-oil is a relatively new product, and the industries which might use it effectively are not familiar with bio-oil. Changing fuel presents both a market risk and a market opportunity. Programs to reduce the technical and financial risk of using bio-oil may be helpful to assist with deployment.

The implementation of biomass pyrolysis also will depend on the complex match between regional feedstock resources, their availability, and the corresponding regional needs for fuels, power, and products, including chemicals and biochar. Analyses such as life cycle studies, technoeconomic projections, and related work will assist industry in making educated decisions on the most effective use of biomass on both a regional and a national basis.

Current Research

Overview of National and International Research:

Biomass research is being conducted by many groups, both in the United States and in other countries.

In the United States, research has been focused primarily on the production of liquid transportation fuels that will be "drop-in" hydrocarbon replacements for gasoline, diesel, and jet fuels. As such, these are compatible with the existing fuel supply, distribution, and utilization infrastructure. Research on pyrolysis-derived biofuels has focused on the major barriers of stabilization and upgrading the bio-oil intermediate. The research in this area has included a range of thermal and catalytic techniques to convert biomass to refinery feedstock that can be finished to transportation fuels. This research has been funded primarily by the U.S. Department of Energy with additional efforts funded by the U.S. Department of Agriculture. The stabilization and upgrading research is directly relevant for producing bio-oil intermediates used in high-efficiency electric generation systems. While the amount of upgrading needed for electric power generation will be less than that needed for hydrocarbon fuels, the same types of processing techniques are likely to be used in both.

In other countries including Canada, Finland, Germany, the United Kingdom, the Netherlands, Australia, and others, researchers are examining the use of pyrolysis bio-oil both for transportation fuel and electricity generation. There is international recognition of the flexibility of pyrolysis to meet a variety of fuel and electricity needs. The interest in producing electricity is particularly strong in countries such as Finland where renewable portfolio mandates provide very significant cost incentives to produce biopower. By comparison, incentives of that magnitude do not exist in the United States. In some countries, biopower is seen as the earliest use of bio-oil, with transportation fuels being viewed as an attractive alternative as the upgrading technology advances.

International cooperation in the area of biomass pyrolysis is fostered by the International Energy Agency's Bioenergy Agreement through their Task 34, Biomass Pyrolysis. This Agreement promotes information exchange, exchange of researchers, and production of original scientific reports. The interests of this group are based on the priorities of the participating countries and include pyrolysis for both biofuels and biopower. The International Energy Agency's Bioenergy Pyrolysis Task has been renewed for a three-year period starting January 2010 through the end of 2012. Douglas C. Elliott, an international expert on biomass pyrolysis at PNNL, leads this Task.

PNNL's Research in Pyrolysis:

PNNL is conducting research in each of the technical barrier areas described above. A primary area of research at PNNL focuses on stabilizing and upgrading bio-oil. Through the Laboratory's Department of Energy-funded program, PNNL teams with key partners, including other national laboratories and industry partners such as Ensyn, a pyrolysis oil company, UOP, a major petroleum refinery technology provider, and others to examine upgrading to produce transportation fuels. PNNL also has privately funded efforts exploring technology development for use with biomass feedstocks unique to Asia.

PNNL is also working in two international collaborations, one with Canada and one with Finland, to examine the extent of stabilization and upgrading needed for utilization of bio-oil for either electric generation or biofuel applications. This work is examining the characteristics of bio-oils produced from a range of biomass feedstocks, including beetle-killed pine, with the intent of matching those with end-use requirements. The work leverages DOE's funding with equivalent amounts from Canada and Finland to organizations such as Finland's VTT Laboratory, Natural Resources Canada (Canmet) laboratory, and the University of British Columbia.

PNNL also conducts research on ways to improve the quality of bio-oil to reduce the need for stabilization and upgrading. Catalytic processing during the initial pyrolysis step is being used to remove more oxygen from the bio-oil. This work, funded by the DOE Office of the Biomass Program is relevant to production of bio-oil for either biopower or biofuel use.

Research to assist in the establishment of bio-oil standards is being conducted at PNNL in association with the efforts of the International Energy Agency's Pyrolysis Task. As noted previously, PNNL leads this Task and helped establish the first ASTM standard for bio-oil quality for boiler use in 2009. Additional work to establish standards for bio-oil use in more efficient applications is ongoing. The International Energy Agency Task also is coordinating research on higher-value chemical products that can potentially be produced from biomass pyrolysis in so-called biorefineries.

Researchers at PNNL also are examining the use of biochar as a soil amendment as part of their work with DOE's Office of the Biomass Program. In collaboration with the U.S. Department of Agriculture at the Prosser Experimental Station, we are focusing on the characterization of biochar from various biomass sources and correlating those differences with changes in soil productivity.

We are also completing a research Cooperative Research and Development Agreement (CRADA) with Archer Daniels Midland Company (ADM) and ConocoPhillips on hydrothermal liquefaction for producing bio-oil from wet biomass feedstocks. Finally, PNNL is involved in engineering studies aimed at developing technoeconomic models for pyrolysis technologies and evaluating life cycle impacts of pyrolysis versus other fuel production options.

It is important to note that biomass pyrolysis must be accomplished in a sustainable manner that minimizes impacts to our water resources and the environment. PNNL, with part of its DOE funding, is examining the sustainability of biomass thermal conversion processes, including pyrolysis. We are also developing water availability and land-use change models that will help ensure a wide range of technologies, such as biomass pyrolysis that can be done on a sustainable basis.

Summary

In summary, biomass pyrolysis offers a flexible and effective way to create a liquid intermediate that can be used for either transportation fuels or electricity generation. Converting the solid biomass to a liquid both increases the energy density and makes the intermediate easier to feed to conversion systems than solid biomass. These characteristics allow expanded use of biomass.

Stabilization and upgrading of the bio-oil intermediate is important. While some systems can potentially operate with raw bio-oil, stabilization and upgrading greatly expands the opportunities for bio-oil utilization. The upgraded bio-oil can be used in higher efficiency electric generation technologies to achieve higher productivity from our finite biomass resources. In addition, upgrading technologies can be utilized to produce "drop-in" transportation fuels compatible with present infrastructure.

Current research programs internationally are addressing the key barriers to biomass pyrolysis utilization. The Federal Government can further advance these research efforts by funding strong core research programs. While emphasis on implementation is vital, it also is important to invest in our nation's science base, which provides the necessary foundation for developing next-generation technology aimed at addressing key research challenges within the scope of DOE's implementation projects and beyond.

Finally, the Nation needs to conduct analyses such as life cycle assessments, technoeconomic projections, and others to help prioritize what the most important uses of our biomass resources are, both nationally and regionally. With finite amounts of biomass available annually, we need solid technical information on a regional and national basis to decide whether it is better to convert these to electricity, to fuels that reduce imported oil, or to some combination of both. This information will be essential to assist industry in determining how to best use biomass resources as they deploy these technologies.

Thank you for this opportunity to share this information.

BIOGRAPHY FOR DON J. STEVENS

Dr. Stevens is presently a Senior Program Manager in the Energy Directorate of Pacific Northwest National Laboratory. He has over 30 years of RD&D experience in the area of biomass energy systems.

In his current position, he is responsible for developing programs with DOE and industry to convert biomass resources to chemicals, fuels and electricity. PNNL's work in this area focuses on the use of thermal catalysis and biotechnology to create fuels and higher value products from biomass residues. The biofuels help the nation meet its goals of reducing imports of petroleum, and the bio-based products are important in providing economic return in the integrated biorefineries of the future. Dr. Stevens is also involved in programs on biofuels sponsored the International Energy Agency and serves as a Director for the Biomass Energy Research Association.

Over a 30-year period, he has conducted research and performed analysis on a variety of bioenergy systems. Dr. Stevens is the author or co-author of numerous publications and has been an editor of three books on biomass energy. He received his Ph.D. Degree in physical chemistry from University of Utah in 1976 and conducted postdoctoral work on biological membranes at the University of Illinois Champaign-Urbana.

Chairman BAIRD. Thank you. Mr. James.

STATEMENT OF MR. JOSEPH J. JAMES, PRESIDENT, AGRI-TECH PRODUCERS, LLC

Mr. JAMES. Mr. Chairman and distinguished Members of the Subcommittee, thank you very much for the opportunity to appear before you today and discuss some things that Agri-Tech Producers, LLC, is doing. I want to give a special thanks to Congressman Inglis for his interest in our work. It turns out that our manufacturing partner is located in his district, even though our company is not within his district, but we greatly appreciate his interest and his support.

I would like to state a problem. Cellulosic material, wood and agricultural material, is not an easy substance to work with. It is generally about 50 percent moisture, particularly in the case of wood, it is bulky, it is of relatively low energy value, and the economics of getting it from the place of harvest to the place where it is actually going to be used as a fuel or energy sometimes means that we leave a lot of that material, of that one billion that was referred to earlier, remains in place where it might have been growing.

So a solution is required to that problem: A solution that removes as much of the water as possible, that densifies the energy content of the material, that also may change its physical characteristics in such a way that utilities can coal fire it and grind it very easily and mix it with coal as well as other users, and other logistical approaches such as densification or crushing the material into briquettes or pellets will help facilitate its usability.

And of course, there is a challenge in developing the appropriate supply chains to get material from the point of where it has been grown and harvested to the point where it could be used. And I do want to emphasize there is a real need for a focus on solid fuels in addition to liquid fuels, so I appreciate your comments earlier, Mr. Chairman.

About three years ago we got focused on something called torrefaction. Torrefaction is essentially a process. Again, it is a mild form of pyrolysis actually which dries off the water, and in the case of the innovations at North Carolina State University has developed, we are able to capture some of the off-gases and use those as process heat. So the process that we operate uses about 80 percent green fuel, if you will, and very little fossil fuel and outside energy. I won't go into anymore details in that. My written testimony has quite a bit about the process.

But the key thing is that it creates fuels from either wood or from agriculture material that can be used cost effectively. When I say cost effectively, we are talking about producing material that may range in the $80 to $100 a ton range, and they have BTU counts or energy content in the 11,000 BTU range which is very comparable to coal, and the pricing of that is also comparable to coal.

Our company has been very fortunate to have received a variety of federal and state support in our efforts to commercialize this very exciting technology. One of our affiliates years back was fortunate to get a grant from the U.S. Forest Service's Woody Biomass Utilization Program, and our assignment was to work in the national forest in South Carolina and try to create new markets for the biomass that results when the forest does its thinnings to reduce the hazard of fire and also to improve forest health. We have quickly learned what I have just described, that if you are close to the customer, it is easy to take that material and ship it to the customer for their use. If you are more than 30, 40, 50 miles away, it is almost impossible to make the economics work. That is when we went looking for a solution to that problem and discovered the torrefaction process at NC State.

We have also been fortunate to have received funding from the U.S. Forest Service's Wood Education Resource Center, and we are using those resources to help us investigate the differences between torrefying hard woods and torrefying soft woods. As you might guess, different materials have different characteristics, so there is a need for research to fine tune or possibly make different kinds of equipment to handle different kinds of material.

Mr. Chairman, we are very fortunate as well recently to have gotten a grant from the Department of Energy (DOE) under their SBIR/STTR program which is allowing us to look at the feasibility of developing mobile torrefaction units, which would allow us to go from farm to farm or forest—logging deck to logging deck, be able to collect more material from disbursed places and put that into the channel of material that can be used.

I do have some suggestions about some additional federal support that would be helpful to us. One is increasing availability of financing for small companies. We are very fortunate at the moment that we don't need financing to advance our manufacturing of torrefaction equipment. However, as we get into, and spend a little bit of our time on, the processing side, the credit crunch that our country is suffering, particularly for small companies, is creating some challenges that we are going to need some help with.

In addition, we have some very exciting intellectual property (IP). Our intellectual property is much in demand around the world, and we are getting inquiries from China, India, Russia and other places, places which may or may not properly respect IP. We would like to be part of the global solution for renewable energy, but as a small company we are very nervous about sharing our IP in certain places abroad. Any help that the Federal Government, either legislatively or in negotiations, bilateral or otherwise, would be extremely helpful to us as well.

And then lastly, we believe that in addition to industrial-scale activity where hundreds and thousands of tons of material are processed by large, fixed units in large facilities, we think there is tremendous opportunity for forest-reliant communities and rural communities to use our technology on a community scale if you will, to work in their forests, to work with their farmers, improve forest health, but also generate new revenues and new jobs in those communities. DOE and the U.S. Department of Agriculture (USDA) have funded large-scale research, or research into large-scale biomass supply and biomass value train operations. We would suggest that in addition to that, in order for us and others to have impact on rural communities, that we should also be looking at the community scale or microscale as well, and we would be glad to participate in that. In your own state, Mr. Chairman, we have had a number of forest communities contact us looking for ways to add value to the materials that they have available to them. We would love to be able to provide demonstration units to them so that they might accomplish that particular mission.

In summary, we are very excited to be with you today. We think there are some great opportunities to move forward, and we look forward to working with the Committee. Thank you.

[The prepared statement of Mr. James follows:]

PREPARED STATEMENT OF JOSEPH J. JAMES

Mr. Chairman and distinguished Members of the Subcommittee, thank you for this opportunity to appear before you today. I am Joseph J. James, President of Agri-Tech Producers, LLC (ATP), a company, which is commercializing innovative torrefaction technology, developed by NC State University, which cost effectively converts cellulosic biomass, like wood and agricultural materials, into a dry, more energy dense and more usable renewable fuel, which can be co-fired with coal and used for a variety of other renewable energy purposes. Most of our efforts are focused on making world-class torrefaction equipment, but we also plan to be involved in a limited number of biomass processing plants, using our torrefaction technology.

Overview of Testimony:

I would like to discuss why it is important to treat cellulosic biomass, in order to make it a cost-effective source of renewable energy, and why that is important to developing effective biomass supply chains necessary for our nation's clean energy future. I will obviously talk about torrefaction and the important role that technology can play, in addition to the need for densification processes to enhance the logistics of shipping and handling cellulosic biomass. Lastly, I will describe the role our Federal Government has played in helping our company compete in the global market place and what additional measures are necessary for our company's and our nation's success.

The Problem:

There are substantial economic and logistical challenges in shipping woody biomass out of the forested areas or agricultural biomass from farming areas, in a cost-effective manner, to distant end-users. Untreated cellulosic biomass, woody or otherwise, is moist and bulky, which limits its ability to be cost-effectively transported to ultimate users and renders a lot of otherwise available biomass useless.

In addition, many forests go without mechanical treatments to remove overgrown underbrush, which is necessary for fire hazard reduction and forest health, because the resultant biomass is not close enough to markets to generate sufficient offsetting revenues.

Solutions:

Solutions to these economic and logistical problems will require new processes, which can cost-effectively remove much of the moisture found in cellulosic biomass, increasing the energy density of the material, converting it into a substance more easily used by the end-user and making it a more valuable substance, before shipping. Also, it is common practice to use physical densification methods, to pelletize or briquette cellulosic biomass, in order to make it more physically dense, so that more energy per ton can be shipped. For example, toffefied biomass has been shown to make stronger, more energy rich and water resistant pellets and the torrefaction process may eliminate the need for a separate drying system, used by most pellet makers, who incur substantial capital and operating costs for such systems.

The U.S. Department of Energy has funded projects to enhance the effectiveness of biomass supply chains and more planning and research in that area is needed, including, in my opinion, research and demonstrations on how to develop small-scale biomass operations, which can generate jobs in many, poor rural communities.

Torrefaction Technology:

Torrefaction is a relatively mild heat treatment of biomass, carried out under atmospheric pressure in the absence of oxygen, at a temperature between 200–300 °C. North Carolina State University (NCSU) has a variation in the temperature by which its torrefaction process is run. During torrefaction, all moisture and volatile organic compounds in the biomass are removed and the properties of biomass are changed to obtain a much better fuel (more energy dense), lowering transportation costs and improving combustion (higher heating value).

Water and the volatile organic compounds (e.g., pinenes and turpenes) are vaporized in the torrefaction process, as is some of the hemicelluloses. In NCSU's process, the gaseous products of torrefaction are captured and combusted to allow the process to run on minimal external energy inputs. When green wood (approximately 50 percent water by weight) is torrefied, ideally about 80 percent of the original energy is available in the final torrefied product, which is roughly 30 percent of the initial green weight. The energy density of the torrefied biomass is approximately 11,000 BTUs, which is comparable to that of coal, at 12,000 BTUs, but with no net carbon dioxide emissions and other pollutants, that make coal a concern.

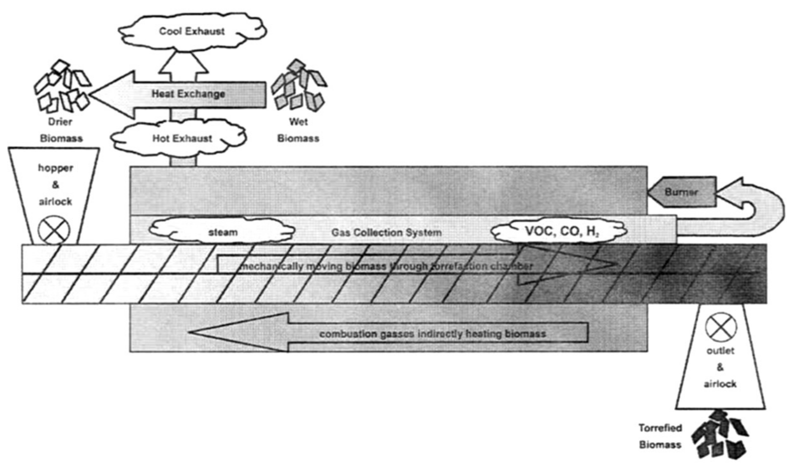
The innovations to the basic torrefaction process, which NCSU has developed, is most easily understood as a mix of counter-flow heat exchanger, indirect heating gasification and wood chip conveyor (see Figure 1, below). The woody biomass (chips) enters a torrefaction chamber (mild steel pipe) that is sealed from the heating fluid surrounding it (combustion gases). The biomass is mechanically conveyed from the cool end to the hot end of the torrefaction chamber and is heated by simple conduction from hot gases moving from the hot end to the cool end, outside the torrefaction chamber. The biomass is also heated by pyrolitic reactions within the torrefaction chamber.

As the biomass is heated, water vapor, volatile organic compounds, carbon monoxide, carbon dioxide, hydrogen, and methane are released and move from the torrefied material, under natural draft to a flame source, where all but the water vapor are combusted with atmospheric oxygen. The combusted gasses and water vapor move around the torrefaction chamber and release their heat to the incoming biomass, before being released to the atmosphere.

The biomass in pipes, within the interior of the torrefaction chamber is not exposed to either a direct flame or the combustion gasses. Volatile organic compounds and water vapor are inhibited from moving out of the torrefaction chamber by the wood chips in the hopper above the wood-metering device, at the inlet of the torrefaction chamber. The torrefied wood is cooled in a sealed chamber while being conveyed to a briquetting or pelletizing machine, a waiting truck or a storage container.

Torrefaction changes cellulosic biomass from a moist, fibrous, perishable, material into a dry, grind-able, stable fuel that can be used as a coal substitute and a feedstock for many other energy-making uses. Torrefaction eliminates the costs associated with transporting the moisture in the biomass, elevates the heating value of the biomass fuel, and reduces the volume of the biomass. The energy density of the torrefied product can be two to three times, more dense than untreated biomass, on a weight basis, and two to four times, on a volume basis. Torrefied biomass offers higher co-firing rates for coal-fueled power generation plants than can be achieved with the combustion of untreated biomass. In addition, torrefaction renders cellulosic a more brittle substance, which can easily be crushed along with coal, without any substantial equipment upgrades by the utility.

Figure 1: Schematic of Torrefaction Machinery



Federal Government Support Provided to ATP:

ATP has been helped by several federal programs, including funding received by ATP's affiliate, under the U.S. Forest Service's Woody Biomass Utilization Grant Program, as well as a grant received by ATP from the Forest Service's Wood Education and Resource Center (WERC) and by ATP under the U.S. Department of Energy's Small Business Innovation Research (SBIR/STTR) Program.

Under the Woody Biomass Utilization Grant Program, our affiliate is working with the Francis Marion & Sumter National Forest, in South Carolina, to find new markets for the woody biomass which results when the Forest does its mechanical thinning, to remove underbrush and small trees, in order to reduce the hazard of severe forest fires and to promote forest health.

It was while operating that program that we learned of the challenges of shipping cellulosic biomass to distant customers. The Forest Service has amended that grant agreement to allow our affiliate to collaborate with ATP, this spring, to demonstrate how torrefaction might overcome the logistical challenges of shipping National Forest biomass to distant customers. Hopefully, the new revenues received might allow more acreage in the National Forest to receive much needed thinning.

Our observations have shown that different types of cellulosic material torrefy differently. ATP's WERC grant allows ATP and NCSU to determine the differences between the way hardwoods torrefy, as compared to softwoods, and to develop processes which will allow hardwoods to be torrefied successfully.

This week, Clemson University will be submitting a grant proposal, allowing us to collaboratively determine how best to torrefy and densify switchgrass, as well.

Lastly, ATP has recently been awarded a Phase 1 Doe STTR grant, which will allow us to determine the feasibility of developing mobile torrefaction units. Such units may make it easier to convert smaller, dispersed sources of agricultural and forestry biomass, from individual farmers or from individual foresters. Such units might also be able to intercept urban wood waste, prevent it from clogging landfills and convert it into a renewable fuel. Such systems may also be able to convert downed trees, in a disaster area, into renewable fuels and much needed revenues.

Suggestions for Additional Federal Support:

1. ATP is ever so grateful for the support we have already received from state and federal sources, but there are additional things which need to be done to help companies, like ours, effectively compete in the global marketplace.

Three of these additional things are:

- Increasing the Availability of Financing for Small Clean Energy Businesses—Although ATP does not now need financing for its core equipment manufacturing operations, it will need financing to become involved in developing biomass processing plants, using its torrefaction technology. Unfortunately, credit for small businesses, especially those using new technologies, is nearly nonexistent. Most federal renewable energy financing programs are geared towards very large projects or rural enterprises.
- Protecting Small Business IP in Third-World Markets—ATP has been regularly contacted by businesses from Third-World countries, like China, India and Russia, where it is difficult to protect intellectual property (IP). Although ATP would like to offer its equipment in such countries, it is afraid to do so, for fear of having its machines copied and losing U.S. technology and jobs.

  We recommend that our government negotiate special protections for small, clean energy business IP, as it has bi-lateral discussions with such Third-World countries, who are demanding access to climate change technology. We also hope that patent applications for renewable energy technologies, which are pending in the U.S. Patent Office, be given expedited treatment. We understand that such a measure may be under consideration by the U.S. Secretary of Commerce.
- Funding to Create and Demonstrate Community-Scale Biomass Production Systems—ATP believes that its torrefaction process and other technologies might be able to reduce rural poverty, if funding for developing small-scale biomass conversion facilities was available. The development of community-based biomass systems is complex and will take a sustained and coordinated effort, especially encouraging and assisting smaller farmers to grow dedicated bio-crops, as well as developing the supply chain elements needed to make such systems work. Funding, similar to DOE's large-scale Biomass Supply Systems program, would be very helpful, along with adding new flexibility to some of the Rural Development Programs offered by the U.S. Department of Agriculture. By the way, USDA's Biomass Capital Assistance Program (BCAP) looks like a very helpful program.

Closing Remarks:

In summary, it is important to treat cellulosic biomass, in order to make it a more cost-effective source of renewable energy. New technologies, including innovations to processes, like torrefaction, can play important roles, in addition to densification processes, to enhance the logistics of shipping and handling cellulosic biomass. Lastly, our Federal Government has played an important role in helping our company compete in the global market place, but there are additional federal measures necessary for our company's and our nation's success in the clean energy economy.

On behalf of Agri-Tech Producers, LLC and our partners and supporters, I thank you for your time and attention. I would be pleased to answer any questions that you may have.

BIOGRAPHY FOR JOSEPH J. JAMES

Joseph J. James is President of Agri-Tech Producers, LLC (ATP), a for-profit company, which is commercializing biomass technology and promoting the utilization of highly productive bio-crops.

ATP is commercializing innovative torrefaction technology, developed by North Carolina State University, which converts cellulosic biomass into a cost-effective fuel for electric utilities to co-fire with coal; makes superior energy pellets; and is a superior feedstock for certain cellulosic ethanol-making processes.

Mr. James is Vice President of the Board of the South Carolina Biomass Council and a member of the Southeast Agriculture and Forestry Energy Resources Alliance (SAFER). Mr. James is a 2008 Purpose Prize winner, for his Greening of Black America Initiative, which seeks to assure the inclusion of rural African-American communities and individuals in the Nation's growing green economy in the Carolinas.

Mr. James has been an economic development professional, for over 35 years, has received a BS, in Science, from Union College and has studied law and business administration at New York University.

Chairman BAIRD. Excellent testimony. Thank you. Mr. Klara.

STATEMENT OF MR. SCOTT M. KLARA, DIRECTOR, STRATEGIC CENTER FOR COAL, NATIONAL ENERGY TECHNOLOGY LABORATORY, U.S. DEPARTMENT OF ENERGY

Mr. KLARA. Thank you, Mr. Chairman, and Members of the Subcommittee. I appreciate this opportunity to provide testimony on behalf of the United States Department of Energy's Clean Coal Research Program, particularly those activities related to co-feeding biomass materials with coal that reduce the life cycle carbon intensity of electric power generation in large industrial processes.

The Clean Coal Research Program, which is administered by the Department's Office of Fossil Energy and implemented by the National Energy Technology Laboratory (NETL), is designed to remove environmental concerns over the future use of coal by developing a portfolio of innovative clean coal technologies. In partnership with the private sector, efforts are focused on maximizing efficiency and environmental performance while minimizing the cost of these new technologies. In recent years, the Clean Coal Research Program has been structured to focus on advanced coal technologies with integrated carbon capture and storage. Co-feeding biomass with coal to current and future power plants is a logical part of this strategy. The coal and biomass co-feeding option, when integrated in an advanced energy system with carbon capture and storage, can provide electric power on a life cycle basis with near-zero greenhouse gas emissions. Biomass can be co-fed to nearly all coal-based processes, including pulverized coal combustion, advanced oxygen-based combustion plants, and advanced gasification-based plants. When combined with pre- or post-combustion carbon capture technologies, co-feeding biomass offers a very sound strategy to reduce the carbon intensity of these energy systems. Coal biomass systems could become part of an early compliance strategy, particularly in existing power plants. Coal biomass systems can benefit from the economies of scale offered by large coal-based energy systems. Large biomass-only plants are often constrained by low biomass energy density, feedstock water content, feedstock collection and preparation and local/regional feedstock availability. Biomass can be used more effectively as a co-feed in large central coal plants to realize the benefits of the economies of scale. Coal can also serve to offset the seasonal and variable nature of the supply and availability of biomass feedstocks.

Considerable experience exists with a number of biomass-to-power generation facilities that have been constructed and operating, particularly in Europe. The International Energy Agency's Bioenergy Task 32 has compiled a very extensive database to provide a nice overview of this experience. It reports that over the past five to ten years there has been remarkable rapid progress in the developing of co-firing. Several plants have been retrofitted for demonstration purposes, while another number of new plants are already being designed for involving biomass co-utilization with fossil fuels. The majority of these plants are equipped with pulverized coal boilers, which is the standard, state-of-the-art technology. Tests have been performed with virtually every commercially significant fuel type, for example, lignite coal, sub-bituminous coal, bituminous coal and opportunity fuels such as petroleum coke and with every major category of biomass, herbaceous and woody fuel pipes generated as residue and energy crops. Over 40 plants in the United States have co-fired coal and biomass over a period of several years. Operations have ranged from several hours of operation to several years with five plants operating continuously for testing purposes, either on wood or switchgrass, and one plant operating commercially over the past two years on a mixture of coal and wood.

Research efforts are currently focused on biomass preparation and pretreatment requirements, feeding coal-biomass mixtures into high-pressure gasifiers at commercial conditions, and characterizing the composition of the resultant stream to determine impacts on downstream components.

Biological capture of CO_2 through algae cultivation is another CO_2 reduction strategy that is gaining attention as a possible means for greenhouse gas reductions from these fossil fuel plants. Algae, the fastest-growing plants on Earth, can double their size as frequently as every two hours while consuming CO_2. Algae can be grown in regions such as desert conditions as not to compete with farmlands and forests, and they do not require fresh water to grow.

While it is recognized that the greenhouse gases stored by algae will ultimately be reduced to the atmosphere, there is a net-carbon offset by effectively using more of the carbon contained in the fuel to produce energy.

In conclusion, to establish a new and widely deployed industry based on growing, harvesting and processing large quantities of biomass fuel on a regular basis, there are some key issues that are needed to be addressed, many of which are here and with the other speakers. The single most important issue we believe is how much biomass can sustainably be made available to economically and reliably support a power industrial facility. This factor alone, biomass availability, will in turn dictate the scale of plant or plants in a particular region. Also, experience dictates that the energy crop must not be competitive with the food chain, so land use and crop choices need to be carefully designed and managed.

There are a number of technical challenges as well to using biomass in future and current plants relative to things like biomass feeding, slagging, fouling and corrosion of downstream processes and components.

This completes my statement, and I look forward to the discussion period. Thank you.

[The prepared statement of Mr. Klara follows:]

PREPARED STATEMENT OF SCOTT M. KLARA

Thank you, Mr. Chairman and Members of the Subcommittee. I appreciate this opportunity to provide testimony on the United States Department of Energy's (DOE) Clean Coal Research Program, particularly those activities related to co-feeding biomass materials with coal that reduce the life cycle carbon intensity of electric power generation and large industrial processes.

Biomass can be introduced to our nation's energy mix as a feedstock input to thermal energy power plants. In addition, the emissions output of fossil energy power plants can be used to cultivate algae for subsequent energy use. Both applications are effective strategies for reducing the carbon intensity of our nation's power generation fleet and industrial processes.

Introduction to Clean Coal Research Program

Fossil fuel resources represent a tremendous national asset. Throughout our history, an abundance of fossil fuels in North America has contributed to our nation's economic prosperity. In Secretary of Energy Steven Chu's October 12, 2009, letter, delivered to Energy Ministers and other attendees of the Carbon Sequestration Leadership Forum in London, he said that: "Coal accounts for 25 percent of the world's energy supply and 40 percent of carbon emissions, and is likely to be a major and growing source of electricity generation for the foreseeable future." Secretary Chu further stated, ". . . I believe we must make it our goal to advance carbon capture and storage technology to the point where widespread, affordable deployment can begin in eight to ten years . . .. But finding safe, affordable, broadly deployable methods to capture and store carbon dioxide is clearly among the most important issues scientists have ever been asked to solve."

The Clean Coal Research Program—administered by DOE's Office of Fossil Energy and implemented by the National Energy Technology Laboratory—is designed to remove environmental concerns over the future use of coal by developing a portfolio of innovative clean coal technologies. In partnership with the private sector, efforts are focused on maximizing efficiency and environmental performance, including carbon dioxide (CO_2) capture and storage, while minimizing the costs of these new technologies. In recent years the Clean Coal Research Program has been structured to focus on advanced coal technologies with integrated Carbon Capture and Storage (CCS). The Program is focused on two major strategies:

- Mitigating emissions of greenhouse gases (GHG) from fossil energy systems; and
- Substantially improving the efficiency of fossil energy systems.

Displacing coal fuel with biomass provides an opportunity to reduce GHG emissions from our nation's power production and industrial facilities.

Background and Potential Importance of Coal-Biomass Systems

A key challenge to enabling the continued widespread use of coal will be our ability to reduce climate warming GHG emissions. Utilizing a coal-biomass feedstock combination complements a carbon capture and storage strategy to reduce GHG. Co-feeding biomass also offers the potential for the Nation to meet its energy and environmental goals, while using domestic energy resources and furthering domestic energy security.

The coal and biomass co-feeding option, when integrated in an advanced energy system like advanced gasification-based technology with CCS, can provide electric power, on a life cycle basis, with near-zero GHG emissions.

Biomass can be co-fed to existing pulverized coal combustion plants, advanced oxygen-based combustion plants, and advanced gasification-based plants. When combined with pre- or post-combustion carbon capture technologies, co-feeding biomass offers a sound strategy to reduce the carbon intensity of existing and future coal-based energy systems.

Coal-biomass systems could become part of an early compliance strategy, particularly in existing power plants. Further, coal-biomass systems can benefit from the economies of scale offered by large coal-based energy systems. Large biomass-alone power plants are constrained by low biomass energy density, feedstock water content, feedstock collection and preparation, and local/regional feedstock availability. Biomass can be used in economically available quantities as co-feed in large central coal plants, to realize the benefits of economies of scale. Coal can also serve to offset the seasonal and variable nature of the supply of biomass feeds.

CO_2 Perspective of Coal-Biomass Systems

CO_2 reductions associated with using biomass in existing pulverized coal-fired power generation facilities is fairly straightforward. CO_2 reductions from existing plants will be nearly equivalent to the amount of carbon in the biomass feedstock, less the amount of fossil fuel produced CO_2 needed to harvest, prepare, and transport the biomass to be combusted in the boiler. Technology modifications needed to co-feed coal and modest amounts of biomass into existing plants available today and being adopted by industry. For example, First Energy is in the process of converting units 4 and 5 of their Burger Plant in Shadyside, Ohio, to produce up to 312 MWe firing up to 100 percent biomass.

Gasification-based units, such as Tampa Electric, offer the opportunity to combine biomass offsets of carbon emissions from coal with CCS, resulting in near-zero overall plant carbon emissions. Recent NETL engineering analyses indicate that net-zero life cycle carbon emissions can be achieved by co-feeding biomass into Integrated Gasification Combined Cycle (IGCC) plants with 90 percent carbon capture and sequestration. The quantity of biomass co-feed needed to reach net-zero emissions varies depending on the type and rank of coal utilized. Limiting issues for both combustion and gasification-based systems include biomass availability and cost, both of which must be overcome by the development of improved technology if we are to dramatically increase the amount of biomass deployed, and the associated carbon benefits in future power production systems.

While biomass feedstocks are generally viewed as having a low-carbon footprint, a careful life cycle analysis must be performed to fairly characterize their true profile; this is especially true when considering cultivating new biomass crops that are to be dedicated to energy production. For example, some carbon capture processes can make large quantities of affordable fertilizer that could have beneficial effects when reclaiming mined or poor quality land, thus serving as a potential pathway for easing land-use considerations associated with biomass energy crops. The potential also exists for the beneficial reuse of CO_2 recovered from coal-biomass power plants to produce and process algae for subsequent energy use. Such energy systems could be located near the markets they would serve. These two strategies could be useful to enhance overall plant economics by the value added from beneficial reuse approaches, thus helping to support the costs of deployment of the needed CO_2 infrastructure—building CO_2 pipelines and paying for transport and storage.

Global Perspectives and Experience with Coal-Biomass Operations

Considerable experience already exists with a number of biomass to power production facilities that have been constructed and are operating, particularly in Europe. The International Energy Agency's Bioenergy Task 32[1] compiled a database to provide an overview of this experience. It reports "Over the past five to ten years there has been remarkably rapid progress over in the development of co-firing. Several plants have been retrofitted for demonstration purposes, while another number of new plants are already being designed for involving biomass co-utilization with fossil fuels. . . . Typical power stations where co-firing is applied are in the range from approximately 50 MWe (a few units are between five and 50 MWe) to 700 MWe. The majority are equipped with pulverized coal boilers . . .. Tests have been performed with every commercially significant (lignite, sub-bituminous coal, bituminous coal, and opportunity fuels such as petroleum coke) fuel type, and with every major category of biomass (herbaceous and woody fuel types generated as residues and energy crops)."

---

[1] *http://www.ieabcc.nl/database/cofiring.html*

For IGCC power generation systems, tests have been performed successfully at the Nuon plant in the Netherlands that fed a mixture of 30 percent demolition wood and 70 percent coal by weight to a Shell high-pressure, entrained gasifier. However, only limited data and information are available from these tests. In the United States, Foster Wheeler has been active assessing various aspects of coal-biomass mixtures, with a focus on fuel selection, emissions control, and corrosion issues. Europe is most active in the area of coal-biomass co-firing, and their experience stresses the importance of biomass processing, to avoid slagging and fouling as potential issues to maintaining optimum combustion performance. In addition, there is presently much discussion of indirect CO_2 emissions of biomass from a life cycle basis that arise from fertilization, harvesting, and transport of the biomass.

United States' Perspectives and Experience with Coal-Biomass

Between 1990 and 2000, research targeted at co-firing coal and biomass within combustion plants was strongly supported by DOE, industry, and academia, all of whom considered co-feeding coal and biomass in combustion power plants to be a technically viable option. Over 40 plants in the United States have co-fired coal and biomass over a period of several years. Operations have ranged from several hours to several years, with five plants operating continuously for testing purposes on either wood or switchgrass, and one plant operating commercially over the past two years on a mixture of coal and wood.

While it is relatively easy to feed small percentages of biomass in co-firing configurations at power plants, care must be taken to specify the type and amount of biomass, and biomass-feed processing requirements that provide optimum carbon reductions with minimal reductions in plant efficiency.

The information base for co-feeding coal and biomass in gasification technology settings in the United States is significantly less than that for combustion. Biomass has been successfully fed in low concentrations at Tampa Electric's IGCC power demonstration in Florida, and biomass co-feeding and preparation tests are currently being conducted at Southern Company's National Carbon Capture Center test center in Wilsonville, Alabama.

Current Office of Fossil Energy Coal-Biomass Activities

Research is being conducted on biomass preparation and pretreatment requirements, feeding coal-biomass mixtures into high-pressure gasifiers at commercial conditions and characterizing the composition of the resultant gas stream to determine impacts on downstream components.

Algae Production as a GHG Reduction Strategy

Biological capture of CO_2 through algae cultivation is another CO_2 reduction strategy that is gaining attention as a possible means to achieve reductions in GHG emissions from fossil-fuel processes. Algae, the fastest growing plants on Earth, can double their size as frequently as every two hours, while consuming CO_2. Algae can be grown in regions, such as desert conditions, so as not to compete with farmland and forests; and they do not require fresh water to grow. Algae will grow in brackish water, plant-recycle water, or even in sewage streams, and, when cultivated within closed systems, these waters can be recycled, thereby minimizing further water use.

While it is recognized that the greenhouse gases stored by the algae will ultimately be released to the atmosphere, there is a net carbon offset by more effectively using the carbon contained in the coal. The coal is used to produce power and then again for algae production, hence, a net-carbon offset is realized by an increase in the energy extracted from the coal, compared to that same coal being used for power generation only.

A cost-effective, large-scale production system for growing algae using CO_2 from a power plant has not yet been demonstrated. Using Recovery Act funds, DOE is sponsoring a project with Arizona Public Service to develop and ultimately demonstrate a large-scale algae system coupled with a power plant. The utilization of algae for carbon management is an integral part of the project. The project has already proven the process at a small scale using a one-third acre algae bioreactor, which has been operating for weeks using power plant stack emissions to produce sustained algae growth. Additionally, a prototype algae cultivation system is being evaluated for continuous operation. The project will ultimately assemble a fully integrated energy system for beneficial CO_2 use, including an algae farm of sufficient size to adequately evaluate effectiveness and costs for commercial applications. To complement the engineered system in Arizona, DOE has solicited Small Business Innovation Research proposals to explore novel and efficient concepts for several processing aspects of CO_2 capture for algae growth. The results from these efforts should prove useful to future algae farming applications.

Conclusion

Prior to the current global emphasis on carbon reductions, coal-biomass research, development, and demonstration focused on waste utilization, e.g., demolition wood in the Netherlands and waste wood from the lumber industry in the United States. The major objective of those efforts was to reduce the amount of wastes going to landfills. More recent interests have also facilitated the use of coal-biomass mixtures, e.g., the co-firing of straw with coal at Denmark's utilities. Now, with carbon reductions at the forefront, there is renewed interest and the possibility of realizing a double benefit to co-firing, particularly for those organizations that have been motivated solely by the benefits of reducing wastes (most of which are biomass-based). Additionally, algae production using CO_2 emissions from fossil fuel power plants is gaining attention as another biologically based option to reduce GHG emissions.

To establish a new and widely deployed industry, based on providing (growing, harvesting, processing) biomass fuel on a regular basis, there are key issues to address—the single most important of which is **how much biomass can sustainably be made available to economically and reliably support a power or industrial facility, and enable that facility to reliably and economically achieve its goal for carbon reduction?** This factor alone (i.e., biomass availability) will, in turn, dictate the scale of the plant or plants in a particular region. Also, experience dictates that the energy crop must not be competitive with the food chain, so land use and crop choices need to be carefully designed and managed. There are technical challenges to adding large quantities of biomass to our nation's energy systems that must be overcome as well. Preparing the biomass before it is used in the plant, as well as potential slagging, fouling, and corrosion of downstream components and processes, must be addressed for both combustion and gasification systems.

BIOGRAPHY FOR SCOTT M. KLARA

Mr. Klara is currently the Director for the Strategic Center for Coal at the National Energy Technology Laboratory. Mr. Klara is responsible for overseeing the Department of Energy's $500 million per year Coal R&D Program that consists of several hundred projects related to technology areas such as coal gasification, carbon sequestration, fuel cells, advanced turbines, and coal to liquid/gaseous fuels. Mr. Klara has over twenty years of diversified engineering and management experience. His experience encompasses a broad spectrum of technology areas including: electric power generation; advanced separation processes; process control; coal conversion processes; and simulation/systems analysis. Mr. Klara holds advanced degrees in chemical engineering and petroleum engineering. He is a certified professional engineer in the states of Pennsylvania and West Virginia. Mr. Klara has more than sixty peer-reviewed publications and presentations.

Chairman BAIRD. Thank you, Mr. Klara. Mr. Spomer.

STATEMENT OF MR. ERIC L. SPOMER, PRESIDENT, CATALYST RENEWABLES

Mr. SPOMER. Thank you, Mr. Chairman and distinguished Subcommittee Members. I appreciate this opportunity to share Catalyst Renewables' operational lessons learned and insights on this important topic. I ask that my detailed written testimony be included in the record as I intend to share only a few key points.

Catalyst was a successful green, renewable and sustainable energy company before being green was so popular. Our biomass experience originates with the Lyonsdale plant in Lyons Falls, New York. We purchased this 19 megawatt combined heat and power facility in 2003. At that time, the plant was in distress, but after significant capital investment and reestablishment of trust and confidence with the local forest community, we have been able to help Lyonsdale return to viability.

Catalyst developed and deployed an approved sustainable forestry management plan in conjunction with its renewable energy credit from the New York State Renewable Portfolio Standard. Today, the Lyonsdale "wood basket" is considered the healthiest forest in New York State. Wood from the forest and purpose-grown woody biomass energy crops offers a significant renewable environmentally acceptable alternative to fossil-based energy supplies.

The United States biopower effort is being led by renewable energy generation innovators like Catalyst, and our strategies can be applied to all our United States forests.

Woody biomass holds significant revitalization potential for the rural economies of our forest and farm communities. Woody biomass is CO_2-neutral. Woody biomass is sustainable and enhances forest health.

So why does woody biomass, around for eons, merit your attention and inclusion in a research and development portfolio for the future? First, wood wins in every environmental, economic and effectiveness category. Using woody biomass offers a clear national security advantage for using clean, renewable, home-grown fuel for baseload thermal energy and electricity. Woody biomass has a proven, reliable national logistics handling system, but biomass is not just wood. Today we have new integrated biomass handling system for the efficient and effective inclusion of crop residues and livestock nutrients. So our first research and development suggestion is the design, development and operational tests and evaluation of regional logistic systems, including integration of rail transport and integrated staging areas for woody biomass, crop residues and nutrient feedstocks. Integrated handling systems must be designed and tested to be commercially and operationally effective and suitable with a minimum of handling "touches" as industry develops new facilities. A concerted effort to advance comingled biomass supplies would enhance resource use, reduce costs, and expand biomass availability for renewable thermal energy and electricity. We suggest multiple regional demonstrations suited to regional feedstocks are reasonable and prudent.

Second, Catalyst is constantly seeking cleaner, more reliable production of renewable baseload heat and power. Our foremost concerns are efficiency, environmental suitability, and elimination of greenhouse gas emissions. Presently, our already permitted 37 megawatt Onondaga Renewables plant under development in Geddes, New York, will be the cleanest woody biomass generating facility in North America. These bragging rights do not come cheap. We are commissioning a bubbling fluidized bed (BFB) boiler. BFB technology is widely recognized as the most efficient combustion conversion device for biomass residues. However, the BFB boilers come with a significant associated energy penalty, pressurized air flow. Large quantities of air required to counterbalance the mass of the boiler bed and propel the mass into a fluidized state, and this results in a six percent penalty on efficiency. In the case of Onondaga, that is 21,000 megawatts-hours a year.

Next, CO_2-neutral woody biomass is also virtually sulphur-free, and our systems can already effectively eliminate particulate matter, leaving emissions of oxides of nitrogen, NO_X, the most important remaining consideration. Today we use catalytic reduction systems, including selective catalytic reduction and regenerative selective catalytic reduction.

Fresh catalytic units are capable of continuously reducing NO_X by more than 98 percent. At Onondaga, the catalyst will operate at high conversion efficiency for about 10,000 hours, but then it must be replaced and disposed of. Presently, NO_X reduction catalysts cannot be regenerated.

Finally, maintaining optimal chemical reaction temperatures in catalytic reduction units operated for the elimination of NO_X and the elimination of use of fossil fuels as reheat or energy source is essential. Presently, oil or natural gas is burned to maintain flue gas temperatures to effect rapid and high NO_X conversion. For a modern biomass conversion plant, the heat approaches 10 percent of the total biomass value. That is 3.7 megawatts of capacity at Onondaga.

To summarize, we must strongly suggest specific congressional direction to the U.S. DOE and funded research and development authorizations for appropriations: to design, test, and deploy integrated biomass logistic systems, to research, develop and test equipments to eliminate parasitic power loss and bubbling fluidized bed biomass boilers, to research, develop, test and deploy catalytic units that have extended operational lives and that can be regenerated in place, and to research, develop, test and deploy energy improvements able to eliminate the need for auxiliary fossil fuel usage in RSCR (regenerative selective catalytic reduction) and SCR–NO_X control devices.

Mr. Chairman and distinguished Subcommittee Members, thank you or the opportunity to provide this testimony.

[The prepared statement of Mr. Spomer follows:]

PREPARED STATEMENT OF ERIC L. SPOMER

Thank you, Mr. Chairman and distinguished Subcommittee Members, for the opportunity to provide testimony to the Committee on Science and Technology, Subcommittee on Energy and Environment for the *“Biomass for Thermal Energy and Electricity Through a Research and Development Portfolio for the Future”* hearing. I appreciate this opportunity to share Catalyst Renewables’ operational lessons learned and insights on this important topic, which is a core area of commercial and environmental concern to Catalyst Renewables. Mr. Chairman, Catalyst was a successful “green,” renewable and sustainable energy company before being “green” was so popular.

Catalyst Renewables develops and owns energy projects deploying leading-edge technologies using clean, renewable resources—woody biomass and geothermal—to produce power and thermal energy. Our goals include creating environmentally sound, renewable energy alternatives that can be sustained in current and future energy markets, and to actively engage the communities that we serve. Catalyst builds fiscally and environmentally responsible solutions that free us from the limited supply and unstable pricing of fossil fuels as we, in fact, build a new pathway to energy’s future.

Our operational biomass experience originates with Lyonsdale Biomass at Lyons Falls, New York. We purchased this 19 MWe Combined Heat and Power (CHP) facility in 2003. At that time, the plant was in distress, but after significant private capital transfusions and re-establishment of trust and confidence with the men and women of the local forest community logistics pipeline, we have been able to help Lyonsdale Biomass return to viability. We were successful in competitive renewable energy credits auctions for the New York State Renewable Portfolio Standard (RPS) . . . the only woody biomass facility ever to do so. In an important sidelight, to qualify for the RPS, Catalyst had to develop, prepare and deploy a New York State Department of Environmental Conservation (NYSDEC)-approved sustainable forestry management plan, which became the first plan deployed in New York State.

Today, we are anecdotally told by NYSDEC that the Lyonsdale "wood basket" is considered the healthiest forest in New York State.

Wood from the forest and farmed purpose grown woody biomass energy crops offers a significant renewable alternative and environmentally more acceptable replacement options to diminishing fossil-based energy supplies. In our western forests, this energy harvested in a thoughtful management plan and released via controlled combustion or gasification instead of devastating forest fires, can produce significant distributive CHP that will spur economic vitality. Across the Northern Forest of New York, New Hampshire, Vermont and Maine, our neighbors are equally embracing the challenge of energy from mixed northern hardwood trees produced in close proximity to urgent demand for renewable energy. This effort is being led by renewable energy generation innovators like Catalyst Renewables and their strategies can be applied to all our United States forests using the extensive renewable energy stored and continually produced by wood.

Woody biomass from the forest and from farmed and purpose-grown woody biomass energy crops holds significant revitalization potential for the rural economies of our forest and farm communities by creating an alternative source of income for landowners and circulating wealth-creating energy dollars through the local economy. In New York, which is characterized by a fossil fuel-intensive power generation sector (~51 percent of power generated), substituting woody biomass for coal-powered electrical generation significantly reduces imported energy costs. Naturally possessing a short supply chain, woody biomass is produced in close proximity to demand and the end-user. This provides an important link and business relationship between the power plant and local community. As these fuels are available locally, the financial resources are spent locally, thereby encouraging the local economy and providing income for local businesses. Wood energy adds financial value to the forest and supports critical restorations and improvements from timber-stand management thinnings. The sustainability of local woodsheds can be enhanced by the inclusion of purpose grown woody biomass on under-utilized or abandoned farmland including fast-growing Root Process Method ® (RPM) native hardwoods and short rotation woody crops such as shrub willows developed by SUNY–ESF and being commercialized by Catalyst Renewables.

The energy life cycle analyses of the purpose grown woody biomass energy crop systems and subsequent conversion of biomass to electricity via combustion and gasification is positive in many ways. The net energy ratio for the production and conversion of purpose grown woody biomass is 1:11 for co-firing and 1:16 for a gasification system. This means that for every unit of nonrenewable fossil fuel energy used for growth and harvest, 11–16 units of usable energy are produced. In essence, forests and purpose grown woody biomass energy crops are large solar collectors that capture the sun's energy and store it as woody biomass. The net energy ratio for woody biomass is far superior to the net energy ratio for electricity from a combined cycle natural gas system (1:0.4). Research directly correlates this data to wide scale energy applications of mixed northern hardwood feedstocks from our northeast states and feedstocks of western hardwood feedstocks.

Woody biomass from the forest and from farmed and purpose-grown woody biomass energy crops are CO_2 neutral, which means that energy and other products can be produced with no net addition of CO_2 to the atmosphere. Biomass for bioenergy including liquid transportation fuels can be drawn from a variety of feedstock sources including forests, agricultural crops, organic residue streams and dedicated woody or herbaceous crops. Research suggests development and deployment of woody biomass resources have distinct energy, economic and environmental advantages over traditional agricultural crop sources:

- Woody biomass is available year round and from multiple sources. End-users are not dependent on single source material.
- The net energy ratios for bio-energy and bio-products including liquid transportation fuels derived from woody biomass are large and positive, meaning that considerably more energy output is produced from these systems than is used in the form of fossil fuels to produce the woody biomass and generate end products.
- Woody biomass can be sustainably managed and produced, while simultaneously providing an array of environmental and socioeconomic benefits.
- The physical-chemical characteristics of woody biomass from hardwoods are fairly consistent even when supplied from multiple sources.
- The forest products industry and wood-based renewable energy generation firms have developed superior technical and engineering competencies to manage woody biomass.

USDOE/USDA estimates sustainably harvested forest woody biomass can nationally provide at least 368 million dry tons of wood per year. Nationally, the net annual incremental forest woody biomass growth on almost 500 million acres of U.S. timberland exceeds forest woody biomass removals by almost 50 percent. In the north-central states growth exceeds removals by 95 percent. This ratio is even greater in the northern forest of the northeast states, where growth exceeds removals by 125 percent. In New York State, there are over 18.5 million acres of timberland with over 750 million tons of standing biomass. The net annual increment growth vs. removals on New York timberland is more than 300 percent.

At a Catalyst Renewables facility, Lyonsdale Biomass, in Lyons Falls, woody biomass is being used to generate 19MWe of electricity for the grid and post-generation thermal power at 15,000 pph for the Burrows Paper Company. Catalyst Renewables is presently harvesting and installing planting stock at Catalyst's commercial shrub willow energy crop plantations in and around Central New York. This 600-acre plantation is the first commercial shrub willow energy crop plantation in North America. For every MWe of renewable power produced, Catalyst off-sets 2,500 tons of coal and $90,000 of exported energy cost. This is very important because New York State imports over $2,500 worth of mostly fossil-based energy for every man, woman and child in the State.

Consumers increasingly need base-load energy that is renewable, clean, and affordable from renewable sources like geothermal and biomass. One of the simplest and oldest of renewables is direct combustion of wood. Wood supplied more energy than fossil fuels in the United States until the 1880s, when coal superseded wood. Today, due to re-growth of forests and improved technologies, sophisticated thermal combustion is being used across Europe, supplying heat, cooling, and power and reducing greenhouse gas emissions. A high-efficiency wood-burning plant was recently opened in Simmering-Vienna with total thermal capacity of 65 MW, delivering electricity to the grid and heat to the city's district energy system. More than 1,000 woody biomass facilities have been constructed in Austria, nearly all local community-based; more than 100 combine heat and electric power. The facilities emit remarkably low quantities of air pollutants, including greenhouse gases, and have thermal efficiencies across the system approaching 90 percent. Europe's thousands of new community-scale woody biomass facilities clearly demonstrate that, woody biomass can be rapidly implemented, can reduce oil imports and greenhouse gas emissions, and can increase energy security with wood drawn from local woodsheds including purpose grown woody biomass from under-utilized or abandoned farmland.

Regionally, areas with sustainable wood supplies need to deploy woody biomass CHP as new construction and renovated fossil CHP sites. Such initiative is well targeted to the Northeast United States, given the region's abundant forest land and dependence on heating oil. Woody biomass CHP has great potential in the Southeast and West as well. Relatively rapid transitions to woody biomass CHP heating and cooling are technically and economically achievable in schools, municipal offices, hospitals, prisons, and industrial facilities. This includes better use of wood collected by municipalities from diseased and storm-damaged trees and from construction sites. The volume of safely combustible urban wood in the United States is nearly 30 million tons per year. Often, local communities dispose of this wood at some expense and incurring negative environmental results while missing energy benefits that could come from its clean combustion.

The potential thermal value of community-based CHP alone is significant. If New York were to commission one hundred community-scale 0.75 MW CHP projects per year over a five-year construction period at an incremental investment would be about $100 million for each of the five construction years. However, fuel savings would increase to at least $100 to $180 million per year, and emissions of fossil CO_2 could decrease by 0.75 to 1.0 million tons per year. The woody biomass required by such an initiative totals less than 20 percent of a recent estimate of New York's energy-wood supply. By increasing the purpose grown biomass component of the supply with fast-growing Root Process Method ® (RPM) native hardwoods and short rotation woody crops such as shrub willows developed by SUNY–ESF and being commercialized by Catalyst Renewables on New York's abandoned and under-utilized farm land the pressure on the open-loop biomass supply could be reduced by 20 percent.

Total U.S. energy consumption is presently about 100 quads [British thermal units (BTUs)] per year. U.S. wood delivers about quads per year and the national sustainable energy-wood supply potentially contains about five quads per year. Although these rates may seem small, they are enormous quantities of energy, comparable to power production from hydroelectric sources (~3 quads per year) or the content of energy in the Nation's Strategic Petroleum Reserve (~4 quads). Considering controversial plans to expand the Nation's nuclear capacity, presently at 10 quads per year, applying purpose grown woody biomass for future potential wood energy is reasonable and prudent as it enhances development from forests and woodlands with resources from low-productivity, abandoned and under-utilized agricultural lands and from urban brownfield sites.

So, why does woody biomass . . . around for eons . . . merit your attention and inclusion in a Research and Development Portfolio for the Future? Wood wins in all the environmental, economic and effectiveness categories. Likewise, using woody biomass offers a clear national strategic advantage of a clean, renewable homegrown base-load thermal energy and electricity resource and woody biomass comes with a significant practical advantage: a proven, reliable national logistics handing system. We appreciate the value of crop residues as a potential biopower feedstock, but we are daunted by our national absence of an efficient and effective crop residue collection and delivery system. On the other hand, the Nation's forest products industry's logistics system is mature and readily adaptable to the demands of CHP systems. This asset is our first research and development focus suggestion: That is, design, development and operational test and evaluation of appropriate regional logistics systems including integration of rail transport and strategic staging areas of woody biomass and crop residue feedstocks. Such systems are not "chicken or egg" situations. Integrated handling systems must be designed and tested to be commercially and operationally effective and suitable with a minimum of handling "touches." In addition, integrating woody biomass with other available feedstocks, such as livestock nutrients, biosolids, and similar products is problematic with currently available handling and processing equipment. A concerted effort to advance co-mingled biomass supplies would enhance resource utilization and reduce cost. We suggest multiple regional demonstrations suited to regional feedstocks are reasonable and prudent. Delivery system inefficiencies as dollars per ton of biomass, manifests throughout the CHP conversion process. Costs saved during biomass harvest, preparation and delivery multiple as costs savings to end-users of both electrical energy and thermal power.

Catalyst Renewables is constantly seeking cleaner, more reliable production of renewable base-load heat and power. Presently, we have a 37MWe facility "Onondaga Renewables" under development in Geddes, New York. Already permitted, Catalyst Renewables asserts based on existing state-of-the art technology that "Onondaga Renewables" will be the cleanest woody biomass generating facility in North America. Employing a Bubbling Fluidized Bed (BFB) boiler, the technology is widely recognized as the most efficient conversion device for combusting woody biomass residue. The BFB's tolerance for fuels having low heating density, having significant moisture content, are irregularly sized and potentially contaminated with miscellaneous inert materials such as soil and rocks make the BFB the premier system for efficiently and reliably converting loggings residues into useful energy.

Owing to the relatively low operating temperatures of BFBs, they intrinsically thermally fix lower amounts of oxides of nitrogen (NO_X) relative to conventional boiler systems. Owing to intimate commingling in the fluidized bed between fuel, hot bed medium and oxidizing gases, combustible material is combusted to completion. Additionally, alkali absorbent material within the fluidized bed can capture and control potential pollutants such as sulfur and acid gases.

However, fluidization comes with a significant, associated energy penalty-pressurized airflow. Large quantities of air are required to counter-balance the mass of the boiler bed and propel the mass into a fluidized state. The associated fan and blower power demands result in a six percent system efficiency penalty as compared to less environmentally beneficial traditional, fixed grate boiler systems. As applied to Onondaga Renewables project, the annual power required for air handling is the equivalent of 21,000 megawatts-hours. Therefore, we suggest a second important research and development focus area is the mitigation of fluidized-bed parasitic power loss. Specifically, biomass CHP would significantly benefit from research and development of more efficient fans, blowers and electric motor drive units for all fluidized bed boiler systems. Likewise, research designed to achieve pressure drop reductions through air conveyance ductwork would reduce associated power requirements and significantly improve overall system efficiency.

Based on Catalyst Renewables' commitment to environmentally benign heat and power production is the elimination of Greenhouse Gas emission. Already CO_2 neutral, woody biomass is also virtually sulphur-free, which leaves emissions of oxides of nitrogen (NO_X) as the next major consideration. Modern combustion installations often reduce NO_X emissions, by causing a chemical reaction between NO_X and a reagent, typically ammonia or urea. The speed and completeness of the reaction is facilitated with catalyst. Popular catalytic NO_X reduction systems include selective catalytic reduction (SCR) and regenerative selective catalytic reduction (RSCR). In both systems, the catalyst is a ceramic matrix, often honeycomb like, contained within a housing comprised of several tons of catalyst.

Fresh catalytic units are capable of continuously reducing NO_X by more than 98 percent. In typical industrial/power generation application such as Onondaga Renewables, catalyst is expected to operate at high conversion efficiency for approximately 10,000 hours after which, the catalyst must be replaced and disposed of as a solid waste—presently, NO_X reduction catalysts cannot be regenerated. As a third research and development focus, Catalyst Renewables suggests operational effectiveness and suitability at biomass conversion facilities can significantly benefit from research and development designed to extend the useful operating life of NO_X reduction catalysts. Whether the deactivation mechanism be physical, thermal or chemical, the biomass conversion operator is focused on permit emission limits and whether the catalyst can produce the desired level of control. Catalyst recharge/replacement is a significant inefficiency; it requires the cessation of operations resulting in opportunity losses, capital expenditure for fresh catalysts, loss of un-reacted reagent while using aged catalyst with lower conversion efficiency, labor expense and disposal costs. For our Onondaga Renewables biomass facility, associated catalyst costs for typical life cycle amount to more than $1.00 per megawatt hour of generation.

The final and most difficult research and development focus involves maintaining optimum chemical reaction temperatures in regenerative selective catalytic reduction (RSCR) units operated for the elimination of oxides of nitrogen (NO_X), while eliminating the use of high quality fossil fuels as an energy source. Presently, distillate oil or more typically natural gas is burned to maintain flue gas temperatures to effect rapid and high NO_X conversion. For a modern biomass conversion power plant, the heat input to a RSCR unit approaches 10 percent of the total biomass energy value. Although RSCR systems are designed to recapture and recycle heat between its multiple sub-units, the reliance on a continuous supplement of fossil fuel remains a substantial huddle to widespread use. Not only does RSCR auxiliary fuel use directly reduce the overall plant conversion efficiency, its emissions contribute to climate change emissions. Furthermore, fossil fuel use even at this relatively low level can ensnare most biomass electrical generating units in regulations for the control and reporting of greenhouse gases. For these reason we advocate for research and development energy improvements that would eliminate the need auxiliary fuel usage in regenerative-SCR NO_X, control devices.

Mr. Chairman and distinguished Subcommittee Members, thank you or the opportunity to provide testimony to the Committee on Science and Technology, Subcommittee on Energy and Environment for the *Biomass for Thermal Energy and Electricity: A Research and Development Portfolio for the Future* hearing. I appreciated this opportunity to share Catalyst Renewables' operational lessons learned and insights on this important topic.

BIOGRAPHY FOR ERIC L. SPOMER

Eric Spomer formed Catalyst Renewables (formerly known as NGP Power Corp.) with Natural Gas Partners VI, L.P. in 2001. Catalyst is now an independent renewable energy development company, and Eric manages a staff with expertise in project development, generation technologies, operations and financing. The company is focused on developing, acquiring and operating power generation facilities utilizing proven technologies and reliably available renewable fuels—primarily biomass and geothermal today.

Eric earned BA and MBA degrees from Southern United Methodist University in 1982 and 1992, respectively. From 1982 to 1986, he worked as an independent landman in the Rocky Mountain region. In 1986 he joined NCNB in Charlotte, NC, as a credit policy officer in the real estate lending group, later moving to Tampa and Dallas in the same capacity. After performing due diligence and transition tasks related NCNB's acquisition of First Republic Bank, Eric joined the Energy Banking Group, where he handled large corporate credits through 1993. From 1993 to 1997, Eric was co-founder, COO and CFO for a natural gas marketing, gathering and processing company. Immediately prior to forming Catalyst Renewables, Eric was a principal in an energy merchant banking group, structuring transactions and assisting in bankruptcies and restructurings within the energy industry.

Chairman BAIRD. Thank you, Mr. Spomer. Dr. Burns.

STATEMENT OF DR. ROBERT T. BURNS, PROFESSOR, DEPARTMENT OF AGRICULTURAL & BIOSYSTEMS ENGINEERING, IOWA STATE UNIVERSITY

Dr. BURNS. I would like to thank the Committee for the opportunity to provide information today. It is a privilege to be invited. I was specifically asked to speak about research and development needs regarding the anaerobic digestion of animal manures to produce energy via biogas.

Anaerobic digestion is the conversion of manure into biogas, which contains primarily methane, through a process that is without oxygen. It is a process that has been around for years, we have used for a long time and have a relatively good handle on.

The biogas that is derived from animal manures can be used as a renewable energy source in various ways. It can be directly utilized on the farm for heat or other uses. It can be directly combusted in boilers to produce hot water. It can be cleaned and conditioned, what we call upgraded, and can be injected into the natural gas pipeline. It can be used to fuel engine generators or micro turbines for electricity generation or used as a fuel source for Stirling engine cycles, fuel cells and some other options.

In addition to producing renewable energy, the anaerobic digestion of animal manures also provides some environmental options. It reduces odors, which in a farm setting is a very important situation. It reduces organic material, potentially reduces pathogens and generates marketable carbon credits for sale through the reduction of the base greenhouse gas emissions from those systems. The manure from dairy, swine, beef, feedlot and layer systems has been successfully digested in the United States and abroad, and some types of manure systems are more easily to install on digester systems than others.

But if we took a look at the manure from all four of these species that I just mentioned: layers, beef feedlot, dairies and swine systems, and were to anaerobically digest all of that manure in the United States to produce electricity, we could generate over 20 billion kilowatt hours, which would represent about one half of a percent of the total United States electricity generation in 2008, or about 17 percent of the nine non-hydroelectric renewable provision in this country.

But we have to recognize that we can't necessarily digest all of that manure, we can't get 100 percent market penetration. The U.S. EPA AgSTAR Program has done some very good reports that have looked at which systems are feasible. Specifically in the diary and swine industry, they believe that some of the larger systems are more feasible, and if we take that market share that they believe would be good candidates for digestion, this still represents about 6.3 billion kilowatt hours per year generated.

The implementation of digestion within the United States has been very limited, however. Currently we have 135 operational manure digesters in this country. If we contrast that to the two leading countries in the world, China and Germany, China currently has 16,000 manure anaerobic digesters that are medium and large-scale, similar to our concentrated animal feeding operation systems, or concentrated animal feeding operations I should say. Germany has approximately 5,000 systems that are manure-based or manure- and silage-based. The AD (anaerobic digestion) technology is proven, but what we have seen is that the AD energy production costs in this country are too high to compete in the competitive market.

From a standpoint of going back on the grid, typically you are going to see wholesale rates in the United States average around three cents per kilowatt hour. It varies by location in the country. Germany is currently receiving 33 U.S. cents per kilowatt hour for that similar energy, and in China, nine to ten cents per kilowatt hour.

The research and development needs then that I see are those that could reduce the cost of energy derived from manure anaerobic digestion systems so we can compete in the current energy market. Specifically, of some examples of these R&D gaps that I would like to share with the group, first is a low-cost biogas upgrading options. We have tried and true biogas upgrading systems, but currently the reported cost to upgrade biogas is equal to or greater than the current cost to purchase natural gas. So it makes it not economically feasible to pursue that option.

The development of lower-cost systems, especially those that could be applied on farm and smaller systems, would be very useful. The development of additional direct use options would also be handy, as I mentioned. Because the cost for biogas upgrading is so high, if we could skip the upgrade costs and directly use unconditioned biogas, especially on the farm, it would give us a much more economical opportunity to do a cost avoidance situation. This is very basic research, but it is very practical in nature. It is something that would provide a lot of forward traction if we could come up with those systems.

Next, the development of anaerobic digestion systems that are compatible with swine, deep-pit finish operations. Most of the pigs in this country, the majority, are finished in the Midwestern United States, and a majority of those finishing systems utilize what is called a deep-pit system. Manure is stored directly under the animals. Those systems are not directly compatible with anaerobic digestion systems, and the development of a system that it would allow the adaptation without large cost would bring that market sector into the game.

The adaptation and development of high solid digestion systems to manure systems—there have been high solids or dry digestion systems in the municipal world for some time. To move those systems into manure would also provide benefits.

Finally, the development of advanced, lower-cost NO_X controls for biogas combustion and generation systems. In some parts of the United States, specifically in California, NO_X limits lower than we can currently achieve are being written into permits with a lot of the technology that is out there, from a cost-effective standpoint, and that has limited some implementation.

I would like to conclude by saying the number of manure digesters in the United States is increasing. I think this is primarily due to the fact that we see increasing grant support at the federal and State level to build digesters, so we are going to continue to see these systems come on line. We are not cost competitive in the energy market right now. This topic touches energy, environment, and agriculture, and I think it presents an excellent opportunity for DOE, EPA and USDA to work synergistically to help answer some of these gaps.

Thank you very much.

[The prepared statement of Dr. Burns follows:]

PREPARED STATEMENT OF ROBERT T. BURNS

Anaerobic Digestion of Animal Manures for Biogas Production

DOCUMENT PREPARED BY
DR. ROBERT T. BURNS, P.E. AND LARA B. MOODY, P.E.
DEPARTMENT OF AGRICULTURE & BIOSYSTEMS ENGINEERING
IOWA STATE UNIVERSITY

OCTOBER 19, 2009

Overview of Manure AD

While the anaerobic digestion of manure and other organic substrates is not a new technology, there has been a recent increase in interest regarding the production of renewable energy from the anaerobic digestion of manures. The primary drivers behind the renewed interest in biogas production from the anaerobic digestion of manures include an increased interest in producing renewable energy, the development and implementation of a viable carbon credit market in the U.S., and an increase in the availability of grant funding to support the development of renewable energy production systems, such as manure anaerobic digestion systems.

Anaerobic digestion is a process for converting organic material into biogas, which is composed primarily of carbon dioxide (CO_2) and methane (CH_4). Because methane is an energy-rich compound, biogas can be used as a fuel. For this reason, anaerobic digestion is considered a means of extracting energy from animal manures and other organic residues. As is suggested by the word anaerobic, the digestion process is carried out by microorganisms that function in an environment without oxygen. Anaerobic digestion is used for processing and treating organic wastes from industry, sewage treatment plants, and animal feeding operations. This document will focus solely on its use at animal feeding operations for manure and process wastewater.

The main gaseous emissions from anaerobic digestion of manure are CO_2 and CH_4; however, trace amounts of gaseous hydrogen sulfide, ammonia, nitrogen, carbon monoxide, and hydrogen can be present in biogas depending on the characteristics of the material being digested. The typical composition of biogas resulting from anaerobically digested manure is 60–70 percent CH_4 and 30–40 percent CO_2. Biogas should be at least 50 percent CH_4 by volume to be effectively combusted as a fuel (USDA–NRCS, 2007). The volume of biogas produced for a given animal species is related to the organic content of the waste, the portion of organic material that could be converted by the digestion process, the fraction of the total manure that can be collected for digestion, and the conversion efficiency of the digester.

Biogas can be used as a renewable energy source in various ways. It can be directly utilized on-farm for heat, light or other purposes, directly combusted in boilers to produce hot water, cleaned and conditioned and sold into a natural gas pipeline, used to fuel engine-generator or micro-turbines for electricity generation, or used as a fuel source for Stirling cycle engines or fuel cells. In each of these cases, the manure-derived biogas can offset fossil-fuel use, thereby providing reductions in greenhouse gas emissions and generating marketable carbon credits. The use of biogas reduces methane emissions from stored manure, and this reduction from the base-line manure management scenarios determines the greenhouse gas emission credits that can be potentially marketed. It should be noted however that the amount of methane emitted by stored manure varies greatly with manure and storage conditions.

In addition to producing renewable energy that can be used to replace traditional fossil fuels, controlled anaerobic digestion of animal manures reduces odors in manure management systems, reduces the organic strength of manures, and can potentially reduce the pathogen content of manures. Odor from stored animal manure is primarily the result of volatile organic compounds (VOC) and reduced sulfur compounds that are produced due to the ongoing microbial processes in any manure or organic-waste storage system. In a digester with a biogas recovery system, both odorous (e.g., hydrogen sulfide & VOCs) and non-odorous (methane, hydrogen) compounds are collected and destroyed during combustion. The organic matter content in manures is reduced during anaerobic digestion; it is microbially degraded and converted to biogas. However, not all organic matter is converted to biogas, and the achievable anaerobic conversion efficiency is dependent upon digester operation and feedstock loading parameters. Anaerobic digestion is a nutrient-neutral process; in other words, you can produce energy but retain the fertilizer value of the manure. While the anaerobic digestion of manure does not remove macro-nutrients such as nitrogen and phosphorus, the digestion process does convert a portion of these nutrients into forms that are more readily available to plants. The anaerobic digestion process also reduces the total solids content of manures and thus makes them easier to land apply as fertilizer in regards to pumping and handling.

Estimated Energy Production Potential from Manure Anaerobic Digestion

Total Animal Manure U.S.

Based on manure storage and handling methods at U.S. animal feeding operations, energy production via anaerobic digestion of animal manure is technically feasible at dairy, swine, beef feedlot, and caged layer facilities. At dairy, swine, beef feedlot, and caged layer facilities manure can easily be collected and handled as a feedstock for an anaerobic digestion system. Meat bird production manure (turkeys and broiler chickens) mixed with bedding is generally only removed from a production house at the end of one or more production cycles, therefore it was excluded from the calculated energy production potentials shown below.

The energy production potential from manure anaerobic digestion can be estimated based on expected methane yield from various digested manure types based on their Chemical Oxygen Demand (COD) content. Methane production is equated to the destruction of organic matter (measured as Chemical Oxygen Demand (COD)), where every gram of COD converted, produces 395 mL of CH_4 (at 35°C and 1 atm) using anaerobic digestion (Speece, 1996). The energy production estimates presented in Table 1 are based on the on-hand inventory of animals by type in the U.S., the mass of organic matter (estimated via COD) excreted per day per animal, and the expected anaerobic digestion conversion efficiency for a given manure type. To provide a basis for comparison, the potential energy production from the anaerobic digestion of manure has been estimated and expressed in billions of kWh per year as shown in Table 1. These estimates assume that one cubic meter of methane contains 33,500 BTU and that engine generators with a conversion efficiency of 30 percent are used. (Table 1).

Table 1. U.S. Energy production potential from anaerobic digestion of available manure sources.

Animal	[1]No. of Animals (Millions)	[2]kg COD/ animal-day	[3]Digester Efficiency	m^3 CH_4/day (Millions)	Production days per year	kWh/year (Billions)
Dairy Cow	9.32	8.1	30%	8.9	365	9.59
Swine						
Breeding	5.97	0.785	60%	1.1	365	1.19
Nursery	21.7	0.120	60%	0.6	336	0.61
Finishing	38.6	0.390	60%	3.6	336	3.53
Beef on Feed	13.9	2.0	30%	3.3	330	3.18
Poultry (Layer & Pullets)	332	0.018	70%	1.7	360	2.28
Total						20.4

[1]Number of animals on hand daily based on USDA-NASS (2009).
[2]Chemical Oxygen Demand (COD) excretion rate based on ASABE Standard D384.2 (2006)
[3]Potential digester efficiency based on USDA-NRCS Tech Note No. 1 (2007)

Based on the number of dairy cows, swine, cattle on feed, and layers in the U.S. (USDA–NASS, 2009) and on manure excretion values (ASABE, 2006), the energy production potential from anaerobic digestion of manure in the U.S. is estimated to 20.4 billion kWh per year. By comparison, in 2008 the total U.S. electricity generation was 4.1 trillion kWh (EIA, 2009). Approximately nine percent of the total U.S. electricity generation in the U.S. was from the renewable energy sector in 2008. Table 2 shows the renewable energy sources and their current electricity net generation. If all of the available manure from the U.S. dairy, swine, beef and egg-layer poultry industries were anaerobically digested it is estimated that 20.4 billion kWh could be produced per year, which would be equivalent to approximately 0.5 percent of the total 2008 U.S. electrical generation. The biomass renewable energy source category (consisting of waste, landfill gas, municipal solid waste, other biomass, and wood and derived fuels) is currently the greatest non-hydroelectric renewable energy source, with wind energy a close second, at 45 percent and 42 percent, respectively. Utilizing energy from anaerobic digestion of manure could potentially provide a significant renewable energy source, supplying as much as 16.5 percent of the current non-hydroelectric renewable energy capacity.

Table 2. U.S. Electricity net generation from renewable energy by energy source for 2008.

Energy Source	Billon kWh/yr
Total	371.7
Non-hydroelectric Total	123.6
Biomass	55.9
Waste	17.1
Landfill	6.6
Municipal Solid Waste Biogenic	8.5
Other Biomass[1]	2.0
Wood and Derived Fuels[2]	38.8
Geothermal	14.9
Hydroelectric	248.1
Solar/Photovoltaic	0.8
Wind	52.0

*Data for this table was obtained from EIA report "Renewable Energy Consumption and Electricity Preliminary Statistics, 2008"

[1]Other Biomass – agricultural byproducts/crops, sludge waste, and other biomass solids, liquids, and gases

[2]Wood and Derived Fuels – Black liquor, and wood/wood waste solids and liquids

However, it must be recognized that anaerobic digestion is not a feasible option for every U.S. animal feeding operation. A study documented by U.S. EPA AgStar (2006) indicated that unit costs for construction and operation decrease significantly as digester system size increases. Specifically, the U.S. EPA AgStar report indicates that anaerobic digestion systems on facilities with milking herds larger than 500 cows are more likely to have positive financial returns than facilities with less than 500 cows. Similarly, confinement swine operations utilizing flush, pit recharge, or pull-plug pit systems with more than 2,000 animals (or deep-pit systems with more than 5,000 animals) are more likely to be economically feasible than operations with fewer animals. Using the constraints above, the U.S. EPA AgStar (2006) document provided an estimated electrical generation capacity of 6.3 billion kWh per year. It is important to note that this estimate does not include potential renewable energy production from U.S. beef or poultry production systems.

The current manure based anaerobic digester electrical production capacity for the systems considered to be most economically feasible, can be derived from the U.S. EPA AgStar Anaerobic Digester Database (U.S. EPA AgStar, 2009). As of September 2009, manure based digesters in the U.S. with electricity and co-generation systems produced a combined total of 422 million kWh per year. Current manure based digesters in the U.S. utilize dairy, swine, beef, layer, and duck manure as well as other industry by-products as co-substrates. In the U.S., dairy and swine operations have the greatest energy production potential. Current manure-biogas-based electrical energy production is seven percent of the U.S. EPA AgStar potential estimated for dairy and swine production, and it is two percent of the potential when basing the estimate on all usable manure sources.

Dairy

Utilizing the U.S. dairy cow numbers available from USDA–NASS (2009), the estimated energy production potential from all dairy cows is 9.6 billion kWh per year. However, recognizing that it may not be feasible to develop biogas recovery systems at all farm locations, U.S. EPA AgStar (2006) reports that there were 2,623 dairy farms with herd sizes greater than 500 animals with a potential energy production yield of 3.0 billion kWh per year. On the basis of animal numbers, California has the greatest energy production potential, with 963 farms maintaining herds greater than 500 animals (Table 3). However, on the basis of current electricity production, Wisconsin leads the country in dairy manure based anaerobic digestion energy by producing 30 percent of the current total anaerobic digestion based electrical production from U.S. dairies. The current U.S. dairy digester projects only produce 10.7 percent of the "feasible" energy production potential reported by the U.S. EPA AgStar report.

Table 3. Top 10 U.S. states for yearly manure based anaerobic digestion energy production potential for dairy and the state's current manure based anaerobic digestion energy production.

State	[1]No. of Farms	Energy Production Potential (million kWh)	[2]Current Electricity Production (million kWh)	[2]Percent of Potential
California	963	1,203	40	3.3%
Idaho	185	267	33	12.4%
New Mexico	123	259	0	0%
Texas	149	154	0	0%
Wisconsin	175	138	102	73.9%
New York	157	132	31	23.5%
Arizona	73	126	0	0%
Washington	122	126	8	6.3%
Michigan	72	73	28	38.3%
Minnesota	60	46	4	8.7%
10 State Sub-Total Dairy	2,623	3,148	337	10.7%
Remaining 40 States	5,442	624	91	14.6%
Total Dairy	6,904	6,332	428	25.3%

*Data for this table was obtained from the U.S. EPA AgStar document "Market Opportunities for Biogas Recovery Systems: A Guide to Identifying Candidates for On-Farm and Centralized Systems (2006)

[1]Dairy farms with more than 500 cows

[2]Current energy production was derived with data obtained from the U.S. EPA AgStar online manure based anaerobic digester database (2009); data includes anaerobic digester systems with electricity and co-generation , and some systems may include substrates in addition to dairy manure.

Swine

Utilizing the U.S. pork production numbers available from USDA–NASS (2009), the estimated energy production potential from all hogs is 5.3 billion kWh per year. However, recognizing that it may not be feasible to develop biogas recovery systems at all farm locations, U.S. EPA AgStar (2006) determined there were 4,281 swine operations utilizing flush, pit recharge, or pull-plug pit systems with more than 2,000 animals (or deep-pit systems with more than 5,000 animals). Deep pit systems, common in the Midwestern U.S., would need to be modified to provide a means of frequent digester loading as well as a storage system for digested effluent before anaerobic digestion systems could be installed on these facilities. The U.S. EPA AgStar study (2006) estimated that it would be feasible for deep pit operations with greater than 5,000 head to undergo the expense necessary to modify a deep pit system for biogas production and recovery. On the basis of animal numbers, North Carolina has the greatest energy production potential (when Mid-western deep-pit systems are excluded), with 1,179 farms maintaining a feasible number of animals (Table 4). The current swine digester projects produce less than one percent of the "feasible" energy production potential.

Table 4. Top 10 U.S. states for yearly manure based anaerobic digestion energy production potential for swine and the state's current manure based anaerobic digestion energy production.

State	[1]No. of Farms	Energy Production Potential (million kWh)	[2]Current Electricity Production (million kWh)	[2]Percent of Potential
North Carolina	1,179	766	0.24	0.03%
Iowa	1,022	677	0	0%
Minnesota	429	234	0	0%
Oklahoma	52	196	0	0%
Illinois	267	184	0.32	0.17%
Missouri	200	177	0	0%
Indiana	234	145	0	0%
Nebraska	148	134	0.62	0.46%
Kansas	91	109	0	0%
Texas	13	75	17.4	0.23%
Remaining 40 States	646	487	4.8	1%
Subtotal	4,281	3,184	23.5	0.7%

*Data for this table was obtained from the U.S. EPA AgStar document "Market Opportunities for Biogas Recovery Systems: A Guide to Identifying Candidates for On-Farm and Centralized Systems (2006)

[1]Swine operations with flush, pit recharge, or pull-plug pit systems with more than 2000 animals or deep-pit systems with more than 5,000 animals

[2]Current energy production was derived with data obtained from the U.S. EPA AgStar online manure based anaerobic digester database (2009); data includes anaerobic digester systems with electricity and co-generation , and some systems may include substrates in addition to dairy manure.

Cattle on Feed

Utilizing the U.S. beef production numbers available from USDA–NASS (2009), the estimated energy production potential from all cattle on feed is 3.2 billion kWh per year. Currently, there are two beef manure digester projects in the U.S. (located in Iowa and Pennsylvania) with a combined electrical generation capacity of 21.8 million kWh per year, which is less than one percent of the production potential. The top five states raising cattle on feed include Texas, Nebraska, Kansas, Iowa, and Colorado (USDA–NASS, 2009). Manure collected from cattle feed-lots for digestion needs to be relatively free from soil or other inert material. As such, concrete feed-lots or cattle house over slatted floors are better candidates for anaerobic digestion systems than earthen feed-lots.

Layers

Utilizing the U.S. layer industry production numbers available from USDA–NASS (2009), the estimated energy production potential from all layers and pullets is 2.3 billion kWh per year. Currently, there are three layer manure digester projects in the U.S. (located in Pennsylvania and North Carolina) with a combined electrical generation capacity of 2.4 million kWh per year, which is 0.1 percent of the production potential. The top five states in number of hens for egg production are Iowa, Ohio, Indiana, Pennsylvania, and California. Layer manure contains more COD (and thus more biogas production potential) on an as-is basis than many other manures. The lack of high-solids manure digesters, as well as concerns over ammonia toxicity and grit removal have limited the implementation of anaerobic digesters on layer farms in the U.S.

State of the Industry

Manure Digester Numbers & Trends

There are currently 135 operational manure based digesters in the United States according the *U.S. EPA AgStar—Guide to Operational Systems* released in February, 2009. It is estimated that approximately 250 manure based anaerobic digesters have been built on U.S. farms over the past 20 years. Other countries, such as Germany and China, have rapidly adopted manure-based anaerobic digesters over the past decade, but the U.S. has been much slower to implement this technology. China currently has approximately 16,000 manure based digesters operating on medium and large-scale concentrated animal production facilities. The number of large-scale manure-based digesters has increased six-fold in China over the past five years. Similarly, Germany has over 5,000 digesters in operation that co-digest manure and other substrates such as corn silage. Like China, the majority of German manure-based digesters have been put into operation in the last five years. Based on estimates made by Eurostat, The United States has approximately four times the number of dairy cows, beef cattle, and pigs as Germany, yet Germany has 37 times the number of manure based biogas plants. Likewise, China has approximately three times the number of dairy cows, beef cattle, and pigs as the United States, yet China has 118 times the number of manure based biogas plants as the United States. This data indicates that both Europe and China are ahead of the U.S. in implementing manure based anaerobic digestion systems for the production of renewable energy from animal manures.

Table 5. Comparison of animal numbers and farm manure digesters for various European countries, China and the United States

	No. of Dairy Cows (1000)[a]	No. of Beef Cattle (1000)[a]	No. of Pigs (1000)[a]	Combined No. of Animals (1,000)[a]	No. of Manure Based Biogas Plants (yr estimated)[b]	Biogas Plants per 1,000,000 Combined No. of Animals
Germany	4,229	12,987	26,716	43,932	5,000 (2009)	114
Austria	530	1,997	3,064	5,591	350 (2007)	63
Italy	1,830	6,486	9,252	17,568	70 (1999)	4
The Netherlands	1,587	3,966	11,735	17,288	70 (2007)	4
Denmark	568	1,570	12,195	14,333	56 (2007)	4
China	9,660	107,095	446,662	563,417	16,000 (2009)	28
USA	9,315	94,491	66,259	170,065	135 (2009)	0.8
Iowa	216	3,940	19,600	23,756	3 (2009)	0.1

[a] Statistics from the European Union were obtained from Eurostat (2009), statistics from China were obtained from USDA-FAS (2009) and statistics from the United States were obtained from USDA-NASS (2009).
[b] Digester numbers were obtained from Birkmose et al., (2007), US EPA AgStar (2009), and Burns (2009)

Both China and Germany have government sponsored programs in place that provide a subsidized electrical purchase rate for electricity produced from manure-based anaerobic digesters. Currently, Germany pays $0.33 per kWh for electricity produced from manure and silage based anaerobic digestion, and China pays $0.09 per kWh. The rate paid for electricity produced from manure-based anaerobic digestion in the United States varies by state. Some states have implemented green rates for electricity generated from renewable sources such as manure anaerobic digestion, but in most areas of the United States, the rate paid for electrical power produced from manure anaerobic digestion that is sold back to the utilities is the prevailing wholesale rate, which averages around $0.03 per kWh. A review of 38 U.S. manure-based digester case-studies suggests that the average cost to produce electricity using a manure-based anaerobic digestion system in the U.S. was approximately $0.10 per kWh in 2006 (USDA–NRCS, 2007). This data highlights the need to develop anaerobic digestion systems and associated technologies that can reduce the energy production cost using manure-based digester systems.

Data collected by the US EPA AgStar program indicates that 78 percent of operational U.S. manure digesters are located on dairies. Additionally, 90 percent of all U.S. manure-based digesters are generating electricity.

Manure based anaerobic digester numbers are increasing in the United States. The 2007 *U.S. EPA AgStar—Guide to Operational Systems* reported that there were 42 operational manure-based digesters in the U.S. in 2007, while the 2009 *U.S. EPA AgStar—Guide to Operational Systems* reports that there are currently 135 operational systems. Additionally, the 2009 AgStar report indicates that there are currently 22 manure-based digesters under construction and an additional 65 more planned in the United States. This recent increase in interest in manure-based digesters is correlated to an increase in grant funding support for manure-based digester construction through State and federal programs.

Manure Anaerobic Digester Technology

The anaerobic digestion process is well understood, and there are examples of manure digesters that have operated successfully for more than 20 years both in the Unites States and abroad. The overall success (defined here as systems remaining in operation) rate of manure anaerobic digestion has been about 50 percent over the past two decades in the United States. An analysis of the most recent U.S. data compiled in the *U.S. EPA AgStar—Guide to Operational Systems* indicates that approximately 250 manure anaerobic digestion systems have been constructed in the United States over the past 20 years. Currently, 54 percent of the total number manure digestion systems that have been constructed in the U.S. are still in operation. It is important to note that a lack of return-on-investment has been the driver that has lead to many decisions to stop the operation of existing manure-based anaerobic digestion systems rather than physical or technological problems with the digesters themselves. Like many alternative energy technologies, the development and utilization of manure anaerobic digestions systems on full-scale farming operations has historically been high-cost and high-risk compared to traditional manure management.

Technology Development Gaps

The primary challenge to the wider adoption of manure anaerobic digestion on U.S. farms has been the lack of a return-on-investment from renewable energy sales from these systems. As such, research and development into technologies that will reduce the renewable energy production costs for manure-based anaerobic digestion systems is needed. Specific examples of research and development needs are listed and further explained below.

Low-cost on-farm biogas cleaning systems

As indicated previously, biogas contains more than methane. Biogas consists of methane (CH_4), carbon dioxide (CO_2), and trace amounts of hydrogen sulfide (H_2S) and other components, such as small amounts of ammonia (NH_4) and hydrogen (H_2). Biogas produced from manures typically contains between 60–70 percent methane by volume. Carbon dioxide concentrations vary between 30–40 percent by volume. Biogas is also typically saturated with water vapor. Methane concentrations must be at least 50 percent for biogas to burn effectively as fuel. Varying levels of hydrogen sulfide and moisture removal are required before biogas and be utilized as a fuel in most applications. Carbon dioxide removal is not required for the direct combustion of biogas for on-farm heat or electricity production, but if a high BTU fuel is needed (examples would include direct sales of biogas to the natural gas pipeline and compression and storage of biogas as a vehicle fuel), CO_2 removal would be required. Although the amount of hydrogen sulfide (H_2S) in manure-based biogas is small (typically measured in hundreds to thousands of parts per million), it must be removed prior to use for most biogas applications. If biogas will be sold to the pipeline as natural gas, it must be completely conditioned (moisture and CO_2 removal) and cleaned (H_2S) to very strict standards.

There are proven and reliable methods for cleaning and conditioning (sometimes referred to as "upgrading") biogas. The cost of biogas upgrading is currently reported to range from $6 to $10 per MMBtu ($0.60 to $1 per therm) depending on the cleaning technology selected and the size of the installation. Typically, biogas cleaning and conditioning costs increase on a $ per MMBtu basis as installation size decreases. The current reported costs to clean and condition biogas currently exceed the commercial price of natural gas. As such, the development of lower-cost biogas cleaning and upgrading technologies are needed for the use or sale of upgraded biogas from manure-based anaerobic digestion systems to be feasible. For smaller on-farm applications, this need is even greater since the cost per MMBtu is typically greater than for larger systems.

Development of biogas Direct-Use options

Biogas can be combusted and used to produce electricity in an engine generator or micro-turbine, cleaned and conditioned and sold to the natural gas pipeline, or used directly on the farm to produce heat. Engine generators and turbines used to produce electricity have been estimated to represent approximately 36 percent of the initial capital cost of farm-based anaerobic digestion systems (USDA–NRCS, 2007). Internal combustion electrical generation systems also represent a large fraction of the operation and maintenance cost of manure-based anaerobic digestion systems. The direct-use of biogas on the farm as an energy source provides a method for farms to produce and utilize renewable energy with a lower capital investment. Direct on-farm use options include use as a heat source for animal housing systems (either through direct combustion or using boiler based systems), as a heat source for grain drying or as a fuel for vehicles and equipment used on the farm. If biogas is well conditioned and cleaned, then the resulting methane can be used as a direct replacement for natural gas or propane on the farm. As noted previously in this document however, the current cost to upgrade biogas to natural gas quality currently equals or exceeds the cost to purchase natural gas. One option to avoid these currently economically unfeasible biogas upgrading costs is to develop on-farm direct use options that can operate on either raw or partially upgraded biogas. Examples would include the development of new, or modification of direct-combustion systems for heating animal housing or for drying grain that could reliably operate on raw (unconditioned and un-cleaned) biogas This is a very basic research and development need, but a very practical one.

AD systems for Mid-west Swine Finish systems (deep-pit systems)

The swine finishing industry represents the second largest renewable energy production potential from anaerobic manure digestion in the U.S. Manure from U.S. swine finisher operations is estimated to have the potential to provide 3.53 billion kWh per year of renewable energy. The greatest concentration of swine finishing operations are located in the Mid-Western United States. Iowa produces more market hogs than any other state in the U.S., but currently no renewable energy is being generated from swine manure anaerobic digestion in the state. All swine systems types together (breeding/gestation/farrowing, nursery and finishing operations) in the U.S. produce less than one percent of the "feasible" energy production potential identified by the U.S. EPA AgStar program. While swine finishing operations represent the largest energy production potential within the swine sector, many finish operations utilize manure management systems that are not easily compatible with current anaerobic digestion technologies. Deep-pit manure management systems are the most commonly used manure management systems on Mid-western swine finish operations. In a deep-pit system the pigs are housed on a slatted floor and their manure is stored in an eight foot deep pit located directly under the animals. Since the manure management system is completely under roof, no rainfall is collected or comes in contact with the manure. Manure is typically stored for a one-year period in a deep-pit system and is then utilized as a crop fertilizer. With a deep-pit system there is no external manure storage, the manure is continually collected in the deep pit as it is excreted by the pigs since it is allowed to fall through the slatted floor. While this approach provides a system that is immune from weather related discharges, the lack of an external manure storage makes the application of current anaerobic digestion systems much more expensive. This is because the raw (undigested) manure and the digested effluent need to be stored separately and not co-mingled with current digester technologies. Research is needed to develop anaerobic digestion systems that can be utilized with current deep-pit manure management systems without the cost of constructing new external storage for digested effluent.

AD systems for Solid and Semi-Solid Manure Digestion

Traditionally, manure anaerobic digestion has been confined to farming operations that generate liquid manures or liquid manure slurries. This is because traditional manure digester designs require manures that can be pumped and handled hydraulically. A large fraction (~30 percent?) of manure in the U.S. that is handled as a solid or semi-solid. One example is layer manure: the estimated energy production potential from the U.S. layer industry through the anaerobic digestion of manure is 2.3 billion kWh per year. Currently, only 0.1 percent of this energy production potential from layer manure has been reached in the U.S. There are currently only three layer manure digester projects in the U.S. with a combined electrical generation capacity of 2.4 million kWh per year. The majority of layer manure in the U.S. is managed as a solid material in either high-rise or manure-belt housing systems. Since manure is collected on a regular schedule from the manure-belt housing systems, they would be very good candidates for anaerobic digestion systems. Additionally, solid-manure handling systems for beef and dairy are also potential candidates for high-solids digestion systems. Solid and semi-solid anaerobic digestion systems have been successfully utilized for nearly two decades on a variety of municipal organic wastes. The development of anaerobic digestion systems that are feasible to utilize with solid and semi-solid animal manure management systems would allow for the production of renewable energy from these animal production systems within the United States.

Advanced NO_X controls for biogas engines and micro-turbines (CA issue)

Dairy farms represent the largest potential for renewable energy production from manure-based anaerobic digestion in the United States of any given animal type. California is the state that has the greatest number of dairy farms with over 500 head. The U.S. EPA AgStar program has identified dairies with more than 500 head as having the greatest potential for the economical application of manure digesters. Yet at present, only 3.3 percent of the potential renewable energy production from California dairies larger than 500 head is being generated. Biogas-to-energy systems in the central valley of California (where the majority of the larger dairies in California are located) must meet strict NO_X emissions limits required by the California Air Resources Board and the San Joaquin Air Pollution Control District. A NO_X limit of nine parts per million has been established as the Best Available Control Technology (BACT) requirement for systems that combust biogas in this area. The engine generator systems commonly used to combust biogas and produce electricity will not meet the California nine-part per million BACT limit. NO_X control systems such as selective catalytic reduction can be utilized on internal combustion biogas engines to meet the California BACT NO_X limits, but the cost of adapting and utilizing currently available technology increases the cost of renewable energy production from these systems. Research into new innovative, lower-cost NO_X control technologies as well as the development of lower-cost selective catalytic reduction systems targeted at farm-scale internal combustion generators for NO_X removal options from exhaust gases generated from the on-farm combustion of biogas needs to be conducted. The identification and development of these systems would enable additional renewable energy generation from the dairy sector.

References

American Society of Agricultural and Biological Engineering. 2006. D384.2 Manure Production Characteristics. ASABE Standard, St. Joseph, MI.

Birkmose, T., H.L. Foged, J. Hinge. 2007. State of Biogas Plants in European Agriculture. Prepared by the Danish Agricultural Advisory Service for the European Parliament.

Burns, R.T. 2009. Current Status of Manure Anaerobic Digestion in the U.S. and Beyond. Presentation at the conference "Energy Production from Anaerobic Digestion of Dairy Manure," Sept. 28–29, 2009, Madison, WI.

Energy Information Administration. 2009. Renewable Energy Consumption and Electricity Preliminary Statistics. U.S. Department of Energy. Viewed on-line on 10/14/09 at: *http://www.eia.doe.gov/cneaf/alternate/page/renew_energy_consump/rea_prereport.html*

Eurostat. 2009. European Union Agricultural Statistics. Viewed on-line on 10/6/09 at: *http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/data/main_tables*

Speece, R. 1996. *Anaerobic Biotechnology for Industrial Wastewaters.* Archae Press. Nashville, TN.

United States Department of Agriculture—National Agricultural Statistics Service. 2009. United States Agricultural Commodity Statistics. Viewed on-line on 10/6/09 at: *http://www.nass.usda.gov/QuickStats/indexbysubject.jsp?Pass_group=Livestock+%26+Animals*

United States Environmental Protection Agency—AgStar. 2009. Anaerobic Digester Database. Viewed on-line on 10/16/09 at: *http://www.epa.gov/agstar/operational.html*

United States Environmental Protection Agency—AgStar. 2006. Market Opportunities for Biogas Recovery Systems: A guide to Identifying Candidates for On-Farm and Centralized Systems. EPA–43008–06–004. Viewed on-line on 10/14/09 at: *http://www.epa.gov/agstar/resources.html*

United States Department of Agriculture—Foreign Agricultural Service. 2009. Global Commodity and Products Markets. Viewed on-line on 10/6/09 at: *http://www.fas.usda.gov/commodities.asp*

United States Department of Agriculture—Natural Resources Conservation Service. 2007. Technical Note No. 1, An Analysis of Energy Production Costs from Anaerobic Digestion Systems on U.S. Livestock Production Facilities.

BIOGRAPHY FOR ROBERT T. BURNS

Robert T. Burns is a tenured Professor of Agricultural and Biosystems Engineering at Iowa State University with a joint extension/research appointment in the area of environmental management of agricultural systems. He holds a B.S. in Agricultural Engineering, a M.S. in Environmental Engineering and a Ph.D. in Civil Engineering from the University of Tennessee. He is a licensed Professional Engineer (P.E.). His research focuses on animal waste management and includes work air emissions monitoring and mitigation from animal production facilities, anaerobic digestion, solids separation and phosphorus recovery. His area of extension specialization is the design of animal waste management systems and nutrient management planning for livestock and poultry operations. Robert currently leads a national Comprehensive Nutrient Management Planning (CNMP) certification program for USDA Technical Service Providers (TSPs). Robert has developed and lead 33 national and international training courses dealing with animal waste management topics. Dr. Burns manages the ISU Animal Waste Management Laboratory and leads a 25-person Animal Waste Management team composed of full-time staff, graduate students and undergraduate students. Dr. Burns' Animal Waste Management team is completely funded by external competitive grants, and has average annual competitive external support of over $1.5 million per year.

Dr. Burns has sixteen years of experience working on environmental and agricultural engineering projects. During his professional career Robert has published over 200 technical publications dealing with animal waste and air quality management, served as PI or Co-PI on 53 funded grants totaling over 6.8 million dollars and served as a major or co-major professor to 24 Master's and doctoral students. Prior to joining the faculty at Iowa State University, Robert was on the faculty at The University of Tennessee for nine years where he served as the Water Quality and Waste Management specialist for the Tennessee Agricultural Extension Service. From May 15–November 15, 2006 Dr. Burns served a six-month assignment as a National Conservation Engineer within the Conservation Engineering Division of the Washington, DC National Headquarters office of the USDA Natural Resources Conservation Service. In this position he worked on alternative manure treatment systems and USDA Technical Service Provider Issues.

Dr. Burns has worked on environmental and agricultural engineering projects and other consulting services with the USEPA, U.S. AID, USDA–NRCS, USDA–FAS, The Commonwealth Development Corporation of Great Britain, America's Clean Water Foundation, Conestoga Rovers and Associates, Thoreau Environmental Capital and numerous State departments of agriculture and environmental protection. Robert has worked on projects in Armenia, Croatia, Bulgaria, Denmark, Romania, The Democratic Republic of Zambia, The Republic of Korea, and the United Kingdom. Robert has designed over 350 animal manure management, irrigation and water supply systems. In 2003 Robert received the Nolan Mitchell Extension Worker Award from the American Society of Agricultural Engineers for distinguished educational programming in the areas of water quality and animal waste management. In 2008 Dr. Burns was appointed to the USDA National Agricultural Air Quality Task Force for a two-year term. This task force is charged with advising the U.S. Secretary of Agriculture with respect to the role of USDA to provide oversight and coordination related to agricultural air quality. Robert also serves as the Chair of the National Pork Producers Council, Pork Air Science Policy Advisory Committee (PASPAC) where he assists the U.S. swine industry to review and best utilize current scientific information in regards to air emissions from pork production systems.

DISCUSSION

Chairman BAIRD. Thank you, Dr. Burns. An outstanding series of information from all of you. Thank you very much, and I will recognize myself for five minutes to ask questions and will be followed by my colleagues here.

Thanks again to our honored guests. We appreciate your presence and wish you a good day and an enjoyable visit. Thank you very much.

METHANE AS A GREENHOUSE GAS

Dr. Burns, I have a question—I have got a lot of questions for all of you, but let me just start with this one since you just spoke. It is my understanding that methane is a more potent greenhouse gas by quite a significant factor relative to CO_2. I don't know the answer to this, and maybe you don't, either, but I am going to ask it. In the energy bill that has been kicked around in the House and what is working in the Senate, does reduction of methane through the kind of process you have described, do you get a greater credit for that than you would if you were reducing CO_2 by volume? I don't know that that is the case, but it seems like it might ought to be.

Dr. BURNS. Let me see if I can rephrase your question to make sure I understand. Methane is recognized, depending on which protocol you are looking at and which time scale between——

Chairman BAIRD. You need to hit your mic again or move it. Is it lit up? There you go.

Dr. BURNS. Yes, sir. Methane is recognized to be 21 to 23 times more potent than CO_2, depending upon which protocol and time scale. Now, if I can rephrase the question, are you asking is the combustion of methane—obviously when we combust methane we also generate some CO_2 in that process, and if I understand you correctly, you are asking if we receive a net gain from the combustion of methane as compared to the CO_2 that is emitted from the process?

Chairman BAIRD. That is part of the question, and then the other question would be this. If we are not in some way using the methane to generate energy, presumably some of that is just being released into the atmosphere. So should you get, under any of the energy bills that are moving, do you think you should get credit for reducing the methane that is going into the atmosphere through your kind of processes?

Dr. BURNS. Yes, and I think the answer is yes, you should get credit, but it has to be recognized that the credit increment is tied to what was the existing system, i.e., if there had not been a digester at this location, how much methane would be generated?

Chairman BAIRD. Right.

Dr. BURNS. Because once the anaerobic digestion process is put in, we are going to greatly increase the methane production. So it is that differential between the two that should be credited.

HOW DOE CAN DIVERSIFY ITS BIOMASS PROGRAMS

Chairman BAIRD. Got you. Very, very good point. One of the things that strikes me as I listen to the testimony of all of you really is that we have got this remarkable resource that can be used in a number of ways, and I really appreciate that. I think our staff has done an outstanding job of giving us diverse perspectives on ways things can be used. But as I look at the biomass program in DOE—and maybe I am wrong and maybe someone can correct me, or if not, help us figure out what we ought to do—but as I look at the biomass program, biopower, really like we are talking about today, it has really been neglected. It has mostly been fuels, and mostly frankly ethanol. I mean, we just put so much effort into that and it seems to me at the expense of much of what you are doing.

And so what I would like to ask your comments—you have all actually given excellent suggestions for things DOE could conceivably do better. It doesn't seem like it is being done now. It is almost solely focused on ethanol. Do you have some comments—if this committee or this Congress were to direct DOE and say, you know, "we want you to give more attention to biopower," in any of the forms you all have talked about, how would that best be accomplished in your interaction with DOE? Some of you work for some of the labs that get funding for DOE. I don't want to put you in a difficult spot there, but from your professional expertise, how would that—how could we best make sure that we are broadening the portfolio of possible uses of biomass? And I will just open that up to whomever wants to take a stab. Mr. Spomer, you look ready to go, so fire away.

Mr. SPOMER. I think the first thing that generally exists today is there is a real bias against things that burn, in whatever form, whether it is gasification or direct combustion. Ultimately there is combustion of wood. If we can get past that bias and start to focus on the fact that, according to USDA, from the forest, there is 386 million bone-dry tons a year from the forest alone. When you add in all these other factors, you start to get into 1.2 billion tons per year of biomass. We are talking about eliminating, whether it is biofuels or biopower, that would be a huge portion of our national need for power and for fuel. So first we have got to get the recognition that this is good for the forest. The methane question is an excellent one. If this stuff lies and rots on the forest floor or whether it is agricultural waste that is lying in the ditch, it is going to convert to 50 percent methane, 50 percent CO_2. By combusting it, we may be carbon-neutral, but we are significantly greenhouse gas positive. The key thing is to use technology and advances in technology and support advances in technology to improve the efficiency of the conversion so we can compete economically.

Chairman BAIRD. And as a businessman, and I don't want to put words in your mouth, but from what I am hearing, it sounds like—would it be fair to say that the bulk of the research that has been coming out of DOE in terms of how to deal with biomass as an energy source—has not been particularly beneficial to the kind of utilization that you do in your industry?

Mr. SPOMER. Almost none.

Chairman BAIRD. Okay. And here is an industry that is using wood products constructively and has revitalized a rural economy. Mr. James, if you wish to comment on that, please?

Mr. JAMES. Thank you, Mr. Chairman. It might be instructive for the Subcommittee to ask DOE to confirm or correct my understanding—and this is from hearing other scientists—that the combustion of biomass is a more efficient conversion of that material into energy than using it to make liquid fuels. I am not one to suggest we should not make liquid fuels with that material, but we should also be striving for, where we can, maximum utilization of maximum benefit.

The other thing, Mr. Chairman, I would suggest that some investigation might be worthy. We are very fortunate to have a technology that is in demand internationally, and I can tell you that the Europeans, and particularly the British here lately, because they have developed some new incentives to use dedicated biomass if you will, are scouring around the United States locking up our biomass in long-term contracts. Now, I don't want to hurt our business opportunities, but as a citizen I am concerned that there could be a point in the future where we have developed our technologies and we have committed ourselves with the appropriate climate legislation and we find out that our feedstocks are being exported in other places. I would urge that the Subcommittee might ask for some research in that particular area.

Chairman BAIRD. Outstanding points. And you know, you said it more delicately than I might, but one of the sad things about I think the ethanol emphasis has been, and my understanding of the research on that, our net energy output is negative on that after a whole lot of work and investment. I mean, with corn-based ethanol at any rate, not to mention all the food impacts and the fertilizer and the water.

I am particularly intrigued also, Mr. James, by this issue of onsite processing of materials. I have got timber communities now that have 20 to 25 percent or more unemployment. They have just been devastated, and the idea that when you go out there with your skidders and everything else, all the logging equipment that you could take out along as part of the contract, as part of the bid, take out equipment to process wood fuels in some fashion—it makes an awful lot of sense to me, especially with the economic implications and the energy implications. So I applaud you for that.

Anyone else want to talk about this issue of DOE and ways they could maybe diversify the portfolio in a different way?

Mr. SPOMER. Just one thing. I would like to give DOE some credit for. They supported our effort at developing plantation fuel purpose-grown biomass in New York. We have done some interesting work with the State University in New York, Environmental Science and Forestry College, on purpose-grown dedicated woody biomass. I think that that, in addition to the existing portfolio that was described, could really make a difference. It takes fallow farmlands, otherwise not useful. This is not a competitor with food. It is an opportunity for people to get a revenue stream, and that is particularly good because it acts as a carbon sink in addition to being carbon-neutral on the generating side.

Chairman BAIRD. Thank you. I recognize Mr. Inglis for five minutes. I apologize to my colleagues. I went over a little bit.

ACTIVITIES AT AGRI-TECH PRODUCERS, LLC

Mr. INGLIS. Thank you, Mr. Chairman. So show and tell, Mr. James. Do you have any of the product with you? I was hoping so, because I saw it in Spartanburg, and I thought that—will you get it, Katrina?

Chairman BAIRD. Is this product placement?

Mr. INGLIS. Yeah, it is. Have you seen what it looks like?

Chairman BAIRD. Has anybody got a match?

Mr. INGLIS. A pipe might be appropriate. If you could light it in a pipe—maybe not.

Chairman BAIRD. We don't deal with that in this committee.

Mr. INGLIS. So anyway, it is really interesting.

Chairman BAIRD. Sometimes people on this committee, I think they have been smoking something. So we are going to leave that.

Mr. INGLIS. I just thought my colleagues would be interested in seeing it because I got to see it in Spartanburg. It is a very interesting product. You can see how it could be fed immediately into the—mixed with the coal, right? That is what we are looking at here?

Mr. JAMES. Yes, Congressman. I have given you two samples, one is torrefied wood chips, and the other is semi-torrefied or a mixture of torrefied——

Chairman BAIRD. You have not mixed up Dr. Burns' substance with this? Before I pass this down, I want to——

Mr. JAMES. Although we are exploring whether the process can be helpful there.

Dr. BURNS. Yeah, sure.

Mr. JAMES. But you also have some torrefied switchgrass condensed into a pellet—excuse me, a briquette. So you have got two forms of samples there.

Chairman BAIRD. Thank you. So this is efficient to burn as an energy source?

Mr. JAMES. It is extremely efficient, much more efficient than untreated wood or cellulosic material.

Chairman BAIRD. And would you burn this—I am sorry. I am jumping into your time.

Mr. INGLIS. No, it is all right. You can smell—it smells sort of like charcoal or something like that.

Chairman BAIRD. Pass this down to Roscoe. He will be wanting some of this on his farm.

Mr. INGLIS. So yeah, by looking at it, you can see how easily it could be co-fed with coal, I guess, because it has sort of the look and feel of coal, pulverized coal. It has less energy density I guess because it is less dense stuff.

And also, I have got one of these brochures, I will show it to the Chairman, of what it looks like out in the field, the machine out in the field so that you can basically at the location get rid of some of the water and thereby reduce the transportation costs if you move it on to where it is going to be burned, right?

Mr. JAMES. Yes, the picture you are referring to is the prototype on campus at North Carolina State University. And we are developing, with the help of Kusters Zima, your constituent company in your district, larger units that are fixed units that will be placed close to forest areas or agriculture areas. But thanks to DOE support, we are also looking at developing mobile units which will be on wheels, we hope, and be able to actually go from logging deck to logging deck, maybe from community to community, in order to process material as close to the point of harvest as possible.

Mr. INGLIS. It is very interesting.

Mr. JAMES. Mr. Chairman, you and your Committee Members or Subcommittee Members are certainly welcome to come and take a look at the prototype as some point in time if you choose to do so. We would be glad to make arrangements for you.

Chairman BAIRD. Thank you.

Mr. INGLIS. Do you have any wipes for everybody up here now? They have got it all over their hands. The Chairman was just wiping his hands all over my papers, I want the record to show. Anyhow, I guess I asked for it. So it is very helpful.

LANDFILL BIOGAS PRODUCTION

Dr. Burns, the BMW in Spartanburg, South Carolina, gets more than 50 percent of its power from a trash dump, takes some methane, runs it through a 10-mile pipeline and powers north of 50 percent of the power needs of the plant. And the interesting thing about that, there are a number of wonderful things about it, but one of them is that they have speculated in the future perhaps rather than the “not in my backyard” (NIMBY) principle, they might actually be saying, here, put your trash right here in my industrial development. I want a big trash dump right here. So instead of a 10-mile pipeline, we have a half-a-mile pipeline to a bunch of industrial facilities that are using. Similar problem I guess for siting hog farms and things like that. If they become an energy producer, then it is less hard to site those, I suppose, right?

Dr. BURNS. There is certainly an economy of scale that is associated with energy production through anaerobic digestion. Landfill biogas production systems are typically much larger in terms of the generating capacity than manure systems would be. My understanding is landfill systems are currently—the electricity generated from those systems is probably done so at a cost that is a third or so of the cost of what we are currently seeing as generation costs from manure digestion systems. Again, they are larger systems, typically three to four megawatt generating capacity, and they are very predictable systems. With the landfill operation, the materials there, it is in tune, and there is a very predictable life expectancy. You are going to be able to draw a curve that says what the gas yield is going to be. It is going to exponentially come up, it is going to level off, it is going to decay. So you know that yield. And there are other factors that make manure digestion a little tougher. I mean, animals are not coming in and out of the landfill. There is not potential changes in your biomass generation capacity in that landfill because the gas yield in the landfills occur generally after they are closed, and then you yield that gas toward energy.

So they have been very successful. It is a model that can be looked at but there are some differences; primarily scale, I think, would be the one that would be different from what we see in ag systems with manure.

Mr. INGLIS. Thank you. Thank you, Mr. Chairman.

Chairman BAIRD. Thank you. Dr. Bartlett.

THE ENERGY NEEDS OF BIOPOWER FUEL PRODUCTION

Mr. BARTLETT. Thank you. You mentioned that you get more energy from burning this than if you burned wood. But unless we are going to suspend the law of thermodynamics, you won't get more energy from it than you would have gotten if you burned that wood because you have some energy invested in creating this product. So really, you are trading convenience for energy because you are going to get less energy out of your wood eventually if you go through this process and then burn it than you would have gotten if you had burned it initially. So you are trading energy for convenience here, are you not?

Mr. JAMES. Congressman, of course, you are correct. However, the systems, boilers and otherwise, that burn material, burn more efficiently with higher BTU and less moist material. There is a lot of energy lost if you were to burn greenwood. You have got to use a lot of energy to evaporate the water off of that, and you are sacrificing some of the efficiency of your boiler——

Mr. BARTLETT. So that helps offset your loss here?

Mr. JAMES. Exactly.

FOREST HEALTH

Mr. BARTLETT. Let me ask you a question about forest health. Absent fires, how does removing biomass from forests make them healthier? If we look at a tropical rainforest, if you remove the biomass, you have removed essentially all of the nutrients because they are all in the cycle of life. That has to be somewhat true in our temperate forests, although nowhere near to the extent of the tropical rainforest. I am having trouble understanding how removing biomass, absent fires, how removing biomass makes the forest healthier.

Mr. SPOMER. I can use the example of upstate New York and really the whole northeastern, mixed northern hardwood forests.

Absent an active—typically what happens in New York, for example, absent a low-grade biomass market, loggers—there is active logging going on up there. They are taking maple, the cherry, the best wood, and with no market for anything else, they take that out, turn it into furniture, tabletops, and they leave the stuff that you really don't want, diseased trees, unmerchantable timber, sometimes non-indigenous species, and then they also leave the junk on the floor. And what happens in the area around, say, our Lyonsdale plant, is that there is active forest thinning because there is a market for the low-grade material. When pulp and paper was active, there was a market for that low-grade material. The pulp industry has basically dried up in the north, and absent a market for that, you have got a changing nature of the native forest in New York and in Maine and in other places, more so in New York. And those forests tend to be less healthy——

Mr. BARTLETT. Less healthy? You mean that they don't have the kind of trees growing there that you would like to have growing? So when you take the trash trees out as biomass, that permits the maples and cherries and so forth to be more competitive?

Mr. SPOMER. Right, and also thinning the forest allows new growth. In a mono-aged forest where you have got a big canopy and you are not getting new growth, you are not as efficient at consuming CO_2. A forest fires is nature's way of fixing that problem. It is not a big problem in the Northeast where it is particularly damp. It is worse in my home State of Colorado where the whole forest can go up in a hurry. Being able to thin the forest and allow new growth, diverse growth, is good. The Audubon Society tells us it is good for habitat, and the Department of Environmental Conservation says it is critical for forest health in New York.

Mr. BARTLETT. That helps me understand what you mean by forest health. It doesn't mean you are growing more forest, it means you are growing the kind of forest you would like to grow.

PROTECTING TOPSOILS AND SOIL QUALITY

I have questions for the second round, and let me just introduce it now, in that I have a huge concern for sustainability. Even with no-till farming, for every bushel of corn we grown in Iowa, three bushels of topsoil go down the Mississippi River, and topsoil is topsoil because it has organic material in it. We can rape our soils for a few years, and then we will not have the quality of soils—we are fighting very hard today to maintain the fertility of our soils. I am having trouble understanding how we can take very much biomass off our soils and still maintain that fertility to the soils.

Let us come back for a second round to a discussion of this because I think that experiments in sustainability are the most needed experiments in this field.

Thank you, Mr. Chairman.

Chairman BAIRD. Thank you, Dr. Bartlett. I am going to go ahead and let you follow up on that if you like because I went over a little bit as did Mr. Inglis, and I think it is an important line of questioning. So if you are interested, let us follow up on that.

Mr. JAMES. Congressman, if I could respond to your earlier question about forest health, the natural course is for a forest to have fires every several years which thin out the underbrush. That is the naturally occurring thing.

Mr. BARTLETT. You are from what state?

Mr. JAMES. I am from South Carolina.

Mr. BARTLETT. Okay. That is different than up here. I cannot remember a forest fire up here. It just doesn't happen in our temperate forests, at least none that I am familiar with. Once in a while you have a little dry litter burn, but a real forest fire, we just don't have them. I never heard of a forest fire here. It is really different than your pine forests down there and in the west. We don't have them here.

Mr. JAMES. My point is, to go onto forest health issues, to the extent there is a lot of underbrush and small diameter trees that are crowded against each other, the rapidity with which disease and infestation spreads in the forest is accelerated. So being able to mechanically thin those, since in most forests we live and we run highways through and we do other things that don't allow prescribed burns to take place, mechanical thinning is what is happening to the extent there is budget for it.

For example, the Forest Service has a limited budget, and one of the reasons that they have developed the Woody Biomass Utilization Program was to try to generate a cash stream off of that biomass that would allow them to treat additional acreage in the forest.

The other thing I would say is that the process that we have, the living parts of the tree, which are the bark and the leaves, tend to turn into a fine powder whereas the corpus of the tree turns—you know, when you feed chips in, you get chips out. That fine powder tends to have more minerals in it, and we are looking to see whether that can be a biochar or soil application material that could go back into the forest or back on the farm to enhance soil health.

Chairman BAIRD. Do other panelists want to address the broader issues of soil quality and the loss thereof in regard to biomass? Dr. Burns.

Dr. BURNS. Yes, sir. I think it is an excellent comment, and I would just like to comment on when we look at manure anaerobic digestion to point out that those manurers will still be land applied as fertilizers. Digestion, it is important to understand, is a nutrient neutral process. The amount of nutrients removed through the anaerobic digestion process for the obligate requirement of the microbes is very, very small. So those macro nutrients are going to be utilized by crops. The nitrogen (N), phosphorus (P), and the potassium (K) are still going to be there, and farmers that utilize anaerobic digesters are still going to have to have the same land base for their nutrient management plan, and that manure is still going to go to the field. It is true, however, that it will go to the field with less carbon content than it contains prior to digestion. For beef and dairy systems, we can expect to see 30 to 40 percent of that organic carbon being converted over to methane and CO_2 in the process and for swine and layers, we are more in the 60 to 70 percent range. But those nutrients from a fertility standpoint will still be there, and the benefits of the fiber, and a lot of that carbon is still going to be there from building the soil till.

MANURE METHANE PRODUCTION

So in that system, we are still going to see manure go into the ground as a fertilizer and be utilized that way.

Mr. BARTLETT. If manure is spread on the field and you go through sheet composting, there is little or no methane produced by that?

Dr. BURNS. In a composting process——

Mr. BARTLETT. If it is sheet composting, you spread the manure on the field so that there is no anaerobic activity going on. It is very thin, then you shouldn't get methane, should you?

Dr. BURNS. No, sir, if we keep the system aerobic in nature, we will not generate methane. It will go through aerobic respiration. It will generate CO_2. There will still be carbon loss there and also unfortunately with that aerobic process, we are probably going to lose nitrogen out of the system as gaseous ammonia.

Mr. BARTLETT. You have to incorporate it into the soil to avoid that?

Dr. BURNS. Incorporation of solid manures is recommended to avoid that gaseous ammonia loss, yes, sir.

Chairman BAIRD. Thank you, Dr. Bartlett, important line of questioning, and I think especially regarding what we have seen with ethanol which you have talked about with great eloquence in the past in this committee.

SITING BIOMASS RESEARCH WITHIN DOE

Continuing on the theme I began earlier, it seems apparent in a number of areas of additional research and government activity—whether it is intellectual property or targeted research on catalysts and a host of areas where we could be doing things—if DOE were to spend, give more attention to biopower broadly, from your gentlemens' perspective, what office of DOE would be technically equipped to do that? Where would we best go within DOE to make this happen? Mr. James and then Dr. Stevens?

Mr. JAMES. Mr. Chairman, I will try to take a stab at that. The answer to your question is I am not exactly sure. However, the Office of Biomass certainly comes to mind. If I could also go back to an earlier point that you made, we participated with others in our region in one of the last solicitations for a biomass supply chain, and as I recall, the language in the solicitation did not exclude making solid fuels, but there may have been a bias toward liquid fuels. I think your staff might wish to analyze the awards that came out of that solicitation. It may make sense for whatever part of DOE that is going to take on this assignment to have a very specific solicitation for solid fuels or some other types of activity that supports some of the testimony that you have heard today. So there is not an ambiguity and then I guess some opportunity for—

I don't want to use the word bias but some opportunity for not fully exploring that opportunity.

Chairman BAIRD. And to follow up, Mr. James, obviously you are in the industry that would deal more with the solid rather than the liquid. Would there be a counter-argument that would say, well, the reason they are biased, if there was a bias, the reason they favored—let us not deal with predilection, but maybe they just made an empirical scientific judgment that there is more bang for the buck, so to speak, or better return on investment in liquid fuels. Is that the case or do you think it was more—I am not trying to put you on the spot, but the question for me is, we should be looking at all our options, but we have to look critically at those options.

Mr. JAMES. I think we should look at all options, and we support all options. However, the understanding that I have from the scientists that I am talking to, suggest that direct combustion, whether treated or untreated, of biomass gets more—you end up with more energy on a net basis than you would by converting it into a liquid fuel.

Chairman BAIRD. Partly because of Dr. Bartlett's repeated observation of the second law of thermodynamics.

Mr. JAMES. I am sure he is right again on that, sir.

Chairman BAIRD. Thank you. So your point would be, whichever branch of DOE is focused on this, we want it to be a focus that it is not just in name only and we are going to go right back to the liquid results?

Mr. JAMES. The other thing I would say, Mr. Chairman, that the electric utilities and other coal users are great collaborators, and we have had, you know, good luck in working with a variety of utilities. So there is an opportunity to leverage some of the users, including coal suppliers, if you will, into this process because we all need to figure out, how do we work together? How do we use existing distribution and supply chains that are already in place in order to make a system work?

So I think if a solicitation could be a little more specific in our case on solid fuels and encourage collaboration between users and suppliers and other members of that value and supply chain, then we could come up with a very robust solution.

Chairman BAIRD. It will be my intention following this hearing to actually inquire precisely of these kind of issues of DOE in writing. We will drop them a note.

Dr. Stevens, I want to applaud PNNL for its work on forest products, obviously given our region, and PNNL has really been a pioneer.

What insights can you offer on this question?

Dr. STEVENS. Well, I am not in the position to recommend where you put your money, but I would simply comment that Office of Biomass Program has had active biopower programs several years ago. And several of the people who worked on those then are still there. The expertise is resident, and the capability exists there today for applications-oriented work, and of course Office of Sciences are capable of doing very basic work as well. As a recommendation it would be very useful to bring together the two to solve both the very fundamental problems and the applications problems in a meaningful way.

Chairman BAIRD. That is very, very useful. Maybe we should move the first presidential caucus to a timber state, and we would have a different focus on the products.

Anyone else wish to comment on this? Mr. Inglis?

BIOPOWER IN URBAN AREAS

Mr. INGLIS. Thank you, Mr. Chairman. You know, Dr. Burns, I am very interested in what you are talking about and how it may apply to human waste as well as animal waste. I was in Mumbai a while ago, and we were traveling through the city at 2:00 or 3:00 in the morning, and I really thought if we struck a match we might have exploded. And we were told, and I don't know if it is correct, but we were told it is because they discharge the effluent into the bay at that time of day. So it was 2:00 or 3:00 in the morning, and it was just an amazing amount of methane aroma, having grown up on the coast and knowing what marsh gas is like. So it really struck me that a country like that that has so many people and has to come up with some way of coping with that waste problem, if you can turn waste into something good, it sure is a win-win proposition. Actually, while there we visited a place where they are doing that. They are taking food waste from a dormitory and turning it into methane that then powers the kitchens. And I asked them about actually not the scalability, it is the opposite of scalability, keeping it small enough that you could actually do a neighborhood that way, and they said that is the challenge. You don't want to, in the case of such a system, you don't want to build it so large because you lose some of the benefits. If you can do it much more locally, you have this great benefit of being able to have a relatively small system that takes a great deal of waste and then turns it into something useful.

Is that something that, as we develop things on the farm, is that a possibility of moving into the city with those kind of lessons learned on the farm?

Dr. BURNS. I think there are great examples around the world of where that has already been done, and I think whether you are going to see that implemented or not is going to depend on where you are in the world, i.e., what is the relative cost of energy. For example, the largest number of manure digesters by far are in the class of what we call "domestic digesters" where human excrement, not soil, is mixed with household waste and some animal manure. Specifically right now there are over 37 million of these household digesters in China, and they have been growing significantly because the central government of the People's Republic of China has put a great amount of funding into supporting their construction. I have done work with these systems outside of Tianjin and some watershed projects where they are using them to try to reduce pathogens and so forth. But what you see is it is a very quickly-adopted system, and the biogas that is generated is used for heat, for light in these systems. India has four million of these systems. Nepal has 140,000. You see them in locations, again, where the relative cost of energy, if you were to look at the cost of, say, purchasing propane or natural gas in those communities, versus the cost of going out and picking up wood to build a fire in the corner of your home, those costs are such that it makes a lot of sense to generate biogas. If we look at the relative cost of energy in this country, you don't see those systems adopted because energy from a relative cost, from our income, is so low that we are going to purchase it rather than pick up wood to cook.

There are, though, examples of a lot of biogas being generated from municipal wastewater treatment plants in this country. It is very common, it has been done for years, it is very successful. Those facilities, however, are typically aerobic treatment plants because, recall that we mentioned anaerobic digestion is nutrient neutral, so we will go through the tertiary treatment process and use an aerobic step where we will biologically remove nutrients, and it may also be with some combinations of some chemical steps as well. But then the solids that are generated off that other primary clarifiers are typically digested anaerobically, and that biogas yield will then be converted through either IC (internal combustion) engines or microturbines into electricity production. So we do see it come from that standpoint.

Mr. INGLIS. Interesting. Anyone else want to add anything to that? If not, thank you, Mr. Chairman.

Chairman BAIRD. Dr. Bartlett.

THE SUSTAINABILITY OF BIOPOWER SOURCES

Mr. BARTLETT. Methane is the coal miner's black banth, is that true? Explosive gas in coal mines is methane, is it not, which is odorless, isn't it? So the odor you get from the swamp is not the methane. It is something that goes along with the methane. Our irrational exuberance over bioenergy has resulted in two bubbles which have burst. The first was the hydrogen bubble, and nobody talks about hydrogen anymore because I think they finally figured out that hydrogen is not an energy source. You will always get less energy out of the hydrogen than it took to make the hydrogen. The second bubble that broke was the corn ethanol bubble, and I and one of my staff people did some early, back-of-the-envelope calculations and reached essentially the same conclusions that the National Academy of Sciences reached. They said if we turned all of our corn into ethanol, every bit of it, and discounted for fossil fuel input, it would displace 2.4 percent of our gasoline. They said you could save more gas than that by tuning up your car and putting air in the tires. They further said that if we took all of our soybeans and converted them into soy diesel, a more efficient process by the way than corn ethanol, that this would displace 2.9 percent of our diesel. Now, most of our arable land, our farmland, is planted to corn and soybeans. So just as an old dirt farmer being very practical, when I note that if we took all of our corn and converted it to ethanol, discounting for fossil fuel input, you would displace 2.4 percent of our gasoline, and if you did the same thing for all of our soybeans for soy diesel, you would displace 2.9 percent of our diesel, and noting that corn and soybeans are grown on almost all of our land that is good enough to grow crops on, I am wondering sustainably how much we should really expect to get from our lands that are not good enough to grow either of these crops on. I just think that the third bubble that is going to break is the cellulosic ethanol bubble. I think we will get something there. I think we will get nothing like the potential that many people feel. Am I wrong?

Mr. SPOMER. This is a topic that I know something about, and you have asked a number of questions in there. First, on the purpose-grown portion of it, let us use the State of New York, for example. We are looking at getting five bone-dry tons per acre on about, up to an available two million acres of fallow farmland that is perfect for fast-growing woody biomass willow. And that is a copus crop. We don't till the soil. You will go through 21 years of life before you have to replace it, harvesting every three years. That five tons per acre—let us assume we just get a million of it planted—is 600 million, potentially, based on a process that we are working on, roughly 600 million gallons of year of petroleum products, not ethanol. The conversation, as I used to say, if it was easy to turn wood into alcohol, some guy in Tennessee would have figured out how to do it a long time ago.

The fact is, though, it is not a stretch to turn it into hydrocarbons, and it is being done, it can be done.

Mr. BARTLETT. Now, what about sustainability, though?

Mr. SPOMER. Well, the sustainability side of it is your harvest plan. Are you taking biomass, which by definition in a forest sense is the waste, not the—you never go down and cut a tree down just for biomass in the Northeast. They are going to go in and do their normal logging thinning process——

Mr. BARTLETT. But if you leave that on, those trimmings, in the forest, it then contributes to the humus in the forest and therefore the nutrients which helps additional trees grow. At least to some extent, our forests have to be a bit like tropical rain forests. When you remove the tropical rain forest, you have laterite soils that bake as hard as a brick and you have essentially no good agricultural land.

Mr. SPOMER. Okay, and the worst thing you can do to the forest is put a farm on it. The best thing you can do for a forest is keep it thin because for example, in New York, it takes up to 60 years to grow a harvestable tree. You have got 60 years of leaf shed from that tree that is putting nutrients back into the soil. When you take down a typical northern hardwood, up to 50 percent of that tree is not going to be turned into furniture. That remaining top and limb is going to rot in the form that you would see it in the forest, and it is not going to necessarily turn into nutrients. It is going to be turning into methane and CO_2. That is the stuff that we clean up. Those leaves that shed every year are going back to put nutrients back into the soil.

So from a sustainability perspective, it is at least demonstrated in New York specifically that thinning the forest properly increases the total rate of growth of that forest and therefore the CO_2 intake of that forest. You are giving it more room to move, you are allowing younger trees to grow. So from a sustainability perspective, at least—and we are not the experts. We rely on experts who have told us this, that it is truly sustainable and truly good for the health of the forest long-term. So if you just assume that on a national basis, assume that is true on a national basis, and we are talking about half of the hydrocarbon fuel use in this country could come from sustainable forest biomass.

Mr. BARTLETT. Mr. Chairman, I am still skeptical and I look at what we could get from all of our arable land, and we expect to get many times that from this land that is not good enough to grow either corn or soybeans on. I still remain skeptical of what the real sustainability is going to be. Even though those limbs and top rot and the CO_2 and methane goes off, you have still got humus there. That is what holds water, that is what holds nutrients in the forest. So you still have something very valuable that is left after that.

Thank you, Mr. Chairman.

FOREST PRODUCTS FROM FEDERAL LANDS AS BIOMASS

Chairman BAIRD. Thank you, Dr. Bartlett. And I can speak just briefly about the—I will get to you in just a second, Dr. Burns. In the Northwest, one of the challenges we have is we have got literally millions of acres of disease, and this is really true in the Rockies, of diseased trees which are tinder dry and are ready to go up in smoke. Now, admittedly, not the entire tree burns unless it is a really bad fire, and what is happening in the northwest is we are actually thinning some of those out for forest health in two ways. The forests are overgrown, and that increases the fire risk, but also if you have got insect-infested trees you need to get those out.

Here is the sad part from a global overheating perspective, we are actually taking that wood out, stacking it up, and burning it. Now, if you care about CO_2, which I know you do, the paradox for me is we are actually spending good money for the sake of forest health to get this stuff out, but we actually are not using it for energy. And sadly the initial draft of the energy bill that passed the house, prohibited, expressly prohibited the use of forest products from federal lands to count as biomass. Not only did it prohibit that, it so severely restricted private lands that that became impractical. And then the down waste stream. So then let us say you process the byproducts to pulp and paper, then you get black liquor out as a byproduct. The only way you can count black liquor, according to the initial bill, a renewable fuel source, was if every shred of fiber upstream came from a renewable source as defined by this. It was a ludicrous approach, and actually I got that fixed in the energy bill. It was myself and a coalition of others. But it was maddening to see a bill that was supposedly designed to diversify our energy portfolio and reduce greenhouse gases basically giving no credit for using greenhouse gases for fuel and leaving it instead on the ground to rot or burn up.

So your point is absolutely well-taken. I think it absolutely does apply if we were to just say we were going to grow huge forests and we are going to cut them down and never replenish that soil. I think you would have some adverse impacts. But when we are taking byproducts out from the normal harvest process or from dead and diseased trees, I think we can use it actually pretty productively, not that it is a panacea as some looked at I think ethanol.

Dr. Burns, you had a comment?

MORE ON SITING BIOMASS RESEARCH AT DOE

Dr. BURNS. Yes, Mr. Chairman. I wondered if it were possible to circle back to your question on what office in DOE would be best equipped to provide broader assistance in the R&D area.

Chairman BAIRD. Not just possible, desirable.

Dr. BURNS. Okay. Thank you, sir. Perhaps the Energy Efficiency and Renewable Energy (EERE) Office might be the correct office to look at some of this. They have been involved in fuel cell work and advanced conversion of electricity work and I believe they might be the appropriate people to take a look at some of the R&D needs that were identified earlier in the hearing.

Chairman BAIRD. Share with me your insights on why that would be superior. I don't have a dog in the fight. You say the biomass activity?

Dr. BURNS. I don't have experience with the Biomass Office, and I am just simply familiar that the Renewables Office has been doing some work that fits closer to this category, or closely with this category. I don't know compared to the Biomass Office.

Chairman BAIRD. Okay. We have gone a long time today. Did you have another follow-up question, Dr. Bartlett? Mr. Inglis?

I am not going to ask you to do this on the record, actually on the record if you want to, but I am not going to ask today, but if any of you want to comment at some point about how DOE can be more responsive. It is not just about what entity is there, but you all have given us very good suggestions for everything ranging from intellectual property rights as mentioned earlier, catalysts, et cetera, to technologies to logistical flow of materials. I don't know, I am not experienced enough or knowledgeable enough, to know—you talked about DOE drops down requests for proposals or grant opportunities, et cetera. To what extent is there a bottom-up process? In other words, where you call could talk—actually, I am going to ask you to answer that, where you folks are, people in the industry, not just you here, but others who may be in the audience or doing other things who can say to DOE, hey, here is what we really need, not you telling us what you think we need but this is what we need. Can you conduct some research or create proposals? What mechanisms exist or have you been able to, both pro and con, if there are both and then we will finish up if my colleagues will indulge that question, please?

Mr. JAMES. Mr. Chairman, I am not aware of any specific mechanism at the moment. We do have relationships with USDA, and they have created conferences and other kinds of get-togethers that allow us to have some dialogue with them. I remember doing a webinar with USDA staff where several dozen of them were on the line with us talking about torrefaction. Thank you for having the hearing. It turns out that some DOE folks that I have been trying to talk with for the last month are here, and we are going to get together and do some chatting after this meeting.

Chairman BAIRD. We will bring donuts to the next one and really get something done.

Mr. JAMES. But you know, I think there needs to be more mechanisms that allow us to get together and have some dialogue, and I am sure the agency will do that.

I want to compliment Secretary Chu and the energy that he has brought to the agency. I see a lot of difference in the agency now, and we are looking forward to finding ways to collaborate with him.

CLOSING

Chairman BAIRD. Great. Anyone else wish to comment on that? If not, I want to bring the hearing to a close. I want to thank our witnesses for testifying before this subcommittee. I want to thank particularly my colleagues for their insightful and informative questions and comments. The record will remain open for two weeks for additional statements for the Members and for answers to any follow-up questions the Subcommittee may ask of the witnesses.

Witnesses are excused with our gratitude, and the hearing now stands adjourned. Thank you all very much and thanks to the guests in the audience as well.

[Whereupon, at 3:52 p.m., the Subcommittee was adjourned.]

Appendix:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Don J. Stevens, Senior Program Manager, Biomass Energy & Environment Directorate, Pacific Northwest National Laboratory, U.S. Department of Energy

Questions submitted by Representative Paul D. Tonko

International Activities

Q1. You mentioned international research activities around biomass pyrolysis in your oral statement. Please provide us more information on this research and the interests of the countries funding it.

- *Of the countries you are working with, which one is leading in the area of biomass pyrolysis for power production?*

A1. There is International recognition of the potential for pyrolysis to meet a variety of fuel and electricity needs. Interest in pyrolysis is strong in European countries including Finland, the Netherlands, Germany, Austria, and the United Kingdom. Canada also has significant, long-standing programs in pyrolysis, and more recently, Australia, Malaysia, China, and other countries have also expressed interest.

The interest in producing electricity is particularly strong in European countries, where renewable energy policies have created markets for high priced biopower. By comparison, policy incentives of similar magnitude do not exist in United States. Some countries see biopower as the earliest use of bio-oil, with transportation fuels being viewed as an attractive alternative as the upgrading technology advances.

Pacific Northwest National Laboratory is involved in several collaborative research programs with international groups. Douglas C. Elliott, an international expert on biomass pyrolysis at PNNL, leads the International Energy Agency's Bioenergy Agreement's Task 34, Biomass Pyrolysis. This Agreement promotes information exchange, exchange of researchers, and production of joint scientific reports. The activities of this group leverage the resources of all participating countries. DOE's Office of the Biomass Program represents the United States at the IEA Bioenergy Agreement's Executive Committee.

PNNL is also working in two international collaborations, one with Canada and one with Finland, to examine the extent of stabilization and upgrading needed for utilization of bio-oil for either electric generation or biofuel applications. This work is examining the characteristics of bio-oils produced from a range of biomass feedstocks, including beetle-killed pine, with the intent of matching those with end-use requirements. The work leverages DOE–OBP's funding with equivalent amounts from Canada and Finland to organizations such as Finland's VTT Laboratory, Natural Resources Canada (Canmet) Laboratory, and the University of British Columbia.

Based on their long-standing interests and also their current RD&D activities, both Finland and Canada can reasonably be considered leading international countries in the area of using pyrolysis for biopower.

Is Additional Biopower RD&D Needed?

Q2. In 2002, the Biomass Program was formed to consolidate the biofuels, bioproducts, and biopower research efforts across DOE into one comprehensive RD&D effort. It is my understanding that the Office of Biomass does little, if any biopower research anymore. Given the pending Renewable Electricity Standard legislation in both the House and the Senate, what would a Biopower Initiative look like at DOE?

- What kind of goals and RD&D would you recommend?
- How much would it cost to implement a strategic biopower program to meet pending Renewable Electricity Standards?
- Under a new biopower initiative what is the best way to organize the RD&D activities?
    - If yes, what office at DOE is technically equipped to conduct this RD&D?
    - What activities is the Office Fossil technically suited to conduct?
    - What activities are EERE technically suited to conduct?

A2. With finite amounts of biomass available annually, our nation must make informed decisions about our priorities for using this resource. To help make these decisions, we need a solid scientific basis to show where the greatest impact can be obtained between the options for power, fuels and chemicals. The scientific basis requires some analysis be conducted.

If this information concludes that biopower is a priority for biomass utilization, then RD&D needs to be focused on technologies that offer high-efficiency electricity generation. Advanced technologies such as gas turbines or fuel cell systems offer potential electric generation efficiencies in the range of 30–40 percent. This compares with typical wood-fired combustion/steam-cycle systems which have electric generation efficiencies of approximately 15–25 percent. By focusing RD&D on the high-efficiency generation technologies, we can achieve the highest impact from the finite biomass resource.

The cost of such a program will depend on many things including the relative levels of research and demonstration activities, as well as other factors. PNNL, as a government Laboratory, is not in a position to recommend a specific funding level.

The organization of such a program will depend on the types of research being conducted, and particularly if co-firing with coal or other fossil resources is included. PNNL conducts research for both DOE–EERE and DOE–FE, and believes that both organizations have relevant capabilities. The DOE Biomass Program had an ongoing biopower program several years ago, and the technical capabilities to conduct such a program still exist there. OBP has a solid understanding of biomass reaction behavior and biomass sustainability, both of which are crucial to a successful program. Likewise, DOE–FE has important capabilities around co-firing biomass with fossil resources. In addition, the efforts of DOE's Office of Science may also be necessary to solve fundamental scientific questions that arise. A successful RD&D effort would likely include all of these organizations.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. Scott M. Klara, Director, Strategic Center for Coal, National Energy Technology Laboratory, U.S. Department of Energy

Questions submitted by Chairman Brian Baird

Q1. Is Additional Biopower R&D Needed?

A1. In 2002, the Biomass Program was formed to consolidate the biofuels, bioproducts, and biopower research efforts across DOE into one comprehensive RD&D effort.

Q1a. It is my understanding that the Office of Biomass does little, if any biopower research anymore.

A1a. The Department's Office of Biomass Program (OBP) has funded biopower related programs since 2000.

In previous years:

- 2000–2001: Awarded several co-firing and gasification-for-power projects (eleven awards made)
- 2002: Directed by the Administration and Congress to reduce emphasis on biopower and/or co-firing
- 2002-Present: Shifted emphasis to develop gasification and pyrolysis-based technologies for transportation biofuels production

Current activties:

- Suny Cobleskill, Biowaste to Bioenergy, FYO8–FY1O, up to $1,279,200—a program to determine the efficacy of a bench-scale prototypic rotary kiln gasification system for the conversion of biomass into a clean energy. Sponsored by Congressman Paul D. Tonko (D–NY 21st District).
- Raceland Raw Sugar Corporation, Bio-Renewable Ethanol and Co-Generation Plant, FY05–FY10, up to $3,557,000—a program to identify, determine, and understand fundamental burn characteristics and properties of alternative fuel sources to replace coal for energy generation, with emphasis on impacts in cement processing. Sponsored by Senator Mary L. Landrieu (D–LA) and Senator David B. Titter (R–LA).
- The National Renewable Energy Laboratory, the Pacific Northwest National Laboratory, UOP, and Ensyn Technologies have a project "Biomass Pyrolysis". In the project's second phase, pyrolysis oil produced in the study will be upgraded to varying degrees and tested for power generation, to establish the level of upgrading required and any cost advantages.
- The Program is involved in several feedstock activities that have relevance to biopower production (although not conducted specifically for this purpose), for example:
    i. The Program is currently updating its 2005 report "Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply." This report assesses the forest-derived and agriculture-derived biomass resources of the U.S.
    ii. The Program is working with the Sun Grant Initiative to address barriers associated with the development of a sustainable and predictable supply of U.S. biomass feedstocks, including woody feedstock.

In addition, EERE's Office of Industrial Technologies Program (ITP) is funding two biomass-related projects:

- Burns & McDonnell Engineering Company, RD&D of Biomass Boiler Applications for the Food Processing Industry, up to $ 1,999,963—Demonstrates use of a biomass (wood waste and tire-derived fuel) boiler system to offset natural gas consumption at the facility.
- Fiscalini Farms L.P., Renewable Energy Power Generation Project, up to $779,300—Measures and analyzes a biogas energy system for power generation. The system will use digester gas from an anaerobic digester located at the Fiscalini Farms dairy for power generation with a reciprocating engine.

Q1b. Given the pending Renewable Electricity Standard legislation in both the House and the Senate, what would a Biopower Initiative look like at DOE?

A1b. During December 2009, OBP is conducting a Biopower Technical Strategy Workshop to identify the technical and economic hurdles of biopower deployment. This knowledge will aid OBP's strategic planning for biopower together with three regional workshops on biomass feedstocks. A draft report of the biopower workshop will be made available.

Q1c. What kind of goals and RD&D would you recommend?

A1c. During December 2009, OBP is conducting a Biopower Technical Strategy Workshop to identify the technical and economic hurdles of biopower deployment which could be used to identify appropriate goals and any RD&D needed to achieve them.

Q1d. How much would it cost to implement a strategic biopower program to meet pending Renewable Electricity Standards?

A1d. The cost of a strategic biopower program is dependent upon the final renewable electricity standards and policy.

Q1e. Under a new biopower initiative what is the best way to organize the RD&D activities?

A1e. During December 2009, OBP is conducting a Biopower Technical Strategy Workshop to identify the technical and economic hurdles of biopower deployment which could be used to identify appropriate goals and any RD&D needed to achieve them.

Q1f. If yes, what office at DOE is technically equipped to conduct this RD&D?

A1f. The OBP within the Office of Energy Efficiency and Renewable Energy (EERE) is technically equipped to conduct this RD&D in coordination with the Office of Fossil Energy's Clean Coal and Natural Gas Power Systems Program.

Q1g?. What activities is the Office Fossil technically suited to conduct?

A1g. The Office of Fossil Energy's Clean Coal and Natural Gas Power Systems Program is technically suited to conduct coal combustion and gasification at scale, and power generation from the gasified stream. Additional RD&D into gasification/co-firing could bring cost reductions and greater acceptability of the technology in the electrical utility industry.

Q1h. What activities are EERE technically suited to conduct?

A1h. Within EERE, the OBP believes that it currently has the capabilities to manage an RD&D program that would cover the breadth of activities which may be suggested by the Biopawer Technical Strategy Workshop.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Robert T. Burns, Professor, Department of Agricultural & Biosystems Engineering, Iowa State University

Questions submitted by Representative Paul D. Tonko

Q1. In your testimony, you mentioned that a 2006 U.S. EPA AgStar report indicates that anaerobic digestion systems on facilities with milking herds larger than 500 cows are more likely to have positive financial returns than facilities with less than 500 cows. There are many of these small and medium sized dairy farms in my district in Upstate New York. In light of this fact, what federal policies do we have in place, or do you think we should *have in place, to incentivize and entice smaller farms to use anaerobic digesters?*

A1. The current dis-incentive for both small and large farms to invest in manure anaerobic digestion is the lack of financial return from the sales of either methane or electricity from these systems. Due to economies of scale and increased efficiency with larger internal combustion generator systems, the larger farms may be able to produce power at a lower cost than smaller farms, but the cost is typically greater than the rate they can sell the power for. Currently there are Federal grant programs that dairy producers can apply to for funds to support some portion of digester construction costs. Specifically the USDA Rural Energy for America (REAP) program can be applied to for a 25 percent construction cost grant with a $500,000 cap, and the *American Recovery and Reinvestment Act* (ARRA) Section 1603 program can be applied to for a 30 percent construction cost grant with no cap. While these funds do provide an incentive to dairies that successfully apply for and receive the grant funds, they do not address the fact without grant support, the cost to produce renewable energy through manure anaerobic digestion typically exceeds the current market value of that energy. Countries that have effectively incentivized the construction of manure anaerobic digestion systems on farms of all sizes include Germany and China. In both cases they have provided a government subsidized rate for electrical power produced using manure digesters. In the case of China, both grant funding for the construction of anaerobic digesters and a subsidized renewable energy rate have been provided.

Q2. You also mention that the current U.S. dairy digester projects only produce 10.7 percent of the feasible energy production potential reported by the U.S. EPA AgStar report. We all recognize that dairy farmers are faced unprecedented and challenging economic times. However, when the industry stabilizes for a bit, what barriers currently exist to enabling a greater number of dairy digester projects to come online? How can we fix these barriers? What can we learn from Wisconsin, where 73.9 percent of the potential for this technology is implemented, versus just 23.5 percent for the United States?

A2. I believe that primary barriers to bringing more dairy manure anaerobic digestion systems online in the U.S. are 1) lack of return from renewable energy sales and 2) lack of a well-developed manure digester support industry in the United States. I also believe that when producers become able to earn a sufficient rate of return from renewable energy production with manure digesters that a sustainable manure digester support industry will develop in the United States. Historically, dairy farmers in Wisconsin were more successful in receiving USDA–9006 funding support for digesters than other locations in other states. I believe this is why Wisconsin has been more successful that other states in terms of achieving a larger percentage in terms of dairy manure digester implementation compared to potential.

Q3. Your testimony suggests that other countries, such as China, which has approximately three times the number of dairy cows, beef cattle and pigs as the U.S. but 118 times the number of manure biogas plants as the U.S., have more favorable policies towards electricity rates for this type of technology. Do you believe a federal policy is necessary to advance this technology in the U.S., as opposed to a piecemeal state-by-state policy?

A3. Countries that have provide a nationally subsided price for renewable energy that is significantly higher than the current market price of energy have many more operational manure anaerobic digesters that the United States. The most notable examples are China and Germany, with over 16,000 and 5,000 operational manure based anaerobic digesters respectively. I believe that if a similar policy were adopted at the Federal level, that it would stimulate the implementation of farm based anaerobic digesters in the United States.