Written Statement of
Dr. Thomas D. Foust
Biomass Technology Manager
National Renewable Energy Laboratory
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Mr. Chairman, thank you for this opportunity to discuss important issues related to the nation's energy policies as we move to reduce our dependence on foreign oil, maintain a healthy environment and fully meet the energy demands of the future. I am the Biomass Technology Manager of the National Renewable Energy Laboratory (NREL) in Golden, Colorado. NREL is the U.S. Department of Energy's primary laboratory for research and development of renewable energy and energy efficiency technologies. I am honored to be here, and to speak with you today.

We applaud the Committee for its examination of alternative transportation fuels to reduce our dependence on imported petroleum. Researchers at NREL have been working on biofuel technologies since our laboratory was founded in 1977. However, it only has been recently that public policy has looked to biofuels as a way to reduce our dependence on petroleum use in the near-term.

Recent studies have shown that there is sufficient biomass potential in the U.S., and worldwide, to produce significant amounts of transportation fuels without impacting food production– enough to displace a major portion of the petroleum we use today. Clearly, this is an area that has great promise; but it must be done correctly.

The Committee has asked what our nation's R&D focus should be in addressing the technical barriers to developing biofuels from diverse feedstocks. Let me address this question first.

Biomass: A Plentiful Resource

While much remains to be done, we as a nation start with some significant strength. The biomass resource in the country is huge, and the potential for it to grow is significant.

The Department of Agriculture and the Department of Energy looked at the question of whether the nation's biomass resource could foster a biofuels industry large enough to meet a significant portion of our nation's future fuel needs. The report, now commonly referred to as "The Billion Ton Study," for the first time confirmed that the U.S. could yield more than a billion tons of biomass annually for energy needs. And, importantly, we could do this without negatively affecting the nation's ongoing needs for food or fiber. This is significant because the 1.3 billion tons of biomass that was forecasted contains as much energy as 3.5 billion barrels of oil.

I should emphasize that such a transition to biofuels will not happen overnight. It will take a significant and sustained national effort to get us there. Still, "The Billion Ton Study" clearly demonstrates the biomass resource is real, and large enough to ultimately replace a large fraction of the petroleum-derived fuels we depend on today. DOE is in the midst of developing a vision for replacing 30% of current motor gasoline with ethanol by 2030 and this should help guide us in realizing the potential of biofuels.

Moreover, the resource is regionally diverse. We envision that every state in the nation could produce biomass and could benefit economically from an expanding biofuels industry.

We also are encouraged by the fact that there already exists a strong and growing ethanol fuels industry in this country. The U.S. currently produces more than 5 billion gallons a year of ethanol, almost exclusively from corn grain, and the industry is growing 30% annually.

To understand where we are today and where we need to go, we need to see ethanol technology issues and biomass resource issues as interrelated. To move the ethanol industry to where we need it to be, we have to move beyond corn grain as the primary biomass resource. One of the most abundant potential resources we have is corn stover, the non-food parts of the corn plant, including the stalks, leaves and husks. Other resources are forest thinnings, hardy grasses like switch grass, and fast growing trees.

To use these and other resources we need to perfect new technologies that convert the *cellulosic* materials of the plants into fuel.

Current and Future Biofuels

First, let's start with ethanol. Production of this alcohol fuel from the starches of corn grain is a well established technology, and accounts for almost all of the current 5.5 billion gallons per year (bgy) U.S. capacity. Additional plants that are planned or currently under construction are estimated to put our capacity close to 12 bgy within a couple years. The limiting factor is, of course, the feedstock itself – corn grain. It is an important food and feed commodity in the U.S., and most believe that we cannot produce more than 12 - 15 bgy of ethanol from corn grain without having significant, unacceptable impacts on the economics of the other critical corn grain products.

There are no other realistic starch or sugar-based crops in the U.S. from which to ferment alcohol in quantity. The Brazilians use sugar cane and in other parts of the world, sugar beets are used as a feedstock, but these sugar crops can probably never be widely grown in the U.S. because of climate differences. One or two bgy in the U.S. is possible from sugar crops in the next decade, but significant growth beyond this amount from this resource will likely never be a major factor for us.

Cellulosic ethanol promises to leap these ethanol capacity hurdles by utilizing feedstocks which are abundant and do not compete with other needs. However, the technology is relatively immature and we have little more than a few pilot plants on the ground. At the National

Renewable Energy Laboratory, our biofuels focus is almost entirely on advancing the cellulosic ethanol technologies to enable competitively priced ethanol from a variety of feedstocks. The current goal is to attain a $1.31/gallon production cost by 2012 in order to make this ethanol pathway competitive with the corn grain pathway. However, to get the production ball rolling, DOE has recently awarded cost-shared contracts with industry to establish 6 cellulosic ethanol biorefineries which can each process approximately 700 tons/day of feedstock, each plant potentially producing 15- 20 million gallons per year (mgy) of ethanol.

But, we still need to significantly improve the technology and reduce the costs for industry to begin major cellulosic biorefinery construction efforts. For that reason, our projections – even with significant incentives for the ethanol refiners and the feedstock growers -- puts our national capacity at 2-5 bgy in 10 years. By 2022 or 2023, however, the cellulosic biorefinery construction rate will be on a steep upward slope, with a significant growth potential for cellulosic biofuels beyond 2017. This, then, is undoubtedly our most promising pathway to meet an aggressive national alternative fuels standard.

Integration of Biorefineries into Existing Industries: the R&D Role

Another exciting area of work is in the development of "biorefineries". Our scientists at NREL, together with those at other DOE national laboratories, universities and corporations, are leading the development of fully integrated refineries that use biomass, instead of petroleum, to produce fuels, chemicals, synthetic materials – virtually all of the products we use from a conventional oil refinery today. It is envisioned that biorefineries will utilize a complex array of processing technologies to break down, convert and recombine a wide range of biomass components into fuels and chemicals, in a manner similar to how petroleum refineries convert petroleum crude oil. We envision that future biorefineries will utilize a wealth of resources that we currently either underutilize or don't use at all today. That includes agricultural residues, forestry residues, dedicated energy crops, municipal solid waste, algae and by-products of the food and grain industry.

A range of biorefinery R&D is underway in partnership with industry. DOE's biomass program is partnering with a number of the major ethanol technology providers and ethanol producers, including Abengoa, ADM, Broin and Cargill, to increase the yield of ethanol from existing corn ethanol facilities and expand the slate of feedstocks. In many ways, a cellulosic biorefinery can be viewed as an expansion of a corn ethanol facility. That's why we believe tomorrow's cellulosic ethanol industry will not replace today's corn grain ethanol industry, it will evolve from it.

At the same time, DOE is partnering with chemical industry leaders, such as DuPont, to develop new opportunities for producing both fuels and chemicals from biomass. DOE is partnering with the forest products industry to explore and develop biorefinery concepts that can integrate into existing forestry operations. And, most recently, NREL is partnering with oil industry technology developers to explore novel options for integrating biomass streams into existing petroleum refineries. These and other partnerships are speeding the progress of new technologies to the marketplace, and may uncover new options for producing fuels from biomass.

Thermal technologies such as gasification, pyrolysis and hydrothermal systems are all worthy of further research and development to determine how these technologies and the respective biofuel products impact the cost, efficiency and integration into existing fuels infrastructure.

Before we leave the alcohol fuels family, let me mention at least one other of these potential fuels – butanol. This higher alcohol has certain advantages over ethanol. In particular, its energy content is significantly higher than ethanol (but still not that of gasoline) and it is has fewer water miscibility challenges than ethanol. However, it is more difficult to ferment, and the economics and technology are well behind that of ethanol. You have probably heard that BP and Dupont are beginning a bio-butanol program in the United Kingdom. However, at least in the nearer term in the U.S., butanol is not out of the starting gate and will assuredly be a minor contributor compared to ethanol. In addition, the challenges of establishing a fuel infrastructure for one new major fuel, and the vehicle and engine implications, are daunting enough. To throw a second alcohol fuel into that challenge, I would propose, is not a good decision or investment in terms of moving up the alternative fuel path as quickly as possible.

Biodiesel and Green Diesel Fuels

Diesel-like fuels - biodiesel and green (or renewable) diesel - can be made from plant oils or animal fats and greases as well as biomass itself. For biodiesel, the oil or fatty feedstock is chemically reacted with methanol in a process called transesterification, which splits the fuel portion of the feedstock from the non-fuel, glycerol co-product. This is a fairly straightforward process and the technology is proven and mature. Essentially this process is used to produce the entire non-petroleum diesel in the U.S. today. The problem is that our current capacity is only around 500 mgy, primarily due to feedstock limitations. If we would, for example, use every acre of the annual U.S. soybean crop to produce soy oil and then use that to make biodiesel, our capacity would be only around 3 bgy. Remember that on-road we burn 40 bgy in the U.S today.

Green or renewable diesel is an emerging technology which uses the same oil or fats feedstock, but instead of the transesterification process, subjects the plant oils or fats to hydrotreating, as is done in the hydrocrackers of a petroleum refinery. The advantages are that we can potentially utilize existing refinery assets and not have to build new transesterification plants, and that the green diesel is essentially identical to petroleum diesel and does not require a unique or new fuel handling infrastructure, nor vehicle or engine modifications. Another process that shows considerable promise for producing renewable diesel is biomass gasification followed by Fischer tropsch synthesis to produce a renewable diesel. This process has considerable long-term promise since it utilizes biomass as a feedstock and is not subject to the feedstock limitations of plant oils or animal fats of the other processes. I will say that, from a technical standpoint, all of these pathways produce a diesel fuel which is not petroleum dependent and reduces CO2 emissions.

Another longer term approach for producing a renewable or green diesel that gets considerable press is to develop an entirely new feedstock source which has a higher gallons-of-oil-per-acre yield and can be produced on otherwise non-arable lands. Algae shows considerable promise in the long term – beyond 2017. Whereas soybeans can only produce about 50 gallons of oil/acre, microalgae might produce significantly higher yields on a per acre basis. Unfortunately, this technology needs significant work and will not contribute materially to the alternative fuels standards under discussion, but in the longer term may be a dominant component of our alternative diesel and jet fuel markets.

Biofuels Infrastructure: Research Needs

The Committee has also asked the panel to address the need for research in the area of biofuels infrastructure.

DOE has sponsored studies that have examined infrastructure needs for large-scale production and utilization of biofuels (i.e., 20 bgy and greater). These studies have specifically looked at the two key components of the infrastructure; distribution of the biofuel from the biorefinery to the refueling station, and vehicle needs. The results have shown that the current biofuel distribution infrastructure is inadequate to handle large volumes of biofuels, thus an improved distribution infrastructure is needed.

Two options are available for accomplishing this; utilizing the existing gasoline and diesel distribution infrastructure for the distribution of biofuels, or developing a dedicated biofuels distribution infrastructure. Although utilization of the existing gasoline and diesel distribution infrastructure would theoretically facilitate a quicker, less costly approach toward addressing this issue, technical challenges exist - such as the miscibility of corrosiveness of ethanol. These challenges could be addressed by a dedicated infrastructure; however the triggering mechanism to drive investment in this dedicated infrastructure in not clear.

The vehicle issue is more easily addressed. Currently, all US cars are capable of utilizing 10% ethanol and studies are underway to see if these vehicles can handle higher ethanol blends up to 20%. Flexible Fuel Vehicles (FFVs), in contrast, are capable of utilizing up to 85% ethanol. FFV sales are growing rapidly and this growth rate is expected to increase in the future. Current projections show that the vehicle infrastructure will be more than adequate to utilize all the ethanol being produced.

Fuel Fungibility

The Committee has asked whether standardization of biofuels, whether ethanol or biodiesel, is needed to ensure fuel fungibility, and whether the standard should focus on blended stock optimization.

When a fuel is produced, either fossil fuel or biofuel, it must meet standards established for its sale for it to be truly fungible. Ethanol and biodiesel already have fuel quality standards established through the American Society for Testing and Materials (ASTM). These standards have been created to partially match the current production methods from corn starch and vegetable oil respectively. They help to establish what will and will not be compatible with the gasoline to which they will be blended. If the predominant process for making ethanol changes (i.e., to lignocellulosic conversion from starch conversion), an ASTM committee will likely want to examine the “typical” fuel produced to determine if there are any minor components that could potentially be present that wouldn't be otherwise using today's technology, especially if they might be harmful to the engine performance.

The standard in question should also focus on gasoline blend stock optimization. For the example of E10, the Reformulated Blendstock for Oxygenate Blending (RBOB) must have certain properties so that the blend does not exceed Reed Vapor Pressure (RVP) maximums. For E85 there may be an opportunity for refiners to blend in low octane, high RVP gasoline materials and still comply with the overall specifications.

Workforce Requirements for Biofuels Technology Innovation

The Committee has asked the panel to comment on the need for trained personnel to form the biofuels workforce of the future. Others on the panel may comment on that, but let me address the topic from a research and development standpoint.

You are all aware that, in general, the U.S. is not producing the numbers of scientists and engineers that we need to stay at the forefront of global technology innovation. This is especially true in the energy field, as well as in the particular area of biofuels and bioenergy.

The National Renewable Energy Laboratory partners with many universities and colleges, and we bring their undergraduate and graduate students and their post-doctoral students to NREL to support our research and to influence them towards a career in this important field. But that is not enough. We need a concerted national effort to encourage and stimulate our young men and women to become energy scientists and engineers. Just as a national space goal dramatically grew the numbers of aeronautics and space scientists in the 1960's, we need to elevate our energy challenge to that level such that our young people acknowledge and respond to the call. There is, perhaps, no more important undertaking we face as we move into the 21st century – ensuring that we have skilled and motivated energy researchers to meet the nation's challenges.

Making Biofuels Information Available to the Public

The Department of Energy's Office of Energy Efficiency and Renewable Energy is funding NREL in late FY07 to create an on-line Biomass Data Center, which will provide current, relevant data about ethanol and other biomass-derived fuels to support informed decisions by industry, policymakers, researchers, and the public. The Data Center will be an extension of the widely recognized Alternative Fuels Data Center (www.eere.energy.gov/afdc) managed by NREL for DOE since 1991, which provides information about availability and utilization of biofuels and other alternative fuels.

The new Biomass Data Center will gather and provide centralized access to information on biofuels resources, production, and infrastructure issues, and will link to existing information from DOE and other agencies to minimize costs and duplication of effort. The project to develop the Biomass Data Center will begin in FY07, will proceed in phases, and will entail ongoing maintenance and enhancements in future years. The Data Center will provide easy access to information from both government and the private sector on feedstocks, production technologies and facilities, incentives and regulations, infrastructure and fuel retailing, and market opportunities.

Summary

Significant potential exists in the next decade and a half to reduce petroleum use in the transportation sector under an aggressive scenario for technology development and public policies to encourage deployment. The biofuels potential for a maximum petroleum reduction scenario in the next decade is large and, if fully realized, will position biofuels for accelerated growth beyond 2017, putting our nation on the path towards energy security with reduced CO_2 emissions.