Research Opportunities and Potential for Fuel/Chemical Production From Agricultural Products

Greetings! I am honored to have been invited to testify before this esteemed committee. It is this very committee that many of us, who hold high hopes for the future of producing fuels and other chemicals from biomass, look toward for passage of both policy and research direction that will challenge the technology development ability of this great country with the establishment of an industrial economy based mainly on renewable feedstocks. I truly believe that this is possible and that we have only begun to tap the vast energetic and chemical resources literally growing around us.

Plants represent the ultimate form of natural energetic resource utilization within the Earth's biosphere. They convert sun light, carbon dioxide, and soil nutrients into complex organic chemicals without adverse environmental impact. With our worldwide petroleum reserves playing out their capability to support industrial activity over the next 100 years, new options for future energetic and industrial feedstock needs must be developed. Plants and animals (organisms that concentrate plant constituents) represent feedstocks whose potential have only begun to be realized with arguably slow commercialization given the vast chemical treasures stored within their systems and this country's dire need for a renewable and environmentally friendly industrial base. Recent commercialization successes of note include dry milling for ethanol production, direct combustion of wood residuals into electricity, and biodiesel produced from soya oil. Even though these processes are in commercial stages, further development/ optimization is needed more than ever to reduce costs, improve products, and discover new products and by-products.

Our industrial capability is almost exclusively based on a petroleum feedstock platform, where crude petroleum is refined into fuels with some components being further processed into other products. Biomass (materials derived from plant and/or animals) is the fully renewable and natural analogy to petroleum. Profitability in the petroleum business is dependent on both the fuel products as well as the other products produced from crude. The same is true for biomass-based industries. Production of fuels, by-products, and other products from biomass must be closely tied to ensure efficient and economically sustainable production.

I firmly believe that industries of the future need to and will be based on multiple feedstocks based on lipid, sugar, protein, hydrogen, synthesis gas, and methane platforms, all of which are directly or indirectly derived entirely from biomass found within the biosphere. Obviously, agriculture will play a critical role in the provision of these vital feedstocks of the future. However, agriculture as an industry that must continue to evolve. Handling of agricultural products must mature from mainly primary processing (production of food or simple plant

components) into secondary and tertiary processing oriented industries (production of both commodity and specialty complex chemicals) that combine modern agricultural skills with developing chemical processing technology.

The analogy between petroleum and biomass for producing fuels and other chemicals is technically accurate. Petroleum is composed of literally hundreds of organic chemicals that over the past 125 or so years, technologists have discovered novel ways to make more and more chemicals from these feedstock chemicals. The discovery of new ways to optimize or develop new petroleum-based technologies continues even today as petroleum approaches the autumn of its utility for mankind. Like petroleum, biomass is also composed of literally hundreds of chemicals. Its chemical complexities are as diverse as petroleum. Its potential for producing fuels and chemicals of great value to mankind is as high as the potential felt about petroleum over the last 125 years. Research on petroleum since its discovery in the mid-1800's has provided the technological foundation that has yielded a world-wide industrial base that is rightly heavily based on petroleum. However, I believe that the chemical utility of biomass will not be realized without a similar developmental effort. I harbor the hope that this country's strategy for discovering the many potential uses of biomass do not totally follow the path of petroleum by taking over 125 years to mature. Unlike the early 1900's when petroleum came into its own, technologically our energy and chemical needs today are much greater and very different.

In terms of potential industries that may utilize biomass, fuels are of course a key focus; however, many other chemicals can be produced along with fuels from these feedstocks. Many of these are actually by-products that may be the deciding factor between process economic viability or not. If petroleum refining only took the first and second run cuts during crude processing, oil refining would likely not be profitable today within the United States. Appropriate attention must be directed toward both fuel and by-product development if the bio-based economy vision is to become a reality within a timely manner. A substantial research resource commitment must be initiated analogous to the effort used to mature petroleum processing to its current high state of development. I believe that "biorefineries" is indeed an excellent term for describing the biomass processing plants of the future. Key biomass components that are likely to be "refined" into energy and other chemical products in the future are:

Bulk Biomass - This relatively unmodified feedstock is converted into valuable products via chemical, biological, or physical processing. Examples include direct combustion of biomass to produce electrical power; thermal processing of lignocellulose and sewage sludge for production of biooils (later potentially used for making fuels, glues, preservative, pesticides, and polymers); methanogenic production of biogas (derived from animal wastes, sewage sludge, and landfills); production of ethanol from lignocellulose using acid hydrolysis,

enzymatic conversion, or syngas fermentation; and production of water treatment media from biomass such as kenaf or peanut hulls.

Lipids - This class of important chemicals are found in almost all plant or animal-derived materials. Example chemicals of the future that can be produced from lipids are biodiesel produced from both traditional and non-traditional lipid sources (a developing new bio-based industry), polymers, and neutraceuticals (such as omega-3 fatty acids and lecithin). Most lipids, such as triglycerides, are broken down into glycerin and fatty acid fractions to produce valuable products; however, more potential products are scientifically possible, but not yet proven viable.

Carbohydrates - This class of biomass components represents a lot of current bio-based feedstocks (such as starches and sugars) that are commercially being used to make ethanol and polylactic acid. Numerous other intriguing chemicals can be made from these chemicals including hydrogen (needed for fuel cells) and acetic acid (a key building block chemical for many products). Although this feedstock has arguably been our most successful commercialized bio-based platform, I believe that we have only begun to scratch the vast potential of carbohydrates for making numerous other fuels and chemicals.

Lignin - This very complex and refractory chemical currently represents a waste product in many developed and developing chemical production processes. However, I believe that on-going work with enzymes and chemical processing will eventually convert this widely available chemical into a feedstock for many valuable products, particularly new glues and preservatives given the stability of this chemical.

Proteins - I realize that the inclusion of proteins into discussions such as my testimony often raises concerns over chemical production competing with food stocks; however, there are many sources of proteins that will not or cannot make their way into products to be used as food or human contact chemicals (such as cosmetics). A prime example is protein derived from algae cultured from treatment plant effluents where concerns over pollutants being present within the protein may eliminate any opportunity for this valuable source from being considered as a feedstock for food or human contact products, yet this protein is an excellent feedstock to polymer production (the pollutants come from the influent to the sewage plant).

It is important to realize that biomass can be found in the form of cultured, waste, or wild sources. The continued pursuit of both traditional crops and non-traditional biomass as potential feedstocks must be fostered. Fuel and chemical feedstocks must be developed based on production quality and quantity and not the feedstock crop. I am concerned that the recently proposed biodiesel financial incentives are the start of a troubling trend in that feedstock type was apparently considered of prime interest as opposed to product quality and per unit cost. Algae and other similar biomass feedstocks were provided only half the financial incentive as traditional crops and animal feedstocks. This approach hinders free thinking and new research ventures. I am not opposed to traditional crops serving as feedstocks (in fact, I am working with many of these in my own laboratories), but I do believe that fuel or product quality-based development coupled with emphasis on per unit cost should be the driver ultimately guiding the future of biomass-based feedstocks in this country. I believe that all feedstock candidates should start on equal footing and let development prove out their value based on product quality and cost. Another non-traditional feedstock that I am concerned may be overlooked is municipal wastewater treatment sludge which has recently been proven to have great potential as a key feedstock for producing liquid fuels or feed into a gasifier for eventual production of ethanol, acetic acid, or electricity. I am concerned that its value will be overlooked by government leaders and hence developers because of minimal development/commercialization support by the federal governmental since it is not a traditional crop. This concerns me because it is a truly a renewable biomass, very cheaply produced in large quantities, and is becoming a huge disposal problem for many municipalities. Developmental efforts should not be oriented exclusively toward any one type of biomass (cultured, waste, or wild). If true development of biorefineries is the goal, then all candidate renewable biomass feedstocks should be assessed for their potential toward contributing to the development of biorefineries.

The tonnage and diversity of biomass resources dramatically differs by geographic region within the United States. Each region has its own unique climate and soil-base capable of providing very differing crops and livestock. If bio-based industries are to mature and prosper, a renewed focus on basic research needs to be initiated that acknowledges and actually capitalizes on these regional differences and biomass resource potential, whether a traditional crop or not. The SunGrant Initiative is an excellent start, but it does not begin to approach the scale nor scope of the developmental effort that needs to be expended. To address this need, I suggest that regional "centers of expertise" be developed within various agricultural regions of the United States that will research and develop biomass-based industrial processes that are best suited to the unique agricultural capabilities of that region. Since many agricultural climates are represented within the United States, this approach also position US industries to be global leaders in bioproduct commercialization. A good example is my home state, Mississippi, where great quantities of biomass are produced every year that are quite comparable to the biomass quantities produced in the great State of Iowa. However, Mississippi's biomass is highly diverse with many of the major biomass products not being compatible to conversion

technologies best suited for the biomass derived from Iowa agricultural activities or vice-versa. The biomass diversity and density associated with the various regions of this country must be taken into account for the full potential of the biomass within this great nation to be realized. Each region should have multiple regional universities (three to six) working in partnership with two to three national laboratories on joint developmental efforts. This will engage new legions of researchers and extension experts from states with currently little to no such R&D infrastructure to further the development of commercially viable industries. It is through universities and regional business interests that most new bio-based industries have evolved.

Finally, I would like to briefly summarize key areas of R&D that I feel need to be addressed by current or new research programs (possibly like the one I proposed above). These are:

Feedstock Development and Management - This area focuses on the provision of improved raw feedstocks, or in other words, primary production. Needs in this area include the development of new and/or improved cultured biomass with characteristics better suited for fuels and chemical production rather than a food source. An example would be dramatically improving the amount and saturation degree of an oil through genetic modification of the plant. Additionally, management issues such as harvesting, storage, and preprocessing all need to be further addressed as part of this developmental effort.

Biomass Conversion into Commodity Chemicals and Secondary Feedstocks - Many experts agree that numerous promising conversion technologies are only one major or a few minor technical breakthroughs from being economically viable fuel production options. And when considering that comparatively minimal research effort has been directed toward processes of this type, imagine the potential for new improvements or technologies to be discovered once more research minds enter the race. Examples of potential breakthroughs would be chemically modifying the saturation level of an oil or development of a highly stable and productive acetogen for production of ethanol from synthesis gas.

Tertiary Processing of Secondary Feedstocks - This development area focuses on further processing of biomass-based chemicals into chemicals of higher value. An example is the potential to utilize acetic acid, produced via the fermentation of biomass, as a feedstock for producing calcium magnesium acetate (CMA) which is an environmentally friendly highway ice control agent. Another example is the potential for tertiary processing of biooils, produced from pine thinnings or poultry litter, into a diesel fuel cut.

Rigorous Economic Assessment - There are numerous products that technically can be produced from biomass using today's state of the art; however, potential markets and process economics are almost always overlooked or under-considered by inventors. I consider the recently completed USDA/DOE evaluation effort on pretreatment technologies for enzymatic conversion of lignocellulose into ethanol an excellent example of a program well designed for addressing this key area of development. More of this is needed as research efforts reach a certain stage of development; particularly, if federal funds are sought for process commercialization.

In closing, I deeply appreciate the opportunity to present this testimony. I am encouraged by the leadership that the members of this committee have exhibited over the past years. This is a period in world history where government leadership and technologists must work in unison to solve a pressing societal crisis literally on our horizon via the development of a fully renewable industrial economy. A reasonable investment in technology development will provide significant payback to this country in terms of an industrial infrastructure based on self-sustainable feedstocks with greatly reduced environmental threats. The strategic and economic implications of this level of independence from foreign feedstocks cannot be overstated in my opinion. The potential of bio-based fuels and products is exciting and represents an opportunity for man and the biosphere itself to finally "partner" with the provision of industrial chemicals for mankind without dramatic adverse environmental impacts.