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BIOMASS USE IN ENERGY PRODUCTION: NEW OPPORTUNITIES IN AGRICULTURE

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BEFORE THE

COMMITTEE ON AGRICULTURE, NUTRITION, AND FORESTRY

UNITED STATES SENATE

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BIOMASS USE IN ENERGY PRODUCTION: NEW OPPORTUNITIES IN AGRICULTURE

THURSDAY, MAY 6, 2004

U.S. SENATE,
COMMITTEE ON AGRICULTURE, NUTRITION AND FORESTRY,
Washington, DC.

The committee met, pursuant to notice, at 10:06 a.m. in room SD–106, Dirksen Senate Office Building, Hon. Thad Cochran, [Chairman of the Committee], presiding.

Present or Submitting a Statement: Senators Cochran, Lugar, Coleman, Harkin, and Lincoln.

STATEMENT OF HON. THAD COCHRAN, A U.S. SENATOR FROM MISSISSIPPI, CHAIRMAN, COMMITTEE ON AGRICULTURE, NUTRITION, AND FORESTRY

The CHAIRMAN. The hearing will please come to order.

Several months ago, I was pleased to notice on my calendar a meeting that was scheduled to take place in my office in the Capitol with former Director of Central Intelligence James Woolsey, former counsel to President George H.W. Bush, Boyden Gray, and my former colleague in the House of Representatives from Colorado, Tim Wirth.

My first thought was what do these guys have in common? Then, why do they want to come together to see me? Well, I found out that their interest was to discuss biomass fuels as an alternative to petroleum, particularly in the operation of automobiles and the progress that has been made in the scientific community. I have discovered this option as something that should be, as a matter of public policy, explored more fully and more carefully than we are currently doing as a government or as a society.

Here we are today to look more carefully into their suggestions to me about steps that could be taken and should be taken by the Congress to help advance this cause. During this hearing, we will explore the role that agricultural and forestry products can play in sustaining a reliable energy supply for our country for the future. Congress has previously recognized the promise in this area of interest; for example, in the year 2000, we passed the Biomass Research and Development Act; the Farm Security and Rural Investment Act of 2002 devotes an entire title to renewable energy; and the Healthy Forest Restoration Act of 2003 contains incentives for commercial utilization of biomass.

The idea of using these agricultural and forestry products for energy production is, therefore, not a new concept, but the process of developing technologies for conversion of these feedstocks is ever changing. Today, the Committee will hear how current programs are contributing to research, demonstration and application of these emerging technologies as well as ideas for future utilization.

The Department of Energy tells us that worldwide energy consumption is projected to grow by 54 percent by the year 2025. I hope that today's hearing will help us uncover information and suggestions and new policies that will help U.S. agricultural producers play an important part in helping make sure that we meet this ever growing need.

We appreciate very much the panel that is with us this morning to open our hearing: the Honorable Mark Rey, Undersecretary for Natural Resources and Environment at the Department of Agriculture; David Garman, Acting Under Secretary of Energy, Science and Environment at the Department of Energy; and Thomas Ewing, Chairman of the Biomass Research and Development Technical Advisory Committee.

We welcome you, and we ask that you proceed in the order in which I have introduced you to make opening statements and provide any other information you think would be helpful to our understanding of these issues.

Mr. Rey, you may begin.

STATEMENT OF HON. MARK REY, UNDER SECRETARY FOR NATURAL RESOURCES AND ENVIRONMENT, UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, DC

Mr. REY. Thank you, Mr. Chairman, and I am pleased to appear before you today to discuss the Department of Agriculture's efforts to advance biomass energy and thereby contribute to the energy security of our nation.

I want to stress the strong support of this administration, as documented in the President's National Energy Plan, for developing domestic biomass as an important way to satisfy America's growing energy demand. As a result, one of USDA's key strategic goals is to increase the use and development of biomass energy.

USDA has many exciting ongoing activities in this area. We support research and development and precommercial work as well as monitoring the role of biomass energy in energy markets and U.S. agricultural markets. USDA biomass energy activities address an array of forms and innovative technology such as starch and cellulosic ethanol, biodiesel from agricultural oils and anaerobic digestion for power.

One of our areas of focus for us is the development of methane digesters for the production of electricity. This technology has positive environmental effects and excellent economic potential for producers as well. More than a year ago, the Natural Resources Conservation Service developed practice standards for methane digesters. These anaerobic systems break down animal waste, producing methane as a fuel source for the generation of electricity.

The digesters can now be funded through the NRCS Environmental Quality Incentive Program. The agency has had excellent successes in assisting producers to incorporate digesters as part of an overall nutrient management approach to their farms. In turn, if market issues can be resolved, we believe the future holds a bright potential for widespread utilization of digesters and conversion to power.

In terms of ethanol, USDA is looking beyond the current successes in ethanol development to future technologies beyond traditional starch-based methods of production. For example, the Forest Service's Forest Products Laboratory is researching ways to derive ethanol from biomass other than corn starch. Currently, researchers are studying the conversion of sugars to ethanol. The key in converting wood to energy is converting five and six carbon sugars to ethanol.

Although this process proposes many challenges, the laboratory is making progress in expanding capacity in this area, making it possible for a much wider variety of materials to be converted to ethanol. Researchers estimate that ethanol from wood can make a significant contribution to the liquid fuels market.

Now, I would like to focus on what we are doing to implement new authorities provided in the energy title of the 2002 Farm bill. Section 9002 requires Federal agencies to increase their procurement of qualifying bio-based products. When fully implemented, the program should stimulate the development of a broad range of high-performing and environmentally friendly bio-based products. A proposed rule was published in the Federal Register in December, and once we have considered the more than 270 public comments, a final rule will be published later this year.

Section 9006 authorizes loans and other assistance to businesses to purchase renewable energy systems and make efficiency improvements. Last year, we selected 114 applications to receive funding to develop renewable energy systems. I would note that yesterday, Secretary Veneman announced $23 million in funding for this year. We anticipate a lot of interest in this and will be accepting proposals under this initiative for the next 74 days.

Section 9010 expands bioenergy production and supports new production capacity. For the 2004 program year up to $150 million has been authorized by Congress. Energy crops are included as eligible feedstocks. I also want to mention that USDA has an ongoing program of research to improve the economics of biomass energy. Our goals in this program are twofold: one, to overcome the technical barriers to developing biomass energy and two, to strengthen coordination with other Federal agencies and with universities, private sector companies and environmental organizations.

Section 9008 provided USDA with $75 million through 2007 for research and development grants, and as you have noted, the Healthy Forest Restoration Act expanded the scope of this initiative, integrating silvacultural activities and authorizing an additional $20 million through fiscal year 2007. Through this Biomass Research and Development Initiative, grants are available to eligible entities to carry out research, development and demonstrations on bio-based products, bioenergy, biofuels, biopower and related processes.

In the 2003 program, USDA received approximately 400 proposals, where were competitively evaluated in a process that included a joint USDA-Department of Energy technical merit review. Although the solicitation stated that $21 million would be awarded, an addition of $2 million from the Department of Energy resulted in $23 million in grant awards. In the fiscal year 2004 program, USDA and the Department of Energy intend to award up to $24 million.

We are very pleased with the outcome of this initiative, as it has resulted in cooperative funding for a diverse and innovative array of products, including anaerobic digestion, biorefineries, biomass-focused forest management training and innovative use of feedstocks. We are optimistic about the future of this program and look forward to continuing collaboration and mutual progress between the Department of Energy and the Department of Agriculture.

Taken together, our efforts will help advance agriculture's key role in realizing its potential in meeting the demand for clean, affordable and renewable energy. It is our conviction that this process will contribute both to the vitality of rural communities and the energy stability of our nation.

That concludes my summary statement, and I would be happy to respond to questions from the members of the Committee.

[The prepared statement of Mr. Rey can be found in the appendix on page 46.]

The CHAIRMAN. Thank you very much, Mr. Rey, for your statement and your participation in this hearing. Before proceeding to hear from David Garman from the Department of Energy, I am pleased to yield to my friend and colleague from Indiana, Senator Lugar, for any opening statement or comments he would like to make at this time.

STATEMENT OF HON. RICHARD LUGAR, A U.S. SENATOR FROM INDIANA

Senator LUGAR. I thank you very much, Mr. Chairman, for this opportunity. I appreciate the distinguished witnesses that you have brought together for this important hearing. I will ask that my opening statement be made a part of the record but simply applaud the forum that this presents once again to give some benchmarks of progress.

This has been an important objective, I know, for the Chairman and for me for many years, and we see our former colleague Mr. Ewing here on this panel today. He has worked with us throughout that period of time, a distinguished member of the House committee. Thank you very much for coming. I look forward to hearing how things are progressing and supporting your efforts.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Lugar.

I might indicate that we will make a part of this record an article that you and Jim Woolsey wrote several years ago, 1999, I believe, that will illustrate the fact that this is a subject that you and Mr. Woolsey have been interested in for some time and have taken the lead in pointing the way for Government policies to help ensure that we do take advantage of and alternative energy sources. Mr. Garman, you may proceed.

STATEMENT OF HON. DAVID GARMAN, ACTING UNDER SECRETARY FOR ENERGY, SCIENCE AND ENVIRONMENT, UNITED STATES DEPARTMENT OF ENERGY, WASHINGTON, DC

Mr. GARMAN. Thank you, Mr. Chairman and members of the Committee.

I appreciate this opportunity to discuss the Department of Energy's biomass R&D program. I am especially pleased to testify with the Undersecretary of Agriculture. Our two agencies have been working together in an unprecedented manner, and we have done so as a direct consequence of the provisions in the Biomass R&D Act of 2000, authored by Senator Lugar and other members of this Committee.

Candidly, the law that you wrote established the framework through which we coordinated our activities, and I am certain we would not have worked together as well as we have without that law. I also want to thank and recognize the work of Tom Ewing and the entire Biomass R&D Technical Advisory Committee. They are performing a tremendously important task, giving us their time and lending us their expertise.

Biomass is a tremendous national asset that is not widely recognized or appreciated beyond the members of this Committee and a few others. We think of biomass mainly as a source of liquid fuel products such as ethanol and biodiesel, but biomass can also be converted to a multitude of products that we use every day. In fact, there are very few products that we use today that are made from a petroleum base, including paints, inks, adhesives, plastics and other value-added products that cannot be made from biomass.

Biomass is also a proven option for generating electricity through the direct combustion of wood, municipal solid waste and other organic materials, co-firing with coal and high-efficiency boilers or combustion of biomass that has been chemically converted into fuel oil. Biopower in 2002 contributed almost 71 percent of our non-hydroelectric renewable energy generation and about 1 percent of total U.S. energy supply.

The Department estimates that the total available domestic biomass resource beyond that we use for food, feed and forest products is currently between 500 and 600 million dry tons per year. Within the Continental U.S., we think we could literally grow and put to use hundreds of millions of tons of additional plant matter each year on a sustainable basis.

These biomass resources represent about 3 to 5 quadrillion BTUs of energy, or quads, or as much as 5 or 6 percent of total U.S. energy consumption. In terms of fuel and power, that translates into 60 billion gallons of fuel ethanol or 160 gigawatts of electricity. That is enough electricity or enough energy to meet 30 percent of U.S. demand for gasoline or service 16 million households with electricity.

The question is why do not we do it, and the major issue that we confront is cost. Current technologies cannot convert biomass resources to fuel and products for the mass market at a widely competitive cost, and we believe that the best way to produce fuel, power and product from biomass in a cost-competitive manner is through what we call an integrated biorefinery, which produces a suite of products, much in the manner of an oil refinery.

By producing multiple products, a biorefinery could take advantage of the differences in plants and other biomass feedstocks and maximize the productivity and value from each of those feedstocks. A biorefinery that produces high-value chemicals, for instance, could enhance the economics of producing higher volumes of lower value liquid transportation fuel, all while generating electricity and process heat for its own operation.

To achieve high volumes of products and fuel, such a refinery would need to take advantage of the vast supplies of corn stover and other lignocellulosic biomass, which is really the "everything else" in biomass beyond the simple sugar, starch and proteins that are valuable inputs to our food supply.

Working with the Biomass R&D Technical Advisory Committee and the Department of Agriculture and others, we have developed our strategic multi-year and annual program plans targeted to overcoming the technical barriers that stand between us and the achievement of the integrated biorefinery utilizing this cellulosic material. The Department's 2005 budget request for biomass activities is $81.3 million. Last year, about half of the biomass budget was earmarked for Congressionally-directed projects, and we are performing these projects as we have been directed to do, but the requirement to do so has resulted in our reducing research and work at some of the national laboratories.

As a consequence, some of the work and some of our work plans have been delayed, and our timeframes for achieving our goals have slipped a little bit, but we remain very, very excited about the prospects for biomass and enhancing not only the economic prosperity of rural America but the energy security of the nation.

I did not really dwell on it in the testimony, but I also want to highlight the potential that biomass has in the coming hydrogen economy, the hydrogen energy economy, both in the near term and the long term. One of the tremendous assets of hydrogen as an energy carrier is that it can be produced from multiple feedstocks, primary energy inputs, and biomass is certainly a very, very important energy input that we are considering as we look forward to the President's Hydrogen Fuel Initiative.

I will stop there and would be happy to answer any questions the Committee has either today or in the future. Thank you, Mr. Chairman.

[The prepared statement of Mr. Garman can be found in the appendix on page 56.]

The CHAIRMAN. Thank you very much.

We are pleased to welcome to the hearing our former colleague in the House of Representatives, Tom Ewing from Illinois, who served in the House from 1991 until his retirement in 2001.

We appreciate your participation in the hearing, Tom. You may proceed.

STATEMENT OF HON. THOMAS EWING, CHAIRMAN, BIOMASS RESEARCH AND DEVELOPMENT TECHNICAL ADVISORY COMMITTEE, PONTIAC, ILLINOIS

Mr. EWING. Thank you, Mr. Chairman.

It is a pleasure to be here today as Chairman of the Biomass Research and Development Technical Advisory Committee. I was the House sponsor of this legislation upon the request of Senator Lugar, and I would not want to proceed further without giving the Senator the credit, for this was his idea and his brainchild, and without your initiative, Senator, probably we would not have the act that we have today.

The Biomass R&D Act recognized the outstanding potential for benefit offered by biomass technologies. The act also acknowledged the need to integrate and coordinate the diverse R&D efforts currently taking place across the Federal Government, in industry, and at the State level. The primary objective of the Biomass Initiative is to coordinate the development of environmentally sound, cost-effective bioenergy and bioproducts.

The Advisory Committee is comprised of individuals from industry, academia, nonprofits, from agriculture and forestry sectors to provide to the Secretaries of Agriculture and Energy and their points of contact, the gentlemen here at the table with me today, advice on the technical focus and direction of requests for proposals issued under the Bioinitiative and advice on the procedures for reviewing and evaluating proposals.

The Advisory Committee recently ended its third year of activity. To date, the Committee's activities have resulted in five major products: one, in December of 2001, the Advisory Committee submitted a preliminary set of recommendations to the Secretaries of Energy and Agriculture on the potential for biomass research and development.

Two, in June of 2002, the Secretaries of Agriculture and Energy requested that the Advisory Committee develop a vision and road map documents to guide future biomass research and development activities. The vision and road map were developed over the next several months. The documents now serve as a resource for the agencies in planning their biomass research and development portfolios. The vision for bioenergy and biobased products in the United States was released in October of 2002 and set far-reaching goals to increase the role of biomass in the U.S. economy.

Three, in January of 2003, the Advisory Committee released the corresponding road map for biomass technologies. The purpose of this document was to outline a research and development road map and identify public policy measures for promoting and developing environmentally desirable biomass fuels, power and products in order to help achieve the goals established by the Advisory Committee in their vision document. The road map is organized by major categories of research and development that will be needed to achieve the vision goals.

Four, in December 2002, the Committee submitted a set of R&D recommendations to the Secretaries of Energy and Agriculture based on research strategies outlined in the road map.

Five, in 2003, the Advisory Committee reviewed the USDA/DOE joint solicitation request for process and awards in order to develop its recommendations. During that year, the Committee also evaluated the USDA and DOE biomass research portfolios and investments, and the Committee developed the assessment of the portfolios and developed recommendations to both the Secretaries of Energy and Agriculture.

Finally, the committee also made specific recommendations for more aggressively pursuing the Federal procurement of biomass products. The Advisory Committee has been pleased to find that USDA and DOE have increased their level of coordination and collaboration as a result of the Biomass Initiative. The Committee also did not find significant duplication of biomass R&D by the USDA and DOE in the area of feedstock productions.

Of major concern to the Advisory Committee is its belief that the Department's current biomass program in the current policy contexts are not adequate to achieve the goals set forth in the vision without an order of magnitude increase in financial and policy support for biomass. Specific steps in this direction are outlined in the full text of my comments submitted to the Committee.

We are looking at 2004, and the Committee plans to complete the following: we want to respond to the USDA and DOE regarding aggressive Federal purchasing of biomass products, develop detailed recommendations regarding the agencies' joint solicitation; track progress in achieving the Committee's vision goals; discuss cellulose ethanol gasification and co-firing and the history of the Federal Government's effort in these areas and discuss hydrogen power.

Mr. Chairman, my complete prepared statement has been submitted, and I would be happy to answer questions. Thank you.

[The prepared statement of Mr. Ewing can be found in the appendix on page 60.]

The CHAIRMAN. Thank you very much, Congressman, for your participation in the hearing.

Before we proceed to questions of the panel, I am pleased to recognize the distinguished Senator from Arkansas, Ms. Lincoln, who has joined the hearing.

Any opening statement or comments you would like to make at this time?

STATEMENT OF HON. BLANCHE LINCOLN, A U.S. SENATOR FROM ARKANSAS

Senator LINCOLN. Thank you, Mr. Chairman. I would like to make just a few brief statements, and then, we will go on to some questioning.

I just want to applaud the Chairman for holding this hearing. It is tremendously exciting to me that we are engaging in this issue and really talking about it, so I want to compliment the Chairman for being willing to hold this hearing and hopefully joining me in the excitement that I find in this issue and the potential that we have for our States and for our country.

It is such a very important topic of converting our vast agricultural biomass resources to transportation fuels and to a host of other products that we can use often what we think of only as trash or left-over but to bring that into an enormously useful world of products that we can provide.

I have worked to promote the use of agricultural products as a source of fuel throughout my public service, and it is not only an agricultural issue but also a security issue. Now more than ever, we must reduce our dependence on foreign oil and look toward renewable sources of energy. This hearing today is the beginning, but certainly, there are multitudes of opportunities for us to begin that search.

I believe that the President and the Congress should consider developing a large-scale biomass and biorefinery initiative. We should look at the Clean Coal Program. A lot of what we have done there, we can see in evidence of what we can do and do in a better way. I know even in my travels, running into scientists in the airports and talking about some of the research that we have been able to get out of biomass and some of the potential that the biomass has, particularly our agricultural biomass is enormous, and the excitement out there in the investigative world, in the research world, is phenomenal, and we on Capitol Hill must seize that excitement. We must move forward in supporting these initiatives.

With the proper financing and the policy focus, I believe we can help our farmers and others turn these farm fields of ours and many of our industries in our States into the energy fields of tomorrow while they still continue to produce the safest, most abundant and affordable food supply on the globe. In order to create favorable market conditions for biofuels, we need market support and tax incentives to foster these conditions, and with today's depressed market for farm commodities oftentimes, and it does become often cyclical, biomass will serve as a ready new market for surplus farm products.

I know that in my example in Arkansas, as the rice hulls in my State that are piling up; we cannot burn them anymore because of clean air requirements. Now, with new industrial enzymes coming available, we have the hope that we can convert these crop residues to useful ethanol transportation fuel.

The investment now in the biomass industry will level the playing field and create new opportunities in rural communities in Arkansas and nationwide. I am excited, and I very much appreciate the Chairman, because I do think that this is an issue that has tremendous potential for our country, for our States and certainly something that is near and dear to my heart, and that is our agricultural producers.

We appreciate the panel being here; look forward to further discussions, questions today, and certainly the other panels that will be here.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Lincoln for your participation and leadership in this hearing.

Senator Coleman from Minnesota has joined our hearing, and I would be pleased to yield to you for any opening statement or comments you would like to make at this time.

STATEMENT OF HON. NORM COLEMAN, A U.S. SENATOR FROM MINNESOTA

Senator COLEMAN. Thank you, Mr. Chairman. Very briefly, Mr. Chairman, I have a more complete statement here that I would like to have entered into the record. I want to join my colleague from Arkansas, Mr. Chairman, in thanking you for your leadership on this issue. In Minnesota, we have United States Steel up in

Northeast Minnesota. It is the largest energy user in the State. They are looking at opportunities to use biomass to cut down the cost of energy, which is a big issue for them.

We have a lot of forestry up there, and we have wood chips and a whole range of other things that create opportunity. I had a chance to visit and check out an anaerobic digester and a 1,400-cow dairy farm that is providing energy not just to the farm but to the local co-op. Although we often talk about biomass in terms of rural issues, in St. Paul, Minnesota, the city which I had the great pleasure to be the mayor of for 8 years, we have a biomass facility now operating as part of District Energy, which provides heating for the entire downtown area of St. Paul.

This is something that is really universal that helps citizens in every corner of the State. We need to do more. There are a few things I know that are before us right now that will continue to move biomass on the forward track it has been on. The renewable energy provisions of the Farm bill are an important part of that. There is also the need to expand the Section 45 tax credit through 2006 and ensure that it applies to biomass projects.

The Senate is poised to get this passed. I hope we do so. I hope this hearing spurs us to do even greater things for something that really holds great hope for meeting America's energy needs in the future.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you very much, Senator.

[The prepared statement of Senator Coleman can be found in the appendix on page 44.]

Mr. Rey, I appreciate very much the discussion that you gave us with respect to the provisions of current law that authorize certain projects. In the Farm bill, we provided authority for $22 million each year to fund renewable energy systems. I wonder whether you think this is a program that has enough authority. Should we consider expanding that at this time? Are there a number of biomass projects available to be funded around the country that offer hope for achieving the goals that we have discussed here this morning?

Mr. REY. Well, we had no trouble awarding the $22 million in the fiscal year 2003 program, and we have recently published a Notice of Funding Availability for $23 million in fiscal year 2004 grants. If you would like, Mr. Chairman, as we get the response to that, we can keep you apprised of what sorts of responses we are getting, what kinds of systems are being suggested, and we can also give you an idea of how the number of responses and requests would compare with the $23 million in 2004 funding that is available.

The CHAIRMAN. I notice that in your testimony, Mr. Garman, you suggested that there is a goal of establishing the first large-scale biorefinery based on agricultural residues by the year 2010. What is the progress that is being made to indicate to you that we may be able to achieve that goal? What are the steps that are being taken now?

Mr. REY. We have been working closely, and let me say with the Department of Agriculture and the mechanisms you have established using both, farm bill money and our money to do joint solicitations to work on the underlying science and technology that has to be developed to make that kind of refinery possible.

We have only done two or 3 years worth of projects. Those projects are underway now. We are starting to get some early results, but it is going to take some more time in the lab, some more time—I have not seen anything that tells me that was not the right goal to set. We can be on track; again, there can be slippage depending on the outcomes of budgets, but that remains our goal at this point, and we have seen nothing from the scientific results of the first three rounds of solicitations that we have done that would dissuade me from that view.

The CHAIRMAN. Thank you.

Senator Lugar.

Senator LUGAR. Thank you very much, Mr. Chairman.

Let me just ask a general question based upon the fact that as the Chairman generously cited an article that Jim Woolsey and I wrote for Foreign Affairs in 1999. We were describing then a perilous situation with regard to our national security and our energy inputs from all over the Earth and specifically the declining amount of oil prospects we had in this country and the difficulty of getting natural gas.

These debates continue in the energy debate this year more urgently and in terms of popular look-see at this, the price of gasoline at the pump goes up, and it is a very large political issue. The fact is the debate has, it seems to me, moved only incrementally in the 5-year period of time with most people who are savants at foreign policy pointing out again how perilous our situation is becoming.

Toby Maxwell, a well-respected oil analyst, points out that as a matter of fact, even the foreign reserves, which we have always anticipated were relatively limitless are not; that we may have reached a tipping point in which the world is actually going through a quantity of oil and natural gas resources that comes to an end at some point.

I expect those who are around this table when that time comes will be very urgent about that situation. This is no fault of any of the Departments here today. You are doing your best. As you point out, Mr. Garman, even given the $81 million you have, Congress has pigeonholed off $40 million, so you really could not quite get on with all of those projects.

There still is obviously not the sense of national urgency quite apart from Congressional urgency. Even if there was, the problems that we saw then and now are that even taking corn for ethanol, the cost of using corn and that process always has been more expensive than simply the petroleum-based situation. Maybe the cost gap is narrowing, but a subsidy of one form or another has been in play.

This has regularly been attacked as pork barrel politics for corn farmers. Leaving aside the validity of that attack one way or another, the fact is that we would have cost differentials elsewhere. Just theoretically, is it ever going to be possible to narrow the gap so that, for example, a corn-based ethanol costs the same or less than petroleum-based, or if not corn-based ethanol, a biomass solution of some other type that, in fact, through American ingenuity, comes in at less?

Now, that does not mean even if it did, in my judgment, people would leap to it. The infrastructure that now supports the petroleum and natural gas business is out there, and the infrastructure that supports the collection of biomass, whatever it is, and the transportation of it and the refining and so forth is not there.

Can you give us some national optimism that it scientifically is possible to come to a point in which, in fact, you make the economic case, it just simply costs less, quite apart from how you have been doing it all these years?

Mr. GARMAN. Well, with the current set of policy measures and subsidies in place, I can say with some assurance that ethanol, dry mill ethanol producers today are making money and getting a good return on investment.

Now, their profit margin has been inhibited in recent years by the high price of natural gas that they need to produce that ethanol. They have to—it is a pretty large energy input, which is why our vision of the integrated biorefinery, your vision of an integrated biorefinery is on target, because it can produce much of or all of the energy it needs for its process, heat and energy inputs.

I believe there is reason for optimism here. Let me qualify that a little bit, provided we are able to break that barrier of using the cellulosic material as the feedstock. That is very important, because we in this nation use about 135 billion gallons of gasoline each year, and we are excited about the prospect through the renewable fuels legislation that the Senate is considering getting up to 5 billion gallons of ethanol production each year.

We do not know exactly where the point is, but when you get much above 5 billion or 6 or 7 billion gallons, you start to impede on other values we have: how much arable land do you want to produce? How much do you want to take starch and sugars out of food production to go into energy production? You start to have some problems.

If we break through the technical barriers that prevent us from using the cellulosic material and waste, then, as I indicated in the testimony, we can get up to around theoretically as much as 60 billion gallons a year, and that is a large percentage of our needs.

Now, when you take the next step and look at how biomass can be converted to hydrogen, as can natural gas, as can coal, as can water if renewable energy or nuclear energy is applied, then, you have a multitude of domestic feedstocks pointed toward the one fuel. That could be a tremendous advantage for us.

I have probably said too much, but the bottom line answer is biomass, we think, plays an important role today and will play an increasingly important role in meeting our energy needs for the——

Senator LUGAR. On the cellulosic idea, though, if you were—on a scale of 1 to 10, through the dead start and 10 being there that you really have, where is that?

Mr. GARMAN. Our current estimates are that ethanol from cellulosic material probably can be produced at a cost of around $2.50 per gallon. Our 2012 target is $1.07 per gallon.

Senator LUGAR. $1.07?

Mr. GARMAN. Yes, sir.

Senator LUGAR. All the way from $2.50 to $1.07.

Mr. GARMAN. Yes.

Senator LUGAR. Through a new process.

Mr. GARMAN. There is, you will hear, in later testimony on the next panel, there is an entity in Canada that is producing small commercial amounts of cellulosic biomass. I do not know with any precision their costs or how much they are actually shipping, but they have begun. That is an indicator to me that the time is coming. We produce cellulosic—ethanol from cellulose at a pilot scale plant at the National Renewable Energy Lab in Golden, Colorado today. We are talking about 2012 or so before we think it can realistically compete with gasoline.

Senator LUGAR. That, optimistically, would—out of the 135 billion gallons we need as a country for everything, 60 might come from this thing if you had the breakthrough on cellulose, and that might become in the cars by 2010, 2012, from what you are saying.

Mr. GARMAN. Yes, and let me add, of course, this morning, oil was priced in the Asian markets this morning at around $40 a barrel.

Senator LUGAR. Yes.

Mr. GARMAN. Of course, when the competing fuel is priced higher, that can hasten the time when biomass-derived fuels can compete.

Senator LUGAR. Now, then, the step to hydrogen, where does that lie, if 2010–12 is somewhere in the neighborhood of where the first jump comes?

Mr. GARMAN. Well, there are two methods that we can use to produce hydrogen from biomass, readily, just off the top of my head. One is through gasification, what we call the synthetic gas or the thermochemical platform, where you can produce a gas from biomass, you can gasify it, which makes a very hydrogen-rich gas. You can strip off that hydrogen and use that as fuel. We are beginning to explore that today.

In the nearer-term, because hydrogen is very difficult to store and move around, ethanol could serve as a hydrogen carrier, where people could produce ethanol the way they are today; it could be distributed the way it is today to local filling stations and then, at the filling station, the ethanol could be converted to gaseous hydrogen, and we have demonstrated some technologies to do that. That is a method where ethanol could continue to play in the transition years of hydrogen, even if we have not dealt with all of the issues related to gasification.

We are trying to look at all of these things in a balanced way and pursue the avenues we think are most promising technically.

Senator LUGAR. Mr. Chairman, I wanted to ask one further question——

The CHAIRMAN. Sure.

Senator LUGAR [continuing]. If I may, of Congressman Ewing, because he cited the act that we worked on in 2000 and which created the panel or the Advisory Committee that he speaks for today. How has that worked? Do the Energy Department and Agriculture work together? Has the coordination situation that we envisioned coming to pass?

Mr. EWING. We found a very good attitude of cooperation between the two, and I have been very pleased with it. We have just scratched the surface with the act that was passed in 2000, and I doubted I would ever appear before a Committee of the Congress and say we need more money, but we really are not putting the resources yet into the development of new biomass energy sources, and what my observation is that there is an incredible amount of interest out there across the country in innovative ideas that they would like to have some help. We get a lot more applicants for the money than we have money to go around.

Senator LUGAR. Thank you, Mr. Chairman.

Mr. GARMAN. Could I add just one thing? I apologize, but I just want to stress that point the Department of Energy and the Department of Agriculture are two completely different agencies with two completely different cultures and outlooks and orientation. I never thought, because I was working for Senator Murkowski on the Energy Committee at the time your bill was passed, that these two agencies could work well together.

We still have a ways to go, but thanks to this legislation and thanks to the work that the Advisory Committee puts us through, we are making great progress.

Senator LUGAR. Well, we have created homeland defense in advance here, coordinated these agencies.

Thank you.

The CHAIRMAN. Thank you very much, Senator.

I am going to ask now our distinguished ranking minority member from Iowa, Senator Harkin, if he would like to make any opening statement and then proceed with any questions he has of this panel.

STATEMENT OF HON. TOM HARKIN, A U.S. SENATOR FROM IOWA, RANKING MEMBER, COMMITTEE ON AGRICULTURE, NUTRITION, AND FORESTRY

Senator HARKIN. Mr. Chairman, thank you very much.

I would just ask that my opening statement be made a part of the record. I apologize for being late, and I will just make a couple of observations and then go into my questions.

First, I want to thank you, Mr. Chairman and the previous Mr. Chairman for the great leadership both of you have shown on this energy matter regarding agriculture and biomass. It was, I remember, several years ago when I sat not in this room but in the Ag Committee room listening to then-Chairman Lugar talk about cellulosic biomass energy, energy from cellulosic material, and I turned to my staff and said what is he talking about. Let us find out about this.

It then evolved into the R & D bill that was passed in 2000, and then, all of us working together put the first energy title ever into the Farm bill, the 2002 Farm bill. We are making progress and moving ahead and getting a better handle on this, and I am just delighted that we have this advisory panel set up, and I look forward to the next panel also coming in to talk to us about what they see as our energy future.

While we are making progress, it seems to me that there are some possible stumbling blocks, and we are not moving fast enough. I am concerned about a report, Mr. Garman, that DOE just came out that gave a significant negative reassessment of the cost of making ethanol from cellulose. The previous assessment was

$1.40 a gallon. You just mentioned now cost that it is up to $2.50 a gallon. Why was this changed? This is a pretty drastic change.

Mr. GARMAN. Yes, and that is an excellent question, and I was somewhat alarmed to see that jump as well, because I had it on a little card I carry around with me all the time, the current estimate, $2.40. It has been revised to $2.75, and I use $2.50 or above. After talking to some folks in the chemical business, I am reassured that this is normal; in fact, It is fairly said that when we said we thought we could do it at $2.40, the professionals in the chemical business did not believe us. They said yes, when you are first discovering a scientific frontier, you make an estimate. Then, as you start to delve into it and start to really and truly understand the technical obstacles that confront you, that estimate usually starts to go up. This was actually a gentleman from DuPont who was telling me this.

Then now, they believe us. Now, they say, OK, $2.50, $2.75, now, you are talking. That is really what it is, because then, that shows us you have done the scientific work, and you have really baselined this thing properly. You have the correct slope toward pathways. What I tell our program managers is that when we discover that our R&D targets are off, let us fess up to it, and let us put that in the budget and make sure that the Congress and everybody else knows that. Because in the process of scientific discovery, those are things that you find out once you start to really get into things.

Senator HARKIN. I have here a press release dated 21 April 2004: cellulose ethanol is ready to go. Iogen Corporation in Canada announced today it is producing the world's first cellulose ethanol fuel for commercial use. This is in cooperation with Shell, Petro Canada, whoever that is, but Shell Global—Shell Oil, the Government of Canada and Petro Canada. I assume Petro Canada is a gas company or something; I do not know.

Anyway, Iogen made—is now making cellulosic ethanol, and they are actually selling it. Do you have any idea that they are now doing it.

Mr. GARMAN. Yes, and that was the Canadian company I mentioned a little bit in the earlier question.

Senator HARKIN. How can they do it at $2.50? What is happening here?

Mr. GARMAN. Well, we do not think they are selling very much of it, and we think it is a start, and they are learning a great deal, and many startup companies or demonstration companies do operate at a loss to get ahead and develop the expertise they think they will need to be the industry leader of the future. Sometimes, they get that kind of financing to do that.

Senator HARKIN. Could it be that they have some more active enzymes or some better enzymes that break down the cellulose?

Mr. GARMAN. We are not aware that they have any kind of process or technology or enzymes that we also do not have access to, and the cost of enzymes is a major factor in the production cost.

Senator HARKIN. Is there any way you can find out what Petro Canada is paying for this?

Mr. GARMAN. It is proprietary, and it is very difficult. There is nothing we can do to compel them to tell us, our folks are talking to their folks, and we are trying to learn everything that we can.

Senator HARKIN. Well, I am told that it is a private company, and I cannot imagine that they would be wasting money. That they would be doing something that would not be at least somewhat beneficial one way or the other. I guess my confusion comes from this reassessment that you have made and the fact that just recently, this Canadian company, which is a privately held company, along with Shell have announced that they are actually making it and marketing it. Someone is buying it, and I cannot imagine they would buy it at some exorbitant price when they could buy an alternative fuel a lot cheaper.

I do not know; I just have a——

Mr. GARMAN. The Department has not seen Iogen's estimated cost for the ethanol produced in their demonstration plant. However, Iogen has communicated to us that from a cost accounting perspective, the company is not including the cost of construction of its production facility in its ethanol product costs. Therefore, the selling price of the company's ethanol under these circumstances only needs to cover operating and delivery costs, plus profit, excluding all capital costs on their income sheet. This situation is unique and makes comparison to the broader ethanol market challenging.

It is also difficult to view the Iogen plant as a commercial entity because of its size. Iogen's current rated production is approximately 250,000 gallons per year, which represents only 0.009 percent of 2003 domestic production. An average farmer-owned corn-to-ethanol plant is 120 times larger, with a capacity of 30,000,000 gallons per year. It is difficult to ascertain how the small size of the Iogen plant could lead to a profitable and cost-competitive situation under normal accounting methods.

Senator HARKIN. Well, sometimes, we always have the attitude, if it is not invented here, it must not be any good they say they have been researching this for 25 years, I do not know; I do not know this company; do not know anybody associated with it, but if they have some new enzymes or new enzymatic process that works better, we ought to be looking at it.

Mr. GARMAN. I have personally met with this company in the past.

Senator HARKIN. You have?

Mr. GARMAN. Oh, yes, sir, and they told us of their plans, and we have been monitoring them. Again, I do not know how much they are producing, and I do not think that release tells us how much they are producing either. This is pretty closely held information. They are certainly not telling us the cost at which they are producing this amount of material.

Senator HARKIN. Well, they just estimated that for cellulose ethanol, there will be a market of $10 billion by 2012.

Mr. GARMAN. I hope they are right.

Senator HARKIN. Well, I hope they are right, too, but I hope we are moving ahead aggressively, too.

The last thing I just want to say, is that in February, final rules released by the Department of Energy will not require local governments and private fleet operators to use alternative fuel vehicles under the Energy Policy Act. The reasons given for not requiring alternative fuel vehicles was that even if the 2 million or so vehicles in these fleets were converted to alternative fuels, it would have little impact on petroleum consumption. In particular, availability of alternative fuels was given as a problem limiting their use.

Well, if this is the case, what is the DOE doing to promote the creation of a nationwide network of E–85 pumps? The decision to not require alternative fuel vehicles in fleet operations seems to be sending a very mixed signal about DOE's commitment to biofuels development. Does the Department, do you, support E–85?

Mr. GARMAN. Oh, absolutely, and we run what we call a Clean Cities Program to help to develop and deploy that refueling infrastructure that can help make E–85, compressed natural gas and some of the other alternative fuels, including biodiesel, a reality. Again, there are certain fleets under the Energy Policy Act that currently are required to use alternative fuel. What we found is that some of the State and private fleets, or State and local fleets are very small, fleet sizes of five vehicles. It was very difficult to justify the refueling infrastructure needed to do five vehicles, and so, many would, under provisions in the law, opt out of actually using alternative fuel in the vehicle.

This is the kind of problem we have had. We can, under the law, compel people to purchase alternative fuel vehicles, but under the law, we cannot compel them to actually use alternative fuel in the vehicles. We have had that problem in the Federal fleet.

Senator HARKIN. I understand that, but again, further promoting E–85 and establishing a system of E–85 ethanol pumps around the country would be very helpful.

Mr. GARMAN. Yes, and in fact, our Clean Cities Coalitions are meeting right now, I believe this week, in Florida. We have coalitions with some 85 cities around the country to promote E–85, and compressed natural gas. We will see, 160 additional compressed natural gas buses plying the streets of Washington, DC in the next few months because of some of these successes.

Senator HARKIN. Thank you, Mr. Chairman. I will just submit questions for Mr. Rey, in writing.

Mr. REY. We will be happy to respond.

The CHAIRMAN. Thank you, Senator.

Senator Lincoln, any questions for the panel?

Senator LINCOLN. Thank you, Mr. Chairman. Lots of questions, but I may not have time for all of them.

Just on this last one that we talked about, lots of times when I hear back from industry side in terms of alternative fuel vehicles, they pretty much get the alternative fuel vehicle and then put it on the lower 40 and never use it. They get their credits for that. Why is it so difficult for us to encourage the use of the alternative fuel? Is it accessibility?

Mr. GARMAN. Accessibility. Most of vehicles that we operate in the Department of Energy, are alternative fuel vehicles, compressed natural gas mainly. There is one fueling station, precisely one in this near area, over near the Pentagon, where you can actually refuel it.

Senator LINCOLN. Right.

Mr. GARMAN. I notice that we opened—or the private sector opened a new E–85 station in Lanham, Maryland just a few weeks ago, and that is a positive development, but you do not see a lot of E–85 stations outside the Midwest. Part of that is changing, and again, the renewable fuels legislation that the Senate is considering to expand renewable fuels production and using renewable fuels as an oxygenate is going to help create that infrastructure as we move more ethanol out of our heartland.

Senator LINCOLN. This company in Canada, is the research that has allowed them to do that, is that Government research, or is it private industry research? Or is it a combination?

Mr. GARMAN. I am not positive. I imagine they have used a combination of both.

Senator LINCOLN. Do we?

Mr. GARMAN. Yes, absolutely.

Senator LINCOLN. How much partnering does go on with private industry?

Mr. GARMAN. We try to predicate all of our work on public-private partnerships, because we think that the most productive kind of R&D we do is when we bring the private sector into the labs, and we work together on precompetitive aspects of the research. Then, they take what they learn in the labs and then go off and do their own proprietary research and try to gain that competitive advantage. That collaboration——

Senator LINCOLN. Well, I do not know as much about the cellulose, just simply because we do not grow as much corn as a lot of these gentlemen do. We grow a lot of rice and certainly soybeans. Biodiesel is really one alternative fuel that I am more focused on. I have also been very focused on what we can do with chicken litter, because it is creating a huge problem for us in the poultry industry and not to mention the municipal solid waste opportunities that exist out there.

I guess my question is in earlier questioning, you continued to focus on the need for more money for research as opposed to really looking at the delivery of how we get this—we know that we have enormous potential in biomass and in alternative fuels, and it seems to me that we have done a remarkable amount of research. Really, the research needs to be more focused if it is research at all that we need in the delivery model of what we are getting out there.

I have farmers in a whole county in Arkansas that have committed to using 5 percent biodiesel in all of their equipment. We have a crusher that we are looking desperately for dollars to get started and then, hopefully, see a refinery for biodiesel there, because we do not need retrofitting, really, there. We can just pump it into a combustible diesel engine.

Mr. GARMAN. Right, and a number of things are going to happen. First, the EPA is going to or has promulgated low-sulfur diesel fuel standards for 2006. There will be a very low content of sulfur in that diesel fuel, less than 15 parts per million. As a consequence, that fuel will lose some lubricity that is very important. Biodiesel, soy biodiesel specifically, is a very good lubricity agent that folks are going to be clamoring for to meet the demand for the 2006 fuel standards.

That is going to assist in deploying the biodiesel technology. There are also some things we need to do. There are not very many engine manufacturers that will honor a warranty on higher blends of biodiesel. Two percent is fine, but if you get up to 10 percent or more, you are in danger of voiding your warranty. Many consumers do not want to do that.

One of the things that we are committed to doing is working with the engine manufacturers and fuel providers to certify the performance of higher blends of biodiesel in engine——

Senator LINCOLN. I heard that problem 10 years ago. Have we been doing that?

Mr. GARMAN. We have been doing some but honestly not enough. There is a question as to whether, outside of certain small, regional markets, you can support blending of much more than 2 percent of diesel or it is going to be a regional and fractured market. We will have to talk to you more about this, because it is an exciting area.

Senator LINCOLN. I guess it is regional and fractured if we allow it to be that way. It seems to me that we have such tremendous potential that we could really energize all of the different sectors of the economy that are going to not only participate but benefit and move it along quicker than we have been seeing.

On the cellulose side of things, where are we on the technological development curve in terms of developing enzymes that can convert that biomass to sugar or ethanol? If there is a classroom curve, where are we on that?

Mr. GARMAN. We can do it today; just the enzymes are too expensive to do it at a price competitive to gasoline or corn-based or starch-based ethanol.

Senator LINCOLN. The curve is pretty steep is what you are telling me in terms of cost.

Mr. GARMAN. Right. As we were saying, it gets into this earlier discussion we were having. We believe the current costs are $2.50 to $2.75 a gallon. Our target for cellulosic biomass is $1.07 a gallon by 2012. That gives you a sense of——

Senator LINCOLN. That indicates to me that we are pretty low on the learning curve here.

Mr. GARMAN. Pretty low on the curve, yes, because we have to reduce, for instance, the cost of the enzymes probably by a factor of 10.

Senator LINCOLN. Can the biorefineries that you are talking about that use the cellulose-based biomass, are they able to operate in all 50 states?

Mr. GARMAN. Well, we have not developed one yet, but yes, the answer would be yes, because I personally think the expense and difficulty of hauling large amounts of feedstocks very far will ruin your economics if you have to haul things from the field a long distance.

Senator LINCOLN. What about hauling the end product? You cannot pipe it, right?

Mr. GARMAN. Yes, you can.

Senator LINCOLN. You can?

Mr. GARMAN. You can. It has an affinity for water, and you have to deal with some of those issues, but we can deal with those issues over time. We will have, instead of the model we have today of oil-based refineries geographically concentrated in certain regions of the country a more even distribution and an even smaller-based refinery system run on a community scale instead of a very large industrial base. That is what I would like to see because that helps farmers share in that value chain closer to home.

Senator LINCOLN. Mr. Chairman, I have used my time, but again, thank you for this, and I have many more questions I may submit for the record to be answered, and again, I appreciate it, because this is a very exciting topic with multitudes of possibilities.

The CHAIRMAN. Thank you, Senator, thank you for participating in the hearing.

Senator Coleman.

Senator COLEMAN. Thank you, Mr. Chairman. Just a comment and then a question.

I mentioned in my opening statement about the urban applications. For me, it is important. This cannot be seen as we are just focusing on rural communities; critically important, but everybody should realize that they have a stake, and everybody has opportunity. In Minneapolis, there is a neighborhood called the Phillips neighborhood. It is one of the lowest-income neighborhoods in the heart of the city, and they are in the process of developing a project that will heat 20,000 homes and about 3 million square feet of business space and multifamily housing. They are looking at using tree stumps and some organic waste from a nearby General Mills plant.

When they come to the Department of Energy and come to the Ag Department, please reflect upon the importance of our urban citizens understanding they have got a dog in this fight; they have got a stake in this, and the more we can get everyone to understand this is good for America, the better-served we are going to be.

A question to Mr. Rey. I applaud the administration's comprehensive energy policy and the energy bill-biomass; ethanol; biodiesel; wind, which we have a lot of, by the way, in Southwest Minnesota; they call it the Saudi Arabia of wind. One area of concern, however, has to do with budget submission for the development of renewable energy systems. You noted in your comments that we did not have any problem with the $20 million or the $23 million in 2003 and 2004.

I understand that budget submission for 2005 is $10.8 million, and I am wondering how do you respond to the critics who say the need is out there; we have shown a commitment to a comprehensive energy policy, and this funding level does not accomplish that?

Mr. REY. Well, what we have done in responding to funding requests for these kinds of systems is not only used the Section 9006 grants, but we have also been using the Value Added Market Development Grant and the Rural Business Enterprise Grant and Rural Business Opportunity Grant programs to supplement the money available for these kinds of systems. We have given a priority in those three other grant programs to renewable energy systems as well, and when you look across what we do in 2004 in all four of those programs and what we hope to do in 2005 with those four programs, assuming a favorable response to the budget request, you will see a significant emphasis on renewable energy systems.

Senator COLEMAN. It is important just to get that word out there. I do not want anyone to have at all the sense that somehow, we are stepping back on this when, in fact, there is this whole world of opportunity that we have to seize. I appreciate that.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator. I appreciate your participation in this hearing.

We appreciate also this panel leading off our hearing today on this subject. We thank you for your submission of your remarks in advance to the Committee. They will be made a part of the record in full. Thank you very much.

The CHAIRMAN. We are pleased to have on our next panel a gentleman whom I mentioned in my opening remarks who came to visit with me and suggested that we take a more active role in trying to promote alternative fuels production, refining and research that is being done in this area of interest. We are pleased to welcome to the Committee James Woolsey, who is a former Director of Central Intelligence. He also served here in the Senate as counsel to the Senate Armed Services Committee about the time I was elected to Congress in 1972. He has chaired advisory boards of the Clean Fuels Foundation and the New Uses Council. He serves on the National Commission on Energy Policy as well; and Boyden Gray, who has been a friend for a long time. He served as legal counsel to Vice-President George Bush in 1981 and then continued in his role as counsel for President Bush when he served as our president from 1989 to 1993.

Mr. Gray is representing the Energy Future Coalition. We appreciate very much your being here. We ask you to make any opening statement to the Committee you think would be helpful to our understanding of these issues.

Mr. Woolsey.

STATEMENT OF HON. R. JAMES WOOLSEY, FORMER DIRECTOR OF CENTRAL INTELLIGENCE, MCLEAN, VIRGINIA.

Mr. WOOLSEY. Thank you very much, Mr. Chairman.

It is an honor to be asked to testify before this distinguished Committee. I first got interested in these issues due to my old friend Bill Holmberg, who is here today, and then, Senator Lugar asked me 7 years ago to testify before this Committee, and then, following that testimony, he and I wrote the article you described. It is an absolutely vital issue for our national security.

Let me say just a word about what I do not think we should be spending a great deal of time on. One is where we buy oil. The world's oil market is more or less one market. We do not accomplish much by buying more from one part and having, say, Europe buy more from the Middle East. The economies are related; the oil prices are closely related. I do not think this is a question of the geographic region from which American imports come. The world's dependence on the Middle East is an extremely delicate and difficult matter because of the instability there and particularly because of the uncertain future of Saudi Arabia.

I say in the written testimony that although Crown Prince Abdullah speaks somewhat hesitantly and not very strongly sometimes but nevertheless does speak to some degree for a reform movement in Saudi Arabia, other important parts of the royal family such as Prince Nayyaf at the Interior Ministry and others are quite opposed to reform, and whether or not that Kingdom moves in a positive direction in cooperation with the world's democracies and the rest of the world in setting oil prices or whether—and in a lot of other ways or whether it is mired in its vulnerability to terrorism and other threats has a good deal to do with the future direction of the world's stability in economic terms as it relates to oil.

It is not only governmental uncertainty in Saudi Arabia. It is the vulnerability to terrorism. Bob Bayer's recent book Sleeping with the Devil opens with the scenario of a fully loaded 747 being crashed into a particularly important part of the fuel processing facilities in Saudi Arabia and thereby setting the world back many millions of barrels a day for many months. It is, unfortunately, a reasonably realistic scenario.

Then, finally, of course, is the problem that could come about not only from terrorist attacks in Saudi Arabia, as we have seen earlier, within the last 5 days, but also in other parts of the Middle East and even the possibility of an Islamist government, people of the stripe of Osama bin Laden coming to power in Saudi Arabia.

It is sometimes said that it does not really matter who is governing Saudi Arabia, because they are going to have to sell their oil anyway. That is not true if those who rule the country want to live in the Seventh Century, as do the Islamists. The uncertainty in the oil picture worldwide, driven by the uncertainty in the Middle East, is a very important aspect of the whole problem. It is also important that as we focus on alternative energy, we not spend a great deal of effort, if one is concerned about the strategic situation, on generation of electricity.

There are interesting, renewable ways to generate electricity. There are a lot of ways to generate electricity. Oil only fuels about 2 percent of our electricity generation now, and that is headed down. Insofar as one is worried about instability from foreign supply, we are really almost exclusively talking about a transportation fuel issue here.

That it is important to focus on the fact that came out in a number of questions to the preceding panel. The problem here is moving along smartly to being able to produce alternative fuel that can be consumed within the existing infrastructure and doing so relatively quickly. There are a couple of fuels that fit that definition, to my mind. One is ethanol from biomass, because ethanol that has been reduced from biomass mixes readily with gasoline, and you can use up to E–85, 85 percent ethanol, in flexible fuel vehicles.

Now, when I talk about these issues, rather than alternative fuel vehicles that sometimes would mean burning entirely, let us say, natural gas or something like that, which some bus fleets do, one wants to focus on the family car. There are millions of flexible fuel vehicles on the road. It costs a little bit extra to produce them, but you get a Ford Taurus that is a flexible fuel vehicle and can burn up to E–85 for no added cost if you walk into a dealer's showroom. It is a slightly different type of plastic in the fuel line and a slightly different kind of computer chip.

One thing that is important is to buildup the fleet of vehicles that the average American family can buy so that when ethanol is available from biomass, we do not have to go through yet another conversion of infrastructure; the infrastructure is already there. I know of nothing that would keep a flexible fuel vehicle from also being a hybrid. If a hybrid gets about 60 miles a gallon, as the Toyota Prius does today, then, if you were using E–85 in it, even with ethanol somewhat lower energy content than gasoline, you are up in the range of getting 300 miles per gallon of gasoline. That is not bad.

It seems to me with those kinds of prospects before us, it is not a wise idea to spend a great deal of time and resources on focusing on the hydrogen economy. We have more of an urgent problem than this. Yes, there are certain attractive features to hydrogen being used to carry energy from one form to another, and it burns cleanly, and that is fine.

Someday, we may have a hydrogen economy and fuel cell vehicles. If we concentrate on what can be done now and financial incentives to get things like biomass ethanol produced now, we will do a lot more for the country and for the agricultural sector of our economy.

One final point: the other technology that I would like to call to your attention is the use not only of agricultural wastes but also waste that is from biomass, from cellulosic biomass but also waste from animal carcasses and manure, particularly animal carcasses, given the dangers from BSE and the like.

In Europe, for example, there are tipping fees, that is, negative costs recognized of over $100 a ton for dead animals. That means with one of the processes that is now commercially operating in Carthage, Missouri, in a joint venture between ConAgra and Changing World Technologies, one could give away the diesel fuel that is produced and still make money. The reason is because the negative costs, the tipping fees from the producer getting rid reliably of those animal carcasses is so recognized by the tax system and so forth.

If we look at waste products, first and center, both those that grow in fields and those that are the result of animals, for instance, rice straw in the process of producing ethanol, we can focus on giving credits for getting rid of substances that we have to get rid of. Often, those costs are not recognized in the systems that we operate today. If one recognized that rice straw has to be gotten out of the field—it is not like stover; it has silicon in it; you cannot plant again and cannot leave it in the field, and if you burn it, it smells awful.

If we recognize those negative costs both in animal and in cellulosic agricultural wastes, we can help move the production of fuel, whether it is diesel that could be refined into gasoline or cellulosic ethanol, along far more quickly than by focusing on the R&D long-term perspective, which is often presented.

With that, I will pause, Mr. Chairman, and turn the floor over at your permission to my friend, Boyden Gray.

[The prepared statement of Mr. Woolsey can be found in the appendix on page 67.]

The CHAIRMAN. Thank you very much, Mr. Woolsey.

Mr. Gray, you may proceed.

STATEMENT OF HON. C. BOYDEN GRAY, ENERGY FUTURE COALITION, WASHINGTON, DC

Mr. GRAY. Mr. Chairman, thank you very much for this opportunity.

I thought what I would concentrate on is a response to what has already transpired rather than summarize the testimony that you already have. Transportation fuels are the key to import insecurity. The DOD commissioned a study from the Arlington Institute that basically came to the conclusion that our Energy Future Coalition came to, which is the road to independence is through ethanol, and through ethanol, you will get ultimately to hydrogen, but the key part is the ethanol.

Our own American automobile industry would love to see this route taken. As much as they are intrigued with hydrogen, the vehicle for moving hydrogen is going to be ethanol, and of course, ethanol from biomass and biodiesel can be used to run the fleet, E–85 or whatever cars you are talking about in the interim.

I believe—we believe ethanol biomass is the key. The questions that have come up have to do, obviously, with costs and capacity. Is there an efficient enough method of attacking the cellulose problem? Assuming you can do that in a cost-effective way that makes the product competitive worldwide with gasoline, is there capacity to make a real dent, to make it worthwhile? Is it worth really trying to do?

The answer to both questions is yes, there is a way to attack the cellulosic problem, and the results would be quite interesting: 60 billion gallons—we rely on a Battelle Memorial Institute study for our purposes which we have submitted which suggests 50 billion gallons. You heard Mr. Garman talk about 60. I will take either number. If you include what the Caribbean basin could do, what Central America could do and South America, the number would be very, very much higher, so this is very, very significant cut of 120 billion, 130 billion gallons of gasoline. It is very, very significant.

Now, what about the costs? I do not think only we really understands; this is something the Committee may and should perhaps try to get to the bottom of. I do not think the cost of the enzymes is the problem. My understanding is the Department of Energy has run studies to get the cost down tenfold that they were talking about. The problem is the commercialization of these technologies. Can they be worked at the plant scale? The huge kind of scale that you need to really realize the benefits of efficiencies?

There, frankly, this is where the Government comes in, that's necessarily to help jump-start the technology. In the same way NIH did for biotech for the drug side of the equation, the Government really has a role to play in sharing some of the risk of this with the private sector.

The payback would come very, very quickly, because studies show, Oak Ridge studies show, that for every 10 or so billion gallons of ethanol consumed, you would save $1 billion or so in crop subsidy supports. You are talking about huge savings that would pay back very, very quickly any investment the Government made in commercialization.

Now, there are certain other side benefits that come from this. If you understand what is going on here, the increase in crop prices resulting from the demand for them in the transportation sector means less subsidies. It also means better prices for farmers worldwide, and William Klein, who is an economist with the Center for Global Development, has estimated that every 50 billion gallon increment produced raises 40 million farmers out of poverty worldwide in the developing world.

The consequences for world agriculture and for the world economy are quite significant. The last point I want to make responsive to what has occurred, what are we comparing the costs of here, at least initially as this thing tries to get underway and ramped up, and people get used to doing this? The highest value of these alternative fuels is as a substitute for—as a source of clean octane for the transportation fleet.

We lose sight of this. I got into this whole issue primarily because of the elimination of lead from gasoline 20 years ago, which was one of the most successful environmental initiatives ever undertaken by the U.S. Government. We are still struggling trying to get the lead out of the gasoline in Africa, for example, but we have done it here. We were 20 years ahead of the rest of the world in this country.

Well, where do you get the octane when you take out the lead? Well, the octane now comes from products called aromatics, which are bad actors. They are the principal remaining source of pollution in this country. They are expensive. They are on a par with ethanol to even produce today. If one were to eliminate the aromatics from the gasoline, one would have a ready market for ethanol at today's prices, let alone what could be happening with a little jump start on the commercialization of these new technologies for cellulose.

One of the benefits would be, and I will close on this, a total elimination of any remaining air quality problems in the United States. That would be a nice thing to do as a side effect of gaining a little energy independence.

Thank you.

[The prepared statement of Mr. Gray can be found in the appendix on page 74.]

The CHAIRMAN. Thank you very much.

Mr. Woolsey, you mentioned in your statement the hybrid engine development and use. What should we do as a Government to help move this along or promote it?

Mr. WOOLSEY. Well, I just bought a Prius a couple of months ago, and the tax advantage was $500 less than it was the previous year. Next year, the tax advantage will be $500 less still. We are headed in the direction of nonencouragement of hybrids, which seems to me a little odd, given the events, for example, as I said, in Saudi Arabia a few days ago.

The taxes are, I would think, the Government's tool, both to encourage early production of biomass ethanol, of diesel fuels that can be used in the existing infrastructure and of hybrid vehicles. I realize, having worked up here, myself, Mr. Chairman, that it is sometimes a real struggle to get the tax system encouraging things that way.

The CHAIRMAN. You also commented in your testimony about the potential of harvesting switchgrass——

Mr. WOOLSEY. Yes.

The CHAIRMAN [continuing]. On Conservation Reserve Program lands. I had a visit in my office some time ago from former Senator Henry Bellman of Oklahoma. He came to town with a research scientist from his State who had been actively working on this technology. What is the prospect of effective and efficient utilization of things like switchgrass? Does it offer real promise of helping us achieve these alternative fuel resources?

Mr. WOOLSEY. I definitely think so. Professor Lee Lynd will be testifying in the next panel, who knows a great deal about this subject. I would just say briefly that although you will get an economic kick to these processes sooner by recognizing waste disposal, things like rice straw and begas in a growing area and things like dead animals or animal carcasses in the other rest of the biological area, switchgrass would probably provide the bulk of what one could use to produce large volumes of cellulosic biomass ethanol.

I know Senator Harkin had a bill a few years ago to permit the harvesting of the CRP lands for purposes of energy, and that is very important, because according to Lee Lynd's calculations that Senator Lugar and I used a few years ago in our article, even at current levels of mileage, gasoline mileage in vehicles, if you harvested a small share of agricultural wastes and harvested just the switchgrass on the CRP lands, no new land into cultivation, no land taken out of cultivation from other crops, that would, as I recall, be able to produce about a quarter to a third of the replacement for the gasoline in the country.

If you move up to hybrid mileages, 60 miles a gallon and better, it could replace all of the gasoline in the country. The trick, both with expanding the biodiesel definition so it covers all types of diesel, because this animal carcass to diesel is now not encouraged by the current biodiesel definition, if you move initially toward using recognition of wastes and getting rid of wastes as an economic incentive for commercialization of these various processes and then for the large-scale move into extremely substantial replacement of imported petroleum, I really believe that switchgrass would have a major role.

The CHAIRMAN. Mr. Gray, you mentioned in your statement this Canadian company that we talked about when the first panel was before the Committee—Iogen, is the name of it—which has begun commercial production of ethanol from cellulose. Do you know of any U.S. investors or companies that are putting together similar joint ventures here in the U.S., or is that likely to happen in the near future without specific Government program development of incentives?

Mr. GRAY. I do not know of any that are as far along as Iogen that are public, publicly known. I do know that there are communities in Kansas, for example, and we discussed this with Senator Roberts, communities that are getting bond issues together to try to start to build plants to do this. I cannot say that one has actually been designed.

I do think that the Government support—maybe it is a guarantee kind of arrangement—for the commercialization of these technologies which the Department of Energy has done on a pilot plant basis may be necessary to get them really launched. It is a small price to pay.

Mr. WOOLSEY. Mr. Chairman, could I add one small point? There was a company, BCCI, a couple of years ago that was reasonably far along. It used a technology of Professor Lonnie Ingram at the University of South Carolina, who is one of the real experts in the world on the modification of these biocatalysts, and it was going to be producing biomass ethanol from begas in Louisiana.

It was reasonably far along, and then, the Department of Energy, in early 2002, withdrew the incentive that they had had in place for about a year for it, and it has slowed down, to the best of my knowledge, to not making any progress now.

The CHAIRMAN. Senator Harkin.

Senator HARKIN. Mr. Chairman, this is not only a fascinating subject, but it is one on which I hope that our Committee continues to focus more time. I thank you for this hearing.

I also want to thank our witnesses here and also the group that you are representing, the Energy Future Coalition. I have read a number of the items that have come out from that coalition, and you are on the right track, and what your message is that we really ought to be doing more things in the tax benefit area, tax incentives, Government procurement.

I am intrigued, Mr. Gray, by what the Battelle Memorial Institute—it is in your testimony but you did not cite it—about the Battelle Institute's estimate that 50 billion gallons of cellulosic ethanol could be made annually without significantly impacting agriculture in a negative way.

You mentioned, Mr. Woolsey, about all of the CRP ground out there with switchgrass. Switchgrass takes very little fertilizer. It grows annually. You can harvest it. I might just point out that I was involved several years ago with starting a switchgrass project, the Chariton Valley RC&D in Southeast Iowa, along with Alliant Energy and a couple of other groups, and we were able to get some funds into it.

We have an ongoing project where they are just simply harvesting switchgrass and burning it in a coal-fired plant nearby. They are mixing it with the coal. That may not be the most efficient way, but at least it is working.

Mr. WOOLSEY. Yes.

Senator HARKIN. It is not impacting the environment in a negative way, and it is on CRP ground.

Mr. WOOLSEY. Yes.

Senator HARKIN. The next step is to get a digester and start using some of that cellulosic material in a digester to produce electricity. I hope that you will take a look at a paper that was developed for me by a scientist once in which he developed the idea of electro-farming, where farmers actually become producers of electricity by putting things through digesters, getting the hydrogen and using the hydrogen through a fuel cell to make electricity.

The parameters he had were pretty interesting, using certain prices of fuel and that type of thing, it looked, actually, in a 10 to 20 year timeframe, promising. It would take some Federal Government involvement, and it would take some pushing and some subsidies and that type of thing to get this going.

I want to get back, Mr. Gray, though, and ask you: tell me about this fly off. I am intrigued by this idea that you had in your testimony that we recommend the Federal Government authorize and conduct a one-time procurement fly off aimed at building 5 to 10 commercial-scale plants.

Just tell me about what that means.

Mr. GRAY. Well, I do not know who would do it; maybe the Department of Defense would do it. They have a keen interest, as I said, and in my testimony says about getting away from oil, not just because of the world security situation but because of their own needs when they go into combat zones.

The idea would be to take five or six or so of the most promising potentially commercialized technologies and order up, pay for or guarantee the construction of five or six or seven or eight different plants and then see which one won. That is what we mean by a competitive sourcing to see which—who had the best mousetrap that would work and come up with the cheapest price.

I am trying to think of an analogy. At the beginning of the petroleum business 100 years ago, the yields from the barrel of crude were pretty low. Just like people now complain that the yield from the kernel of corn is pretty low, the yield from the barrel of crude was very, very low. The Federal Government did not get in this directly, but the companies did compete.

When Standard Oil of Indiana, the original Standard Oil trust was broken up, all heck broke loose as it were, and these independent refineries, now, began to rapidly increase the technological capacity. Well, that is what needs to happen. What the oil industry had as a benefit was a huge subsidy from the Federal Government in the form of the depletion allowance and also the intangible drilling cost writeoff, which made the product they were buying artificially cheap, which allowed them to do it.

Now, meanwhile, ethanol was being taxed. This was all before the Second World War. Things went in divergent directions from the original version that the founders of the automobile industry had. Henry Ford expected our transportation fleet to run on ethanol.

If you just a little jump start, just giving the agricultural sector just a little bit of juice to do this fly off would yield enormous benefits very, very quickly and represent only a fraction of the subsidy the oil industry has over the last century.

Senator HARKIN. Would your Energy Future Coalition have any suggestions as to what that prize might be, or how much we would have to put—to say if you are going to do a fly off, what would we have to have in the end?

Mr. GRAY. Well, it is a big number but I do not think in the larger context of what we are dealing with here it is insurmountable. It is $1 billion. We think it would probably take $1 billion to do this; not in 1 year; it would be over a 5-year period. That is not—I do not, luckily, have any responsibility for meeting budget caps, but that is your problem.

Senator HARKIN. I do not think we do either.

[Laughter.]

Mr. GRAY. One billion would do it. That is what our best—and we can supply more material for the record, but that is my understanding of the best number, what it would take, and it would yield huge benefits.

Senator HARKIN. I forget which one of you mentioned something about what we think in terms of the capacity in the United States, and Mr. Garman was mentioning that before, but one of you mentioned that we have got to think beyond that, think about the Caribbean basin, Mexico, sugar.

Mr. GRAY. Yes.

Senator HARKIN. We have more sugar than we know what to do with, and we are always having our sugar wars with Mexico and the Caribbean and everybody else, but it seems to me sugar is very efficient for conversion to ethanol.

Mr. WOOLSEY. Well, Brazil has to subsidize it, but, of course, they have been the major country in the world that has moved in this direction, and if one can start with sugar and then get the genetically modified biocatalysts working right so you could use not only sugar but the begas that is left over, then, the cost would really go down.

I must say I disagree with Mr. Garman about the degree of R&D that still needs to be done here. I would encourage the Committee to get in touch with Professor Lonnie Ingram of the University of South Carolina, who is the head of the program down there. As I remember several years ago, the genetically modified biocatalyst which he had designed was able to first of all ferment the C–5 sugar in hemicellulose. Hemicellulose may be, I do not know, 20 percent of what grows, so already, you are going from using well under 1 percent of what grows to using 20 percent or so of what grows by being able to ferment that sugar.

Then, cellulose is a polymer of C–6 sugars, regular sugar, but it is hard to break. It is hard to hydrolyze it, to break it down. Lonnie's genetically modified biocatalyst, I believe, already produced at that point two of the three enzymes that were necessary in order to break down cellulose. At that point, you are being able to use maybe 80, 85 percent of what grows in order to produce ethanol.

I believe one of the enzymes would have had to have been purchased from a plant that makes enzymes, and it would be better if we could do what Lee Lynd calls consolidated bioprocessing, that is, have everything happen together at once. It would make it a lot cheaper.

I do not think we are years of R&D away on this. I agree very much with Boyden: what we need is some commercial incentives to people to move out and take some of these technologies into production.

Senator HARKIN. It seems to me that in a lot of this, we have the chicken and egg. Now, why don't more people use biomass energy? Well, because it is too expensive. Why is it so expensive? Because not very many people use it. Somehow, and that is what I am getting at here, is sometimes. You need a demand pull.

Mr. WOOLSEY. Senator, if I might add, too, people need to be able to use it in what they have. They need to be able to use it in an existing vehicle. That is why the flexible fuel vehicles are important, because I do not have to decide now whether I am going to pump E–5 or E–10 or E–85. It will all work in my Ford Taurus. The same needs to be true of biodiesel. The biodiesel that is produced today is a very limited thing, and it does have the problems of mixing with other fuels and the problems that were described in the questioning with Senator Lincoln.

The biodiesel that is produced by this ConAgra joint venture is regular diesel. It can mix with any other diesel. It can be used in existing vehicles. It is coming out of a turkey processing plant in Carthage, Missouri, right now.

One needs to broaden the definition of biodiesel to include things like that, and one needs to focus on getting these transportation fuels, whether ethanol or a broadly defined biodiesel in a form that they can be used in the vehicles we all have and are driving, because if you have a separate alternative fuel vehicle, it probably will sit in the garage or the pasture or someplace if you have to have a special delivery of special fuel for it.

You can mix ethanol with gasoline just fine, and you can mix some types of diesel that come out of biological processes with regular diesel just fine, and that, to me, is absolutely the heart of the matter.

Senator HARKIN. Well, again, I know the Chairman wants to move on. It just seems to me that the Federal Government is a 900-pound gorilla here in a lot of ways, both with the tax things that we could do but also with procurement. I ask you and your Energy Future Coalition to look at Section 9002 of the last Farm bill. In that, we put in a provision that mandates—shall—the word is shall—every department and agency of the Federal Government shall give a preference to bio-based products in their purchasing as long as they are equivalent in price, performance and availability.

Now, that is in the Farm bill. Two years later, we do not even have the rules issued. The GAO did a report on this about a month ago, Boyden, about a month or so ago, they came out with this and just blistered the Department of Agriculture for not managing it, not promoting it, giving it a low priority.

I happened to be in a car with President Bush a couple of weeks ago in Iowa, and I mentioned this to him about this bio-based requirement. It is not so much pertinent to ethanol. It is not ethanol. It is bio-based products. It is like the corn starch-based products but it would give an impetus to start getting these things built out there. We have some plants out there making these products already. We are making soy grease, and we are making corn starch-based products and McDonald's is buying some of that material now. It just seemed to me that if the Federal Government could, again, breaking down that chicken and egg, get more people buying it, the price per unit comes down.

Mr. WOOLSEY. Polylactid acid for all sorts of plastic being made out of corn in Nebraska right now.

Senator HARKIN. Right in Nebraska. They are doing that in Nebraska right now. Take a look at that and see if you—well, just take a look at it. I appreciate it.

Thank you very much, Mr. Chairman.

The CHAIRMAN. Thank you, Senator.

Thank you, Mr. Woolsey, Mr. Gray, for your contribution to this hearing and for bringing this initial idea of moving forward again on this issue to me initially. Thank you.

Mr. WOOLSEY. Thank you, Mr. Chairman. Thank you, Senator Harkin.

The CHAIRMAN. Our final panel of witnesses today includes Dr. Mark Zappi, who is the director of the Department of Energy for the Mississippi Research Consortium for the Utilization of Biomass. He is a professor of chemical engineering at Mississippi State University, and Dr. Tom Richard, who is an associate professor in the Department of Agricultural and Biosystems Engineering at Iowa State University—guess which two Senators recommended these two witnesses?

[Laughter.]

The CHAIRMAN. We are also pleased to have joining this panel Dr. Lee Lynd, who is a professor of engineering and an adjunct professor of biological sciences at Dartmouth College. He is a co-leader of a project entitled the Role of Biomass in America's Energy Future; and Dr. Samuel McLaughlin, who is a research professor with the University of Tennessee and a former senior research scientist with the Ecosystem Studies section of the Environmental Sciences Division at Oak Ridge National Laboratory. He has worked with the Bioenergy Feed Stock Development Program, which has examined switchgrass as a model species, as a source of renewable energy.

Welcome to each of you. We thank you for being here today to help us understand better the issues that are involved in the subject of this hearing: biomass use in energy production, new opportunities for agriculture. Dr. Zappi, you may proceed.

STATEMENT OF MARK ZAPPI, DIRECTOR, DEPARTMENT OF ENERGY MISSISSIPPI RESEARCH CONSORTIUM FOR THE UTILIZATION OF BIOMASS, MISSISSIPPI STATE UNIVERSITY, MISSISSIPPI STATE, MISSISSIPPI.

Mr. ZAPPI. Thank you, sir.

Good morning. I would like to extend my thanks to this esteemed Committee for allowing me to testify today. My testimony today will hit on the four following key points: first, I would like to provide a brief comparison of the future of biomass and compare it to what we are getting from petroleum today. I would also like to take a look to show you the vision for what biomass feedstock industrial platforms of the future may look like; also discuss some obstacles to the future development and commercialization of biomass-based process. Then, I would like to end with some suggested R&D efforts.

I would like to now briefly compare the potential of biomass to petroleum. The term biorefineries is a very accurate term, given the vast yet differing amount of chemicals found in both biomass and petroleum. The modern refinery for petroleum of today produces about 25 products. They really squeeze everything they can out of that crude petroleum. It is not to mention the many other chemicals they make once those chemicals leave the refinery.

On the other hand, most biomass-based industrial processes of today or biorefineries will produce two to three products. Yet, the chemical complexity of biomass is on par with what we have with petroleum. Clearly, we need to fully develop the biomass potential in terms of what chemicals can we get out of biomass.

It is very important that we do not separate energy production from biomass from what other chemicals we can make from biomass, because it is those other chemicals that I truly believe will provide the profitability to support this energy production we are after. Biodiesel is a good example. It is hard for me to envision an economically viable biodiesel business if we do not come up with another high-dollar co-product other than glycerol, and/or we have got to reduce those production costs, because that is really what is killing that particular fuel.

I would also now like to move on to what I envision to be the products of the future: where are we going with this? As we know, industry today is pretty much based on a petroleum platform. I envision numerous other biomass-based industrial platforms in the future. The first that I would like to discuss is what I call the bulk biomass platform. Here, we are going to see cogeneration of electricity using cultured grasses, wood waste and poultry litter.

We are also going to see an increased production of biogas from swine manure, other agricultural manures and municipal manures, municipal sludges. I would also like to see the further development of bio-oils for the production of novel adhesives, wood preservatives, diesel cuts and polymers.

The next platform would be our lipid platform. The lipid platform is where we get oils from plants and fats from animals. Here, of course, is where biodiesel is coming from. I envision polymers and paints and even nutraceuticals coming out of this lipid platform. Examples of the nutraceuticals I am talking about would be the omega–3 fatty acids and lecithin. These are very high-dollar products that would impart a high profitability to our vision for biorefineries.

The next platform would be the carbohydrate platform. This is where we get our ethanol from. This is where hydrogen is going to come to run our fuel cells and many other chemicals such as acetic acid, which is in the top 20 most used chemicals in the world today. The next platform is a little more researchy. That is going to be the lignant platform.

Lignant is still very much a waste product in many manufacturing systems and the future envisioned biorefineries. The reason why it is such a refractory and stable chemical. I believe it is that stable and refractory nature that might make it a wonderful feedstock for wood preservative and glues.

The final platform would be the protein platform. Here, I envision us manufacturing environmentally friendly polymers and also new animal feeds derived from pretty novel feedstock such as algae cake as well as manures.

Now, I would like to provide to the Committee what I believe are the obstacles to truly establishing viable biomass-based industrial platforms. The first one is the heterogeneity of biomass resources between the various geographic areas of the United States. Developing a one-size-all technology for making ethanol is not conducive to allowing all areas of the United States to become biorefineries or homes of green processing.

Another one is we have some proposed financial incentives that are being directed toward feedstocks and not the final product. Also we cannot accept bulk chemicals as a final developmental target. We have to look beyond the bulk chemical, the energetic chemical, into what the high-dollar by-products can be. I also think there is a lack of solid economic assessments of process viability prior to the construction of some projects here within the United States.

I also think there is insufficient interest by some power companies to truly adopt green power, particularly biomass-based systems. Finally, there is limited engagement of the university research community, particularly in the chemical processing and chemical production area.

I would like to end by suggesting some R&D efforts. I would like to see us organize regional centers of expertise to address the unique biomass resources found in each region of the United States. I personally think the Sun Grant program is a wonderful program, but it is too small and limited in scope. I also propose four R&D focal areas that will move us a little further ahead. The first focal area would be the feedstock development and management. Here, we would target an increased amount of oil or fermentable products or components we get out of existing agricultural products. At the same time, we need to be working toward development of new energy and chemical crops. What are the crops of the future to support what we are after?

The next focal point would be biomass conversion into bulk, secondary and specialty chemicals using novel processing techniques. The third would be tertiary processing of the secondary processing of these secondary products into high-dollar chemicals, specialty chemicals. This is what is going to pay for the biorefinery.

Finally, we need rigorous economic assessments of maturing processes, done so we can ensure that we are on the right track to an economic reality for our biorefinery vision.

In closing, I would like to thank this Committee for its leadership in the development of biomass-based products over the years. I truly believe that biomass does indeed offer us a lot of great opportunity to develop new industrial platforms, and those platforms will be based on renewable resources grown here in the United States.

I thank you.

[The prepared statement of Mr. Zappi can be found in the appendix on page 78.]

The CHAIRMAN. Thank you, Dr. Zappi, for your testimony.

Dr. Richard, you may proceed.

STATEMENT OF TOM RICHARD, ASSOCIATE PROFESSOR, DEPARTMENT OF AGRICULTURAL AND BIOSYSTEMS ENGINEERING, IOWA STATE UNIVERSITY, AMES, IOWA

Mr. RICHARD. Thank you, Chairman Cochran and members of the Committee. Thank you for convening this panel and for the opportunity to share some of the exciting possibilities for expanding biomass energy production in the coming years. The opportunities to convert agricultural crops and residues into bio-based products and bioenergy present entirely new, value-added pathways for agriculture and industry.

Coordinating business, government and university partnerships can greatly accelerate the emergence of these new pathways and facilitate their success. In Iowa, the BIOWA Development Association, composed of representatives from production agriculture, industry, environmental interests and academia has been formed to support and promote the growth and development of Iowa's bioeconomy. BIOWA is working closely with the Iowa Department of Economic Development to structure Iowa's economic development portfolio so that it focuses on the opportunities and challenges produced by possibilities for bio-based businesses.

While near-term bio-based agricultural and economic development opportunities are being nurtured by business and government, research investments will drive the next generation of innovation needed for the bioeconomy to flourish.

These research efforts will need to span both basic and applied sciences and also be widespread and diverse. Even with effective partnerships and significant investments, the development of a bio-based economy will not happen overnight. Extensive analysis of a range of feedstocks has identified several opportunities for near-term progress. Two of the feedstocks of particular interest are livestock manure and crop residues. Other organic residues and by-products, including wood and paper wastes, agroprocessing wastes and biotechnology by-products also represent immediate opportunities to pursue.

In an earlier panel, Mark Rey summarized some of the opportunities for manure and anaerobic digestion, and my written testimony confirms those while outlining some of the challenges that also need to be met. Crop residues are an agricultural by-product with even greater energy potential than manure. Among the many straws and crop residues produced at present, corn stover is widely recognized as the most promising high-volume, low-cost lignocellulosic feedstock on which to base a range of bio-based energy, chemical and material industries for the next several decades.

However, several significant challenges must be addressed before this vision can be achieved. First, stover biomass must be supplied at a price that is competitive with petroleum, profitable for producers and favorable for the growth of the rural agroindustrial economy. Current stover harvest systems rely on multiple passes across each field, followed by dry storage of stover bales. Unfortunately, this technology is not really achieving the target the Department of Energy has set for price of this feedstock.

An alternative system, coupling single-pass simultaneous harvest of grain and stover with ensiled stover storage has recently been shown to reduce centralized delivery costs by 26 percent. With targeted research and demonstration of these and similar new strategies as well as effective implementation, corn stover biomass appears poised to become the high-volume price competitive biorefinery feedstock that many had hoped.

While manure, corn stover and other agricultural residues represent immediate opportunities for biomass energy, long-term growth of the bioeconomy will require additional feedstocks as well. Increased use of perennials and cover crops in agricultural systems has a number of environmental advantages, including reduced soil erosion, soil organic matter improvements, and carbon sequestration.

The Conservation Security Program, established by the 2002 Farm bill, provides a mechanism for encouraging greater use of cover crops and perennial species to conserve our working lands. The potential synergies with biomass feedstock production provide additional motivation for making sure that this conservation program gets stronger support.

One of the distinct characteristics of biomass as an industrial feedstock is its low energy density relative to fossil fuels, and this is especially true of non-woody plants. As a result, transportation costs associated with large, centralized conversion facilities generate significant diseconomies of scale. Optimum sizing of bio-based facilities thus requires a decentralized infrastructure with many loci of bio-industrial development.

While a decentralized mode of development has obvious advantages for rural development, it faces particular challenges as well. Perhaps one of the most critical issues that needs to be addressed as we ramp up the development of bio-based businesses is the business models of the supply chains. In particular, we need to find ways to recognize and reward the farmers through the foundation of bioeconomy value chains. One proposed solution is for producers to use their equity to vertically integrate up the value chain, as has been done for many of the ethanol plants in the Midwest. However, given the size of the capital investments that will be required for establishing integrated biorefineries and because of intellectual property protections, it is likely that the ethanol model will be rare. New types of business relationships need to be evaluated so that the new systems result in economically sustainable rural development.

This concludes my summary of my written testimony, and I welcome any comments the Committee might have and questions.

[The prepared statement of Mr. Richard can be found in the appendix on page 83.]

The CHAIRMAN. Thank you, Dr. Richard, for your contribution to the hearing.

Dr. Lynd, we will hear from you now.

STATEMENT OF LEE R. LYND, PROFESSOR OF ENGINEERING AND ADJUNCT PROFESSOR OF BIOLOGICAL SCIENCES, THAYER SCHOOL OF ENGINEERING, DARTMOUTH COLLEGE, HANOVER, NEW HAMPSHIRE

Mr. LYND. Thank you, Mr. Chairman, for the opportunity to appear before your Committee.

I suggest the following points be among those you leave this hearing with: one, solutions exist to the energy and security challenges we face, and biomass, particularly cellulosic biomass, could play a major role. Two, widespread energy production from cellulosic biomass offers transformative benefits for American agriculture. Three, the Government should do much more than it is doing now to enable and accelerate biomass energy production.

I am an expert in science and technology directly related to biomass energy production. My perspective is shaped by over 20 years' experience in the field and most recently by an in-progress project entitled the Role of Biomass in America's Energy Future. Working hypotheses of the RBAEF project include, first, large improvements of cellulosic energy crops; for example, doubling per-acre productivity, can reasonably be expected from an aggressive and sustained research and development effort. Second, such an effort is also expected to dramatically increase the cost competitiveness and efficiency of technology for biomass processing. I note in this context that cellulosic biomass at $50 a ton is equivalent on an energy basis to oil at $14 a barrel. Third, an amount of fuel sufficient to provide for current levels of vehicular mobility in the United States could be produced from biomass. Moreover, this could be accomplished within the existing agricultural land base while greatly increasing income to American farmers. Fourth, the project has identified some very large environmental benefits accompanying expanded biomass energy production, including essentially zero net greenhouse gas emissions and improved soil fertility and has identified no environmental show-stoppers.

I turn now to my third point: the Government should be doing much more. Sustainability and security are poorly reflected in market prices. The market provides only limited incentive to overcome obstacles associated with first of a kind technology and reinvestments of profits from a nascent energy processing cellulosic biomass will result in but a small flow of funding for innovation-focused R&D during the critical early growth phase.

For these reasons and regardless of one's political philosophy, it is appropriate that the Government play an active role in enabling and advancing biomass energy production. In particular, I am confident that the growth of biomass energy production will be much more rapid with substantial and well-directed governmental support than without it.

How well are we doing? Let us assume for a moment that sustainability and security challenges are deemed important to respond to and that biomass could play an important part of such a response, as I have argued. When viewed from these premises, the effort the U.S. is expending to enable and accelerate biomass energy production is far short of what it should be, as elaborated in my written testimony.

I find it mindboggling that U.S. Federal expenditures on applied energy technology R&D are about what they were in real terms just before the oil price shock of 1973, although our economy is now more than twice as large, and energy-related challenges are much more evident. In short, we are not acting as if we have a lot at stake and an important solution at hand.

What might we do differently? I recommend one, increase by several fold the amount of funding for biomass energy R&D, with clearly demarcated support for both precommercial research devoted to innovation and applied fundamentals as well as cost-sharing for first of a kind industrial plants. Two: commit to pursuing increased biomass energy production in ways that expand opportunities for farmers and that achieve sustainability, security and environmental benefits. It is important that these features embody transition phases as well as targeted endpoints. Three, allocate funds in a way that is responsive to potential for enhanced sustainability and security, reliant to a significant extent on open solicitations and based on technical merit.

If we are serious about cost-effectively realizing the benefits of biomass energy to the national interest, extensive earmarking needs to be curtailed. The cost of these measures are small on any relevant scale and significant relative to the potential benefits. Consider: quadrupling funding for bioenergy R&D would represent an additional expenditure of about $500 million. The cumulative cost of a focused R&D effort to develop technology for producing ethanol from cellulosic crops at a cost competitive on an unsubsidized basis with current gasoline prices has been estimated at less than 1 year's expenditure for the current ethanol tax incentive.

I believe that completion of such development within 5 years is a realistic goal if we are prepared to change how we do business. Much can be done within existing legislative mechanisms that are already in place; for example, by adding new funding authorized by the Biomass Research and Development Act to funding levels of preexisting programs and by fully funding the Biorefinery Development Grants portion of the Farm bill.

Mr. Chairman, as current events make clearer the urgent need for sustainable and secure energy sources, and analyses such as the RBAEF project make clearer the potential of biomass to serve these needs in a meaningful way, the case for business as usual in the biomass energy arena is becoming progressively more weak. I urge your Committee and the U.S. Congress to take decisive action.

[The prepared statement of Mr. Lynd can be found in the appendix on page 92.]

The CHAIRMAN. Thank you very much, Dr. Lynd, for your interesting comments and statement.

Dr. McLaughlin, you are our best for last.

STATEMENT OF SAMUEL B. MCLAUGHLIN, RESEARCHER, OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENNESSEE

Mr. MCLAUGHLIN. Thank you, Mr. Chairman, for the opportunity to speak before you and the Committee about a topic that has generated great enthusiasm among the research community and amongst the farm community, which stands to benefit as we proceed with the use of cellulosic energy crops.

I am going to talk to you about an energy crop this morning, switchgrass, which has been mentioned several times this morning. Switchgrass can be produced on American farms to provide benefits to the rural economy, to improve soil quality, to reduce erosion and improve stream quality, and to add significantly to our ability to displace foreign oil. Switchgrass is one of a group of cellulosic crops which are similar in the sense that the cell wall material that was laid down when they were formed can be used to produce chemicals, to produce energy. They include municipal waste, agricultural waste such as corn stover, rice hulls, cotton hulls, and forestry wastes.

There are similarities in terms of cellulosic content amongst these potential feedstocks, but there are also big differences. As we keep our eye on the ball of reducing dependency on foreign oil, there are important things to think to consider as we look at feedstocks: Where will they be produced? What is the quantity we can produce per unit of land area? How much energy does it take to produce the feedstocks, so that when we balance the energy cost and supply components, we have actually gained significantly in using a particular type of feedstock.

What are the benefits? What are the values that these feedstocks can provide to society in addition to just the cost that industry pays at the industry gate? These kinds of considerations lead us certainly to know that we will have to depend on multiple feedstocks and multiple chemical processes in the future, but there are best choices for achieving rapid gains as we move toward greater energy self-sufficiency.

Switchgrass is a species that we picked in the Bioenergy Feed Stock Development Program at Oak Ridge National Laboratory after screening over 30 species of herbaceous agricultural crops. We picked switchgrass for a number of reasons that we think make it compatible with American agriculture and enable it to provide the kinds of benefits that we hope would be a part of an overall energy picture. It is a native prairie grass. It was here when the settlers came and contributed to the rich soils that were here when these mid-plains were settled.

It occurs over most of the eastern United States, so it can be grown by a large segment of farmers. Participation in energy production can be regionwide, not just in a certain segment of the country. It is produced and harvested with equipment that is now used to produce 60 million acres of hay in this country. It puts about as much energy below ground as is harvested above ground. We have looked extensively at switchgrass roots, and there is just about as much biomass, roughly 5 to 10 tons of roots in the belowground system that is turning over and adding carbon to the soil. An absolutely important component of soil fertility is how much organic carbon is sequestered in the soil, and that relates to nutrient supply, water supply, erosion and retention of nutrients within the system.

In 12 years of research with switchgrass, we learned a lot before the program was stopped as one of the casualties of the Congressional earmarks a couple of years ago, but we made tremendous progress in terms of how to grow switchgrass, how to harvest it, and how to measure its benefits to agriculture. We found we could reduce the nitrogen needed to grow switchgrass by perhaps a half to a third, which reduces the energy input. We learned a lot about the basic genetics of switchgrass and incorporated that into breeding programs and made gains of 3 to 5 percent per year in the initial phases of this program. Those gains are comparable to what was achieved with corn, which started 60 years ago and increased five to sixfold in the 60 years hence. We think there is great potential to improve yields beyond current levels.

We learned a lot about the production levels of switchgrass and they vary across the eastern region, two-thirds of the United States where our research plots were located. This has allowed us to interface with an important tool that has been developed by a collaboration between DOE and USDA scientists. It is an econometric model called POLYSYS. The economic effects of introducing energy crops into POLYSYS allows us to look at U.S. agriculture. This has provided a tool that has allowed us to see how various energy crop prices, production costs, and production levels influence gains to American agriculture.

POLYSYS considers what crops are currently grown in over 300 U. S. agricultural districts what it costs to grow these crops, and what the prices are. As we introduce an additional crop into this system, we can estimate what its impact will be on farm income, and also, because POLYSYS is tied to the Government subsidy program, how revised from income levels might influence Government subsidies.

An input to this program derived from our production research is that it costs about $20 a ton to produce switchgrass. The model has also been used to look at how much acreage would come into play as the price we are willing to offer for an energy crop such as switchgrass changes from current crops. We estimate that at roughly $28 a ton, 7.6 million acres would be converted to switchgrass if farmers want to go with a more profitable crop. At $48 a ton, roughly 50 million acres of crop land would be converted to switchgrass production for energy from the land that is being used right now for agriculture.

There are important benefits of energy crop production on farm income. At the lowest price level (28/t) annual, farm income would increase about $1.3 billion, and there would be about a $1.3 billion reduction in Government subsidies required to support crop prices. At the highest price level, farmer income increase about $6 billion per year, with $5.7 billion of subsidy savings.

These price and benefit levels provide options to Government. At that lowest price, the subsidy decreases would more than cover the costs of purchasing the feedstock by industry. Thus, initial stages of feedstock production could be subsidized by that amount of savings to the governments derived from subsidy savings. By looking at these things in a balanced way, it allows one to consider what the policy options might be, so that a subsidy is not considered as a one-way street. It is a reward for value to society.

The fact that this crop can add farm income, can improve soil quality, as well as providing a continuous supply of clean removable energy, gives us the flexibility to consider in policy decisions how we might work toward the greatest good to agricultural and to society.

I would like to conclude my comments with summary statements derived from my written report. First of all, cellulosic biomass produced on American farms can contribute significantly to the nation's energy self-sufficiency and to both its economic and its ecological health. The American farmer and the American consumer should both benefit economically from increased reliance on biomass-derived fuels.

It is my hope, Mr. Chairman, that the farmer would not just be the producer but the partner in this process. There are great opportunities for farm co-ops to be involved in this production process. The farmer should not get the lowest price possible but be able to be involved fully in the whole energy production industry just as the corn farmers have become involved in some of the ethanol producing plants in the Midwest.

The costs of biomass-derived fuels to society both now and in the future are likely to be much lower than the costs of fossil fuels, and that seems controversial, but it is based on considering the values to society. We have values in terms of rural income, reduced Government subsidies, clean air. Ultimately, we will probably place a value on carbon emissions reduction, and there is about a ton of carbon per acre that is stored below ground each year when you produce switchgrass. There are human health effects of fossil fuels that would lead to avoidance benefits, and there are the tremendous oil shock effects to our economy resulting from our having to rely on highly variable oil price and supply levels as we are doing now.

An important and appropriate focus of future energy policy should be the biomass utilization that minimizes net uses of imported energy maximizes net reduction in greenhouse gas emissions, and gives credit for reduction in societal costs of energy. Production, considering energy production values as well as costs, would accelerate near-term incorporation of cellulosic biomass into a U.S. energy strategy.

There is flexibility within our system to enhance and accelerate benefits to be gained from increased reliance on cellulosic energy, however, it will require planning to consider how we most efficiently proceed to reduce energy costs and to enhance the associated values.

Thank you, Mr. Chairman.

[The prepared statement of Mr. McLaughlin can be found in the appendix on page 98.]

The CHAIRMAN. Thank you very much for your statement.

This panel has really added an extra dimension of understanding and important facts for us to consider as we try to figure out exactly what our role ought to be now to build on the incentives that are in current law and the opportunities that we have to make a difference in our future energy security, as well as the efficiency and profitability of American farms.

These are interesting topics to consider, and I am very glad that the Committee was able to conduct this hearing today, and we appreciate especially the participation of this last panel. Senator Harkin and I both agreed with Dr. Zappi's suggestion that regional centers of expertise ought to be taken seriously as a matter of policy by this Committee, and we will look for ways to try to help ensure that that becomes a reality.

Dr. Richard's comments about integrating the entire feedstock supply system was an interesting observation, I thought. I wonder if you could prophecize, what would be a reasonable timeframe for achieving this kind of integration that you mentioned?

Mr. RICHARD. Well, there are two parts to that question. First, to really understand how to do that well, and the science has potential to put together integrated systems in the next three to 5 years. My colleagues, some at this table, are doing research on that, as I am as well. The second part, implementation, is going to face some of those challenges I mentioned earlier. Trying to develop decentralized economic development strategies, and getting the capital involved for many different farmers and many different communities to build these systems, will be a bigger step.

The CHAIRMAN. Dr. Lynd, you pointed out the beneficial consequences for American agriculture in taking advantage of these opportunities for more production of biomass materials on farms. What if we put a lot of money in these incentives and encourage that production, and then, we still fall short? Are we going to be accused of wasting money? Do you think this is going to be a wasteful expenditure of Government money, or are you pretty confident that this is going to turn out to be a wise investment?

Mr. LYND. It could be a wasteful expenditure of Government money, and I also think it could be a historically successful expenditure of Government money, and it depends on how we do it. We need to recognize that we need a combination of funding for first of a kind commercialization but also, and I would disagree with several of the speakers who have appeared before this morning, a really much, much accelerated and more aggressive R&D program.

In the absence of that R&D program to move that technology forward, we are just kidding ourselves if we think we are getting over the hump just by putting in the first of a kind plants or that revenue from those plants is going to drive the R&D process at any significant rate. If we do both of those and do them effectively, as I have suggested, then, I am confident this will be a very, very successful investment. We sure cannot take that for granted.

The CHAIRMAN. Thank you.

Dr. McLaughlin, you talked about the commercialization of switchgrass in particular as an energy source. I was impressed by the depth of research that has already been done at the university and within the program that you are involved in. Has the support from the national government, the Federal Government, been important to the conduct of this program? Is it one of those things that without which there would not be a program like yours?

Mr. MCLAUGHLIN. Support was absolutely essential for the Feed Stock Development Program. It began back in 1978, which we can testify to somebody's vision that we needed to be doing this work way back when. A lot of the early work was screening, looking for the best choices. What we developed with Government support, and in some cases, in many cases, it was matched by other programs going on at universities, was a very interactive program that evolved—there were seven groups working directly with us, including regional universities and one USDA laboratory.

We functioned somewhat as subregional centers, but the overall program was very interactive, and the Government support was absolutely essential. I would add that when that support largely dried up in 2002, some of these folks have been able to get additional support. We would like to think because they made really good starts on things that were very promising. One, for instance, was on genetic transformation of switchgrass to increase the content, precursors for plastic formation, and an individual company supported that. Other work has been picked up by USDA and others.

Government support is essential is focusing national research efforts on integrated and interactive targets.

The CHAIRMAN. Dr. Zappi, as we talked about the regional centers, or you talked about then, I was impressed with the fact that we do need to have a diversified analysis and not just concentrate research in one particular area or on one specific subject. Could you elaborate a little bit on why you think it is important to have the regional centers? Would they be more cost-effective or more likely to bring us answers to the questions we need in order to help assure that alternative sources of energy really can become a reality for our country?

Mr. ZAPPI. Well, It will be more cost-effective, because it will bring more players into the game. If you take our home state of Mississippi, we produce a tremendous amount of biomass, but it is very diverse compared to mainly corn in Iowa. If we want to bring more players to the table, we have to realize that each region has its own unique biomass feedstock it contributes. A lot of the research is oriented toward probably one or two key technologies, and there are other potential technologies that are just not receiving enough attention. That is because some of the ones that are not receiving enough attention are not predominantly corn-based at this time.

We are very oriented toward corn and corn stover, and I am not against it. It is an excellent feedstock, both of them, but we do not recognize the differences from region to region. To be more cost-effective, that as I said, as we increase the volume of biodiesel we can make, the market becomes more competitive; we find more by-products. In Mississippi, getting back to our home state, some of the by-products that may come out of biodiesel production could bring some new revenue.

The CHAIRMAN. Well, thank you very much for your responses to our questions and our invitation to attend this hearing. We appreciate you helping us with our understanding and helping us develop a level of expertise to assist us in the shaping of our public policy formulation that is so important to this area of interest and concern.

I do not know of any time in our history when this has been a more important subject for our consideration. The situation in the Middle East, the Persian Gulf, is strong evidence of how important sources of energy are, and the costs of energy can affect our own economy. We can look at the prices at the gasoline pumps right now, and the incentive is there as never before to look for alternative sources and try to help ensure that we are not so dependent on one form of energy for our economic survival and progress.

Thank you for helping us at this hearing. It has been a very important and constructive step toward assuring a greater degree of independence for our country in the years ahead. We are going to make a part of the record, too, an article that impressed me that I read in preparation for this hearing written by Senator Richard Lugar and James Woolsey, who was one of our witnesses today. It was published in Foreign Affairs magazine in the January-February 1999 edition, and it is a very important statement, and we want to make that a part of our hearing record, and we will.

With that, we thank all Senators for participating and all of our witnesses. The hearing is adjourned.

[Whereupon, at 12:25 p.m., the committee was adjourned.]

APPENDIX

MAY 6, 2004

Senator Norm Coleman
Submitted Statement
May 6, 2004

Mr. Chairman, I want to first thank you for holding this hearing today. There definitely are more benefits to come for agriculture and our nation's farm families through biomass energy production, and I'm pleased that we have this distinguished panel of witnesses here today to give the committee their views on these opportunities. Again, thank you.

It's safe to say that biomass has changed the face of energy in the United States. Years ago, we set a goal to advance our own energy sources and supplies, and rightly so. To do this, we turned to rural America and the abundance of commodities and resources it provides.

I can simply go home to Minnesota to see that this goal is being met, and that the state's agricultural sector, energy needs, and overall economy are seeing the benefits.

In Virginia, Minnesota, loggers are processing the tree trimmings usually left on the forest floor into pellets that can heat homes. This by-product is also burned in a formerly-unused boiler to generate electricity in Virginia and nearby Hibbing. This all means more money for the loggers and their families.

Mankato State University got accolades from two very, very important groups in Minnesota - snowmobilers and corn farmers - after it developed a snowmobile engine that runs on E85. Farmers now have another customer for their corn-derived fuel, and snowmobilers now have a clean fuel to run on.

The installation of one anaerobic digester by a 1,400 cow dairy brought many benefits to the town of Perham, Minnesota. Now, the Barrel-of-Fun potato chip plant located in town doesn't have to ship it's waste 190 miles to Minneapolis, saving them so much money that they decided to double the plant's size. And, waste from the plant and the dairy generates so much power that there is plenty left over to sell to the local electric co-op, which provides it to area residents.

And I know that most, if not everyone, here is aware that Minnesota is a national leader in ethanol plants and E85 gas pumps. The benefits from this infrastructure to the State of Minnesota are endless.

I do want to make one important point that I think many folks out there do not realize - efforts like these do not just benefit the economy and people of rural America. There is a place - a need - in urban areas for the biomass projects that are prevalent throughout our countryside.

For example, the Phillips neighborhood in South Minneapolis is one of the lowest income neighborhoods in Minnesota, where the residents put more of their income towards energy bills than anyone else in the state.

To change this, the neighborhood is developing a facility that will generate electricity for about 20,000 homes and heating for over three million square feet of business space and multi-family housing, all at an affordable rate.

Like the anaerobic digester in Perham, this facility will be fueled by local resources commonly seen as waste: tree trimmings, stump removals, oat hulls from a nearby General Mills plant, and excess heat from the electricity generated by a district energy heating system.

This operation will literally turn the neighborhood around. It'll bring affordable energy, create jobs, and give the neighborhood a better sense of place.

Today, we're here to discuss new opportunities for biomass energy. And while bringing biomass projects like this to urban areas is not some new technology, it definitely is a new opportunity. I hope those witnesses here today keep this in mind as they continue their efforts.

To close, Mr. Chairman, I want to add that I know there are many new ideas and opportunities for biomass in the works. However, I think there are a few things before us right now that will continue to move biomass on the forward track it's been on. The renewable energy provisions of the Farm Bill, for example. I hope these continue to be maintained. There is also the need to extend the Section 45 tax credit through 2006 and expand it so that it applies to biomass projects. The Senate is poised to get this passed, and I hope that we do.

Thank you.

STATEMENT OF MARK E. REY
UNDER SECRETARY FOR NATURAL RESOURCES AND ENVIRONMENT
UNITED STATES DEPARTMENT OF AGRICULTURE
BEFORE THE
SENATE COMMITTEE ON AGRICULTURE, NUTRITION AND FORESTRY
May 6, 2004

Mr. Chairman and Members of the Committee, I am pleased to appear before you today to discuss the Department of Agriculture's (USDA) efforts to advance biomass energy and thereby contribute to the energy security of our nation.

My remarks will focus largely on the economics of biomass energy, followed by a brief discussion of USDA programs that promote biomass energy. At the outset, I want to emphasize two underlying themes throughout this discussion: the ongoing role of research as biomass energy systems are developing technologies, and the overall need for coordination – among federal agencies, as well as government partnerships with the private sector, academia and others – to conduct research effectively.

I also want to stress the strong support of this Administration – as documented in the President's National Energy Policy – for developing biomass energy as part of efforts to increase domestic energy supplies to satisfy America's growing demand for energy. Within this framework, one of USDA's goals is to increase the use of biomass energy. By doing so, we have the potential to create jobs, stimulate economic activity, reduce dependence on foreign oil and cut back on environmental pollution.

USDA is involved in many aspects of biomass energy that contribute to its increased use.
Our programs support production of biomass energy. We also support research, development, and

pre-commercial work to advance biomass technology and to reduce costs. USDA also monitors the role of biomass energy in energy markets and U.S. agriculture markets, and conducts economic analyses that alert us to both roadblocks to greater biomass energy use and opportunities for expansion.

USDA biomass energy activities address an array of energy forms, such as starch and cellulosic ethanol, biodiesel from agricultural oils, biomass, and anaerobic digestion for power.

Methane Digesters

One area of focus for us is the development of methane digesters for the production of electricity. This technology has positive environmental effects, and excellent economic potential for producers as well. More than a year ago, the USDA Natural Resources Conservation Service (NRCS) developed practice standards for methane digesters. These anaerobic systems break down animal waste, producing methane as a fuel source for the generation of electricity. The digesters can now be funded through the NRCS Environmental Quality Incentives Program. The agency has had excellent successes with assisting producers to incorporate digesters as part of an overall nutrient management approach. In turn, if market issues can be resolved we believe the future holds a bright potential for widespread utilization of digesters and conversion to power.

Ethanol

The ethanol industry is experiencing tremendous growth due, in large part, to government support policies. Currently, seventy-three ethanol plants are operating in 20 states, with a total production capacity of 3.1 billion gallons per year. With 15 ethanol plants now under construction, total production capacity will increase to 3.7 billion gallons per year by early 2005.

Last year, U.S. ethanol producers converted more than 1 billion bushels of corn and sorghum to more than 2.8 billion gallons of ethanol. This was an increase of 680 million gallons – or 32 percent – over 2002. As new plants come on line and as current plants operate at higher levels, we project this year's production to reach 3.3 billion gallons. We believe ethanol demand will continue increasing in the United States. Moreover, if the energy bill is passed and the renewable fuels standard implemented, ethanol production will increase to at least 5 billion gallons per year by 2012.

Ethanol demand increased significantly in 2003 when California, New York, and Connecticut replaced methyl tertiary butyl ether (MTBE) in their gasoline with ethanol. More than 900 million gallons of ethanol are required annually to replace MTBE in California and about 450 million gallons are required in New York and Connecticut. With this greater demand, ethanol prices rose to over $1.60 per gallon during November and December 2003. Seventeen states have now banned MTBE in their gasoline, an important factor in ethanol's growth.

In terms of production inputs and expense, corn accounts for 95 percent of feedstock used to produce ethanol. Although corn prices are higher this year, these price increases are offset by higher prices paid for ethanol production inputs. Following corn, fuel – mainly natural gas – is the second largest cost item in producing ethanol. Natural gas prices increased from $2.50 per million British thermal units (Btu) in 1999 to $5.50 per million Btu in 2003, and energy experts expect the price of natural gas to remain high during the next five years. There are no economic alternatives to natural gas for existing ethanol plants. Using petroleum products instead of natural gas would require additional capital investment and prices for both have been moving together.

Historically, estimates of the energy efficiency of ethanol have been the subject of debate. Some past studies estimate that there is a net energy loss and an environmental loss from ethanol. Although it takes energy to produce ethanol, we emphasize that repeated USDA studies, using robust corn yields and increasingly efficient fertilizer and alcohol conversion processes, show a positive net-energy balance of corn ethanol: we believe that the energy in ethanol exceeds the amount of energy used to produce it, and that this energy balance has improved over time.

Technological innovations in corn production and ethanol conversion are important factors in this improvement. Corn yields have improved, and ethanol plants are rapidly adopting innovations which substantially reduce the energy required to convert corn into ethanol. Our most recent estimate of the energy ratio is 1.67, up from 1.22 in 1995. This indicates that the energy content of ethanol is 67 percent greater than the energy used to grow, harvest, and transport corn, and to produce and distribute the ethanol. We are estimating similar positive energy ratios for biodiesel.

Research directed at lowering both feedstock and production costs is key to improving ethanol's competitiveness as a fuel or fuel additive. To achieve these cost reductions, USDA research is targeting several areas: the development of organisms that will convert multiple, mixed substrates; superior product recovery and separation technology; high-value co-products; more efficient technologies and processes for co-product recovery and separation; and better fractionation of feedstocks. We also have scientific work focused on developing varieties of corn that would be easy to mill and provide optimum levels of fermentable substrate and co-products. Complementing DOE work, USDA is conducting research on cellulosic feedstocks and conversion.

The USDA Forest Service, Forest Products Laboratory (FPL) is researching ways to derive ethanol from biomass other than corn starch. Currently, researchers are studying the conversion of sugars to ethanol. The key to converting wood to energy is converting five and six-carbon sugars to ethanol.
The process for converting six-carbon sugars is well established but five- carbon sugars, which make up about 30% of the sugars in wood, have presented a problem. FPL has developed the capability to ferment the once problematic five-carbon sugars to ethanol and is working toward a process that will convert five- and six- carbon sugars simultaneously. This capability will make it possible for a much wider variety of materials to be converted to ethanol. Researchers estimate that ethanol from wood can make a significant contribution to the liquid fuels market.

Additional Biomass Energy Sources

Biodiesel, lubricants, chemicals, and solvents produced from agricultural fats and oils, offer an opportunity to supplant petroleum derivatives in the coming decade. In the process, "new uses" for agricultural fats and oils may expand, giving farmers new outlets for their crops and bringing them into high-volume markets producing high-value nonfood products.

As these markets develop, they have important national policy implications. Because agricultural fats and oils are very energy efficient to produce, our calculations show that their emission of greenhouse gases is much lower than petroleum-based fuels on a net emissions basis. They also represent a sustainable source of domestic liquid transportation fuels.

Selected niche market opportunities for biodiesel are emerging. USDA assessed the life-cycle costs of alternative fuel technologies to determine whether biodiesel is cost competitive for urban bus use. We found that while biodiesel and biodiesel blends have higher total costs than some alternative fuels, they have the potential to compete with compressed natural gas and methanol as fuels for urban transit buses.

The major obstacle to the widespread use of fats and oils for biodiesel manufacture is the relatively high cost of biodiesel from food-grade oils: about $2 per gallon (B 100) compared to $1 per gallon for petroleum diesel on a pre-tax basis. Tallows, yellow and white greases (often termed waste vegetable oil), and true wastes, such as sewage trap grease, are cheaper to use than food-grade oils.

A focused research program is critical to creating economically viable sustainable fuels and chemicals markets based on renewable fats and oils. USDA's research is aimed at lowering the cost of production, optimizing the properties of feedstocks used to produce biodiesel, and developing conversion and utilization technologies which take advantage of the unique properties of the fats and oils.
Biomass crops, such as poplar, willow, and switch grass, have the potential to become important feedstocks for electric power, liquid fuel, and chemical production. They can offer significant environmental benefits over fossil fuels. As long as there is no net energy loss, the energy produced from

biomass crops does not add greenhouse gases to the atmosphere during the life cycle of the production and use of the crops.

Analysis by USDA and the Department of Energy (DOE) suggests that, with an aggressive research program aimed at boosting crop yields and developing appropriate power and chemical conversion technologies, biomass might compete with fossil fuels for a broad range of uses. Higher fossil fuel prices make biomass-derived fuels more competitive. A key assumption in our analysis is the development of improved production, harvesting, delivery, and utilization systems. Much hard engineering, organizational, and research work will be required to demonstrate the workability of these systems.

USDA Biomass Energy Activities

USDA has a wide variety of ongoing renewable energy programs. Now, I would like to focus on what we are doing to implement new authorities provided in the energy title of the Farm Security and Rural Investment Act of 2002 (Farm Bill). Section 9002, Federal Procurement of Biobased Products, requires federal agencies to increase their procurement of qualifying biobased products. When fully implemented, the program should stimulate development of a broad range of high performing and environmentally friendly biobased products. This section also provides for a voluntary labeling program and use of a "USDA Certified Biobased Product" label. A proposed rule was published in the *Federal Register* on December 19, 2003, and the comment period ended on February 17, 2004. Once we have considered the more than 270 public comments received, a final rule will be published.

Section 9006, Renewable Energy Systems and Energy Efficiency Improvements, authorizes loans, loan guarantees, and grants to farmers, ranchers, and rural small businesses to purchase renewable energy systems and make energy efficiency improvements. We are developing a proposed rule for this program to operate it on a long-term basis. Last year, we selected 114 applications to receive funding to help develop renewable energy systems, including 30 applications totaling $7 million for anaerobic digesters and 16 totaling $3.9 million for ethanol plant/anaerobic digesters, direct combustion, and fuel pellet systems.

Section 9010, the Commodity Credit Corporation (CCC) Bioenergy Program, provides payments to eligible processors to encourage increased purchases of eligible commodities to expand bioenergy production and support new production capacity. For the 2004 program year, up to $150 million has been authorized by Congress. Energy crops are included as eligible feedstocks. I also want to mention that USDA has an ongoing program of research to improve the economics of biomass energy. Our goals are two-fold: to overcome the technical barriers to developing biomass energy, and to strengthen coordination with other federal agencies and with universities, private sector companies, and environmental organizations.

Biomass Research and Development Program

I would now like to turn to a section of the Energy Title in which the Natural Resources and Environment Mission area of the Department is cooperating with the Department of Energy in implementation. Section 9008 of the Farm Security and Rural Investment Act of 2002 reauthorized the Biomass Research and Development Act of 2000 and provided USDA with $75 million in funding from the Commodity Credit Corporation (CCC) for fiscal years 2002 through 2007. In addition, Section 2306 of the Energy Policy

Act provides authority and requirements for financial assistance for programs covered by Titles XX through XXII of that Act. In 2003, Title II of the Healthy Forests Restoration Act Restoration Act (PL 108-148) expanded the scope of this initiative, integrating silvicultural activities and authorizing an additional $20 million through FY 2007. Through this Biomass Research and Development Initiative, grants are available to eligible entities to carry out research, development, and demonstrations on biobased products, bioenergy, biofuels, biopower, and related processes.

In March 2003, the U.S. Department of Agriculture released the request for proposals (RFP) for the 2003 USDA/DOE Joint Solicitation for the Biomass Research and Development Initiative.. USDA received approximately 400 proposals in response to the solicitation. All eligible proposals were competitively evaluated in a process that included a joint USDA/DOE technical merit review as well as cost analysis and programmatic review based on the respective independent priorities of the departments as published in the solicitation. Although the solicitation stated that $21 million would be awarded, an addition of $2 million from DOE resulted in $23 million in grant awards.

In FY 2004, USDA and DOE jointly released a request for proposals on December 22, 2003, with pre-applications due at the end of January 2004. The solicitation was modified from FY2003 to accommodate suggestions from a federal advisory committee, and to meet new statutory changes to the Biomass Research and Development Act that were contained in the Healthy Forests Restoration Act of 2003. The agencies intend to award up to $24 million, combining $14 million of USDA funds with $10 million DOE appropriated funds.

We are very pleased with the outcome of the Biomass Research and Development program. The initiative has resulted in cooperative funding for a diverse and innovative array of projects including anaerobic digestion, biorefineries, biomass focused forest management training, and innovative use of feedstocks. We are optimistic about the future of this program and look forward to continued collaboration and mutual progress with the Department of Energy.

Continued implementation of the Biomass Research and Development Act of 2000 is a key vehicle for improving coordination. The Act creates a structure led by USDA and DOE to coordinate federal biomass research activities and develop more effective plans. I also want to acknowledge the outstanding support DOE has provided USDA in implementing Section 9006 of the Farm Bill. DOE experts were instrumental in helping us evaluate the technical merits of grant applications. In addition to the ongoing activities, energy is a component of the new Conservation Security Program. We are currently developing ways to include energy activities as CSP enhancement payments. NRCS is also developing a web-based tool to assist farmers in assessing energy consumption and energy use efficiency in crop production. The tool will be semi-quantitative and will provide farmers with another perspective on their energy consumption patterns and assist them in exploring ways to improve the efficiency of their operations.

Taken together, our programs, our research, as well as our direction and focus, will help advance agriculture's key role and realize its potential in meeting the demand for clean, affordable renewable energy. It is our conviction that this process will contribute both to the vitality of rural communities and energy stability of our nation.

That completes my statement Mr. Chairman. I would be happy to respond to any questions the Members of the Committee might have.

Prepared Statement of David Garman
Acting Under Secretary for Energy, Science and Environment
Assistant Secretary for Energy Efficiency and Renewable Energy
U.S. Department of Energy
before the
Committee on Agriculture, Nutrition and Forestry
United States Senate
May 6, 2004

Mr. Chairman, Members of the Committee, I appreciate the opportunity to discuss the Department of Energy's Biomass program. I'm especially pleased to testify with the Under Secretary of Agriculture. Our two agencies have been working closely together over the last few years to promote our Nation's biomass resources, which we believe will enhance our energy security, provide for a cleaner environment, and stimulate economic growth in rural communities.

Biomass – agricultural crops, trees, wood wastes, plants, grasses, fibers, animal and other wastes – represents an abundant, domestic and renewable source of energy that has tremendous potential to increase domestic energy supplies. Many think of biomass mainly as a source for liquid fuel products such as ethanol and biodiesel. But biomass can also be converted to a multitude of products we use every day. In fact, there are very few products that are made today from a petroleum base, including paints, inks, adhesives, plastics and other value-added products, that cannot be produced from biomass.

The Department estimates that the total available domestic biomass resource, beyond current uses for food, feed, and forest products, is between 500-600 million dry tons per year. Within the continental U.S., we can literally grow and put to use hundreds of millions of tons of additional plant matter per year on a sustainable basis. These biomass resources represent about 3-5 quadrillion Btus (quads) of delivered energy or as much as 5-6 percent of total U.S. energy consumption. In terms of fuels and power, that translates into 60 billion gallons of fuel ethanol or 160 gigawatts of electricity. This is enough energy to meet 30 percent of U.S. demand for gasoline or service 16 million households with power.

In addition to production of alternative liquid transportation fuels such as ethanol and biodiesel, biomass is a proven option for generating electricity through the direct combustion of wood, municipal solid waste, and other organic materials; co-firing with coal in high efficiency boilers; or combustion of biomass that has been chemically converted into fuel oil. So-called "biopower" in 2002 accounted for about 71 percent of non-hydroelectric renewable electricity generation and about 1.0 percent of total U.S. energy supply. It also accounted for about 9,733 MW in 2002 of installed capacity. This includes about 5,886 MW of wood and wood waste, 3,308 MW of generating capacity from municipal solid waste and landfill gas, and 538 MW of other capacity such as agricultural byproducts, sludge waste, and tires. The majority of electricity production from biomass is used as base load power in the existing electrical distribution system.

The Energy Information Administration (EIA) forecasts that electricity output from biomass (including municipal waste) combustion will increase from 59 billion kWh in 2002 (1.5 percent of generation) to 112 billion kWh in 2025 (1.9 percent of generation).

More than 200 companies outside the wood products and food industries generate power in the United States from biomass. Where power producers have access to very low cost biomass supplies, the choice to use biomass in the fuel mix enhances their competitiveness in the marketplace. This is particularly true in the near term for power companies choosing to co-fire biomass with coal to save fuel costs and earn emissions credits. An increasing number of power marketers are starting to offer environmentally friendly electricity in response to consumer demand and regulatory requirements.

DOE Biomass Program

The focus of the DOE Biomass and Biorefinery Program today is advanced technologies to transform the Nation's domestic biomass resources into high value chemicals, fuels, and power.

Recognizing the growing importance of biomass technologies, two years ago we integrated several bioenergy activities into one office to allow a clear and consistent set of goals and objectives and increased collaboration with industry. The program worked closely with industry to produce a vision and R&D roadmap that focuses on the most promising long-term opportunities that, with leveraged funding from industry, can realize a goal of establishing the first large-scale biorefinery based on agricultural residues by 2010. A multiyear technical plan in support of this goal provides a comprehensive work breakdown structure with milestones, costs and schedule, so that every project is linked to program goals, objectives and technical barriers.

The Department of Energy's FY 2005 budget request for biomass activities is $81.3 million. Notably, Congressionally-directed projects accounted for $41 million of the FY 2004 appropriation, or nearly half of the biomass budget. The need to fund these specific projects has delayed progress toward the program goals and diminished core research capabilities at the National Laboratories.

The current focus of the DOE Biomass program is an integrated approach to the simultaneous production of liquid fuels, power and products in what we call a "biorefinery" that would produce a suite of products much in the manner of an oil refinery. By producing multiple products, a biorefinery could take advantage of the differences in plants and other biomass, and maximize the productivity and value from each of the feedstocks. A biorefinery might produce low volume, high value chemicals and low value, high volume liquid transportation fuel while generating enough electricity and process heat for its operation. The high value products enhance profitability, the high volume fuel helps meet national energy needs, and power production reduces costs. Such a refinery would take advantage of the vast supplies of corn stover and other lignocellulosic biomass – the "everything else" in biomass beyond the simple sugars, starch and protein that are valuable inputs into our food supply.

The concept of a biorefinery is based on two technology pathway "platforms" that would promote different products. The "sugar platform" uses a biochemical conversion process to ferment sugars extracted from biomass feedstocks. The "thermochemical platform" involves gasifying biomass feedstocks and by-products from the conversion process. We are currently supporting six major biorefinery projects across the country, each involving private sector partners, focused on developing new technologies for integrating production of biomass-derived fuels and products in a biorefinery.

For example, DOE is partnering with chemical industry leaders such as DuPont and Dow Chemical to develop new opportunities for producing both fuels and chemicals from biomass. DuPont and DOE are working with other industrial partners to develop what DuPont calls an "Integrated Corn Biorefinery" – the goal of which is a refinery that can efficiently convert the starch in corn grain to a low-cost sugar as feedstock to make value-added chemicals, while using the remaining lignocellulosic parts of the corn plant to produce ethanol and power. The ethanol would be competitive at first with corn grain ethanol, and possibly with gasoline. If successful, DuPont's process design could be added onto existing corn ethanol facilities to dramatically improve the yield of ethanol and overall profitability of the facility.

In another project, DOE is working with Cargill-Dow (a joint venture of Cargill and Dow Chemical) to develop new biorefineries that use the corn plant (both the grain and the lignocellulosic fraction) to produce polylactic acid (PLA) – a unique and environmentally friendly renewable polymer. Cargill-Dow has constructed its first PLA facility in Blair, Nebraska and it is producing PLA from the starch in corn while the technology focus is to utilize the remaining lignocellulosic components in the corn plant in the PLA production process.

Interagency Cooperation

We recognize that a new bioindustry will also encourage better use of agricultural land and forestry residues, such as woody biomass. Last December President Bush signed the Healthy Forest Restoration Act (HFRA), which was aimed at reducing the threat of wildland fire to communities by thinning forest lands. These efforts will yield large volumes of materials in the form of brush and small-diameter trees that today have little commercial application. Title II of HFRA is intended to help focus research on overcoming barriers hindering the use of biomass, accelerating assistance to community-based enterprises, and encouraging the adoption of technologies that use biomass and small diameter material.

Woody biomass utilization is an important part of a Memorandum of Understanding signed last year by the Departments of Agriculture, Interior and Energy. We work very closely with the Department of Agriculture in implementing the biomass program. The Biomass Research and Development Act of 2000 required the Secretary of Agriculture and the Secretary of Energy to establish and carry out a Biomass Research and Development Initiative under which competitively awarded grants, contracts, and financial assistance would be provided to eligible entities to carry out research on biobased industrial products. The Act also established the Biomass R&D Board, chaired by Under Secretary Rey and myself, and that also includes the Department of Interior, the Environmental Protection Agency, the National Science Foundation, the Office of Science and Technology Policy, and the Federal Environmental Executive.

The Act also created the Biomass R&D Technical Advisory Committee, an advisory group to the Secretaries of Energy and Agriculture. The Committee includes 30 industrial and other biomass experts that advise the Department (and the Department of Agriculture) on program technical focus. The Committee facilitates partnerships among Federal and State agencies, producers, consumers, the research community, and other interested groups. In October 2002, the Federal Advisory Committee released its "Vision for the Bioenergy and Biobased Products in the United States." The report sets aggressive goals to increase the role of biomass in the US economy by 2020 and beyond.

The 2002 Farm Bill provided direct funding of $75 million for USDA research, development and demonstration projects under the Biomass Research and Development Act of 2000. USDA's Natural Resources Conservation Service and EERE coordinated efforts to issue a joint solicitation that is providing nearly $16 million in USDA funding and more than $7 million from DOE. Nineteen projects (4 DOE and 15 USDA) were selected from more than 400 submitted. This is an unprecedented level of cooperation between our two agencies that we hope to continue in the future.

Conclusion

Mr. Chairman, that completes my prepared statement. I would be happy to answer any questions at this time.

Prepared Statement of Thomas Ewing
Committee Chair of the
Biomass Research and Development Technical Advisory Committee
Before the
Committee on Agriculture, Nutrition and Forestry
United States Senate
May 6, 2004

Mr. Chairman, Members of the Committee, as the Chairman of the Biomass Research and Development Technical Advisory Committee (Advisory Committee) and as House sponsor of the Biomass Research and Development Act of 2000 (Title III of P.L.106-224), I appreciate the opportunity to discuss the Advisory Committee's activities in addition to the developments of the Biomass Research and Development Initiative (BioInitiative) established by the Act. I do not want to proceed further to discuss this Act without giving due credit to Senator Richard Lugar, whose brainchild this initiative was.

The Biomass R&D Act recognizes the "outstanding potential for benefit" offered by biomass technologies. The Act also acknowledges the need to integrate and coordinate the diverse R&D efforts currently taking place across the federal government, in industry, and at the state-level. By creating the BioInitiative, the Act establishes the framework for coordinating and implementing Federal biomass research.

The primary objective of the BioInitiative is to coordinate the development of environmentally sound and cost-effective bioenergy and biobased products and technologies in order to increase the availability and use of those products and technologies. This includes the development and demonstration of low-cost, value-added feedstock conversion processes that serve as precursors to producing power, steam, fuels, chemicals, and consumer products. Reaching this objective entails developing the process chemistry, biochemistry, separation and recovery technologies, and power generation knowledge needed to process biomass streams to final products.

As part of the BioInitiative, the Biomass R&D Board aids in the review of existing R&D programs and to assist in offering advice on strategic direction. The Biomass R&D Board is co-chaired by Mark E. Rey, the Under Secretary of Natural Resources and Environment for the U.S. Department of Agriculture (USDA), and David Garman, the Assistant Secretary for Energy Efficiency and Renewable Energy of the U.S. Department of Energy (DOE). Biomass R&D Board members also include the Department of Interior, the Environmental Protection Agency, the National Science Foundation, the Office of Science and Technology Policy, and the Office of Federal Environmental Executive. The Biomass R&D Board is guided by an Advisory Committee of which I am the Committee Chair.

The Advisory Committee comprises individuals from industry, academia, non-profits, and the agricultural and forestry sectors to provide to the Secretaries of Agriculture and Energy and their points-of-contact (the Under Secretary for Natural Resources and Environment, U.S. Department of Agriculture and the Assistant Secretary for Energy Efficiency and Renewable Energy, Department of Energy) advise on the technical focus and direction of requests for proposals issued under the BioInitiative, and advice on the procedures for reviewing and evaluating the proposals.

The Advisory Committee also facilitates consultations and partnerships among Federal and State agencies, agricultural producers, industry, consumers, the research community, and other interested groups to carry out program activities relating to the BioInitiative, and evaluates and performs strategic planning on program activities relating to the BioInitiative.

For each fiscal year in which funds are made available to carry out the BioInitiative, the Advisory Committee provides a report to the Secretaries of Energy and Agriculture on whether funds appropriated for the BioInitiative have been distributed and used in a manner that is consistent with the purposes described in the Act, whether those funds were appropriated using the criteria established in the Act, and whether any recommendations that have been made by the Advisory Committee have been taken into account.

The Advisory Committee recently ended its third year of activities. To date, the Committee's activities have resulted in five major products:

- In December 2001, the Committee submitted a preliminary set of recommendations to the Secretaries of Energy and Agriculture on the potential of biomass research and development.
- In June 2002, the Secretaries of Agriculture and Energy requested that the Committee develop *Vision* and *Roadmap* documents to guide future biomass research and development activities. The *Vision* and *Roadmap* were developed over the next several months in 2002, and comprised a major portion of the Committee's work that year. These documents now serve as a resource for the agencies in planning their biomass research and development portfolios. The *Vision for Bioenergy and Biobased Products in the United States* was released in October 2002 and set far-reaching goals for increasing the role of biomass in our nation's economy in three categories: biomass power (biopower), biobased transportation fuels (biofuels), and biobased products (bioproducts).
    - BIOPOWER: The *Vision* goals for biopower were to increase "biomass consumption in the industrial sector at an annual rate of 2 percent through the year 2030, increasing from 2.7 quads in 2001 to 3.2 quads in 2010, 3.9 quads in 2020, and 4.8 quads in 2030." The *Vision* goals for biopower also included "biomass use in electric utilities to double every ten years through 2030". Overall, the *Vision* goals stated that "biopower will meet 4 percent of total industrial and electric generator energy demand in 2010, and 5 percent in 2020."
    - BIOFUELS: For transportation fuels, the *Vision* goals outlined that "transportation fuels from biomass will increase significantly from 0.5 percent of U.S. transportation fuel consumption in 2001 (0.147 quads) to 4

percent of transportation fuel consumption in 2010 (1.3 quads), 10 percent in 2020 (4.0 quads), and 20 percent in 2030.

- BIOPRODUCTS: In the third category, Biobased products, the *Vision* goal was that "production of chemicals and materials from biobased products will increase substantially from approximately 12.5 billion pounds, or 5 percent of the current production of targeted U.S. chemical commodities in 2001, to 12 percent in 2010, 18 percent in 2020, and 25 percent in 2030."

The Committee recognizes that economic, international, and many other factors can impact the future demand for and development of biomass technologies, but feels these goals are technically feasible. The Committee believes, however, that it is appropriate that long-term goals be challenging and feel that this *Vision* puts forth the challenge of pursuing the opportunities that biomass technologies hold for the United States.

- In January 2003, the Committee released the corresponding *Roadmap for Biomass Technologies*. The purpose of this document was to outline a research and development roadmap and identify public policy measures for promoting and developing environmentally desirable biobased fuels, power, and products. It represents the collective assessment and expertise of the Committee. The research strategies outlined in this roadmap will help achieve the goals established by the Committee in their *Vision* document. The Roadmap is organized by the major categories of research and development that will be needed to achieve the Vision goals.
- In December 2002, the Committee submitted a set of R&D recommendations to the Secretaries of Energy and Agriculture based on the research strategies outlined in the Roadmap categories,
- In 2003, the Advisory Committee reviewed the USDA-DOE joint solicitation request for proposals (RFP), solicitation process, and awards in order to develop its recommendations. In 2003, the Advisory Committee also evaluated the USDA and DOE biomass research portfolios and investments. The Advisory Committee developed its assessment of the portfolios and developed recommendations to the

Secretaries of Energy and Agriculture. The Advisory Committee used its *Vision* and *Roadmap* documents as a baseline to develop its recommendations on biomass research and development. The Advisory Committee also made specific recommendations to more aggressively pursue federal procurement of biobased products. In December 2003, the Advisory Committee provided its recommendations to the agencies and the agencies considered the Advisory Committee's recommendations and implemented a number of them for the 2004 joint solicitation RFP and process currently underway

As part of the BioInitiative, the USDA and DOE have conducted joint solicitations in the fiscal year 2002 and 2003 and a joint solicitation is currently underway for fiscal year 2004. In total for the FY`02 and FY`03, 27 projects have received federal funds under the joint biomass solicitation. Total federal funds that were made available in FY`02 were $76M over five years from DOE, and $2.7M from USDA. For FY 2003, $23M of federal funds were made available; $7M from DOE and $16M from USDA. In FY 2004, the total federal funds currently made available are $22M, with $10M from DOE and $12M from USDA.

The Advisory Committee is pleased to find that the USDA and DOE have increased their level of coordination and collaboration as a result of the BioInitiative. The Advisory Committee also did not find significant duplication of biomass R&D by the USDA and DOE in the area of feedstock production. However, the Advisory Committee does not believe that the U.S. government's current funding for biomass programs is sufficient to implement the *Roadmap*.

Underlying the Advisory Committee's FY`03 recommendations is the consensus that an effective research and development program in the biomass area must work in a coordinated fashion, with the goal of demonstrating technologies at a commercial scale and implementing public policies, including public education, incentives, government purchasing, and removal of regulatory roadblocks. A role for USDA, DOE, and other sectors of the federal government exists across these areas, including financial support prior to transfer to the private sector. This fundamental premise is the foundation on which the *Vision* and *Roadmap* were built.

The Advisory Committee does not believe that the Departments' current biomass programs, in the current policy context, are adequate to achieve the goals set forth in the *Vision*. While the specific recommendations were designed to help the agencies modify current programs to bring them into conformity with the *Roadmap*, one overall recommendation is that the *Roadmap* cannot be effectively implemented and the *Vision* goals cannot be achieved without an order of magnitude increase in financial and policy support for biomass. Specific first steps in this direction should include:

1. **A request for $60 million to support the construction of three cellulose-to-ethanol plants capable of processing a variety of cellulose raw materials and using different production technologies to be operational by 2008.**
2. **Active support for substantial procurement and incentive policies that will dramatically increase the production of biomass energy and biobased products.**

In response to the Advisory Committee's recommendations, the DOE has stated that in FY 2005 it is requesting $81.3 million for biomass program activities, which is $30.1 million more than the unencumbered appropriation it received last year. However, the FY 2004 Biomass Program appropriation included nearly $41.0 million, or nearly half of the biomass budget, targeted to specific projects not identified in program plans. Congressional earmarking has also delayed progress toward the program goals and diminished core research capabilities at the National Laboratories. The DOE was recently forced to dismiss research personnel at the National Renewable Energy Laboratory (NREL) and other national laboratories because of the lack of funding available for their planned program activities.

As of 2004, the Committee currently includes 30 industrial and other biomass experts that advise DOE and USDA on program technical focus. In 2004, the Committee plans to complete the following:

- Respond to reports from USDA and DOE regarding aggressive federal purchasing of biobased products.
- Develop detailed recommendations regarding the USDA/DOE joint solicitation. Develop a matrix to track the progress of R&D funded under the solicitation.
- Track progress in achieving the Committee's Vision goals.
- Discuss cellulosic ethanol, gasification, and co-firing, and the history of the federal government's efforts in those areas.
- Discuss hydrogen power.
- Create a subcommittee to develop a definition of "biorefinery."

Conclusion

Mr. Chairman, that completes my prepared statement. I would be happy to answer any questions at this time.

TESTIMONY OF R. JAMES WOOLSEY
FORMER DIRECTOR OF CENTRAL INTELLIGENCE

COMMITTEE ON AGRICULTURE, NUTRITION AND FORESTRY
UNITED STATES SENATE
MAY 6, 2004

Mr. Chairman, Members of the Committee:

It is an honor to be invited to appear before this distinguished Committee on the important issue you are addressing today. I would like to speak to two aspects of it: the strategic context of the current dependence on imported oil; and in that context the potential role of American agriculture in improving, *inter alia*, our security by becoming a major source of our transportation fuel. I will not address the use of biomass or other agricultural sources in the production of electricity – a separable and, in my view, much less important issue. There are many ways to produce electricity, and only two per cent of our electricity, headed down, is produced by oil. Insofar as fuel supply is concerned, the security issue, in my view, is dominated by the question of dependence on imported oil.

The Strategic Context of Oil Dependence

The headlines of recent weeks pointedly emphasize the importance of today's hearing: two Americans and three others killed by terrorists in Saudi Arabia within the last week; terrorist attacks on oil facilities in Iraq, as well as elsewhere in the Middle East; OPEC production cutbacks, leading to rapidly rising prices at the gasoline pump here in the U.S.; and uncertainty about the future of our effort to bring stability in the form of democracy and the rule of law to Iraq, illustrated by the recent turn of events in the streets of Fallujah and Najaf.

The location of the world's easily accessible oil supplies in the volatile Middle East frames the picture of our current dilemma. I would note at the outset that all oil-importing nations are in a real sense in this together – there is, to a first approximation, one worldwide market in oil. Given the integrated nature of the world economy and the degree to which our economic fortunes are intertwined, we accomplish nothing particularly useful if we merely shift our own purchases of oil from one of the world's regions to another and thereby re-shuffle the existing buyers and sellers. Under current circumstances, an oil crisis will affect all our economies, regardless of the source of our own imports. We must think in terms of the world's dependence, not only our own.

As oil fields reach and pass their halfway point in production, their costs of production rise substantially. Some production is inherently high-cost, such as that in Russia, because of factors such as weather, environment, and transportation limitations. Other production, such as the huge deposits of heavy oil in Alberta, are potentially quite promising if technological progress can continue to reduce economic and environmental costs. But a very large share of the fields outside the Middle East have reached their halfway point in production and are seeing rising production costs. So for a number of years into the future those who control the low-cost production in the great oil fields of the Middle East and also the majority of the world's swing production capacity will be in the driver's seat with respect to the world's oil supply and oil prices. Through such control they will have a major hand in the world's economic future.

I should add that the current state of affairs in the Middle East should deepen our concern. It is true that if the region were at peace, and if the regimes controlling the lion's share of Middle Eastern oil were stable and reliably moderate friends of the world's democracies, then we might expect a steady flow of reasonably priced oil to help the world's economies grow – even considering the added demand that will come from increased Indian and Chinese oil consumption. But is there anyone who would assert that this is the condition of the Middle East today, or that it is likely to be the case any time in the foreseeable future?

One potential source of disruption of oil supplies is of course terrorism. We have recently seen attacks on the Iraqi oil port of the Persian Gulf, there continue to be many attacks on Iraqi pipelines, and there were earlier terrorist attacks on oil tankers. Al Qaeda terrorists and Baathists both know that disrupting the resuscitation of the Iraqi oil industry is central to their efforts to defeat the Coalition and either restore fascist totalitarianism to Iraq or, for others, to introduce theocratic totalitarianism there.

The terrorist threat to oil supplies is not limited to Iraq or to the high seas – for example, the opening pages in *Sleeping With the Devil*, by former CIA officer Robert Baer, centers on the unfortunately plausible scenario of a hijacked 747 being flown into a vulnerable and crucial part of Saudi Arabia's oil refining complex, taking millions of barrels per day out of production for a number of months and devastating the world's economy.

We must also be concerned about the potential instability and potential hostility in more than one major Middle Eastern oil producer. The key country is Saudi Arabia, and I would first point out that the picture there is not entirely bleak. Crown Prince Abdullah is trying to respond positively to some of the calls for reform in the Kingdom, and over the long run that could enhance the Kingdom's stability. He has made efforts to promote nationwide local elections, for example, and he has limited the role of the religious police in some matters. He has not been nearly as much a reformer as others, such as the Emir of Bahrain, but his actions seem to me to indicate a positive effort.

The Crown Prince is, however, an octogenarian. If the ailing King Fahd is succeeded instead by one frequently mentioned candidate, the Interior Minister, Prince Nayef, it is not only the outlook for reform that will be bleak. Prince Nayef regularly imprisons reformers and fires newspaper editors who call for reform, and the last time the Prince, who is in charge of the Kingdom's counter-terrorism efforts, spoke publicly on the issue of 9/11 he opined that it was the Jews who had executed the attack. Cooperative efforts with a King Nayef could, to put it gently, be quite challenging.

And of course one cannot ignore the possibility of a terrorist takeover of the Kingdom by Islamists of the stripe of Osama bin Laden. It is sometimes said that whoever is in power in Saudi Arabia, the Saudi Government will have to sell substantial oil to the world. This is not the case, however, if those who take power wish to live in the 7th century. We can hope for movement in the Kingdom toward reform and subsequent stability under the sort of policies advocated, in however limited a fashion, by the Crown Prince. But we certainly cannot prudently count on such a course of events.

The Role of American Agriculture: Utilizing Agricultural Waste to Produce Fuel for the Existing Transportation Infrastructure

I have submitted to the Committee two articles that deal in whole or in part with this issue. One, "The New Petroleum," published in *Foreign Affairs* in 1999, I was privileged to co-author with the Committee's then-Chairman, Senator Lugar; it followed from testimony he asked me to give before this Committee seven years ago. The second, "Defeating the Oil Weapon," I published a year ago last September in *Commentary*. Both make the case for concentrating on using inexpensive feedstocks or, even better, waste products from our nation's agricultural sector to produce transportation fuel that can be used within our existing transportation infrastructure.

The ability for such fuels to be used within the existing infrastructure is the key to making rapid progress – and speed is now essential in light of the critical situation in the Middle East described above. Thus the highest priority should be given to encouraging the production of alternative fuels that require minimal or no change to today's transportation infrastructure.

In light of the likelihood that they will require substantial infrastructure changes, for example, I believe that far too much focus is being placed on automotive fuel cells, and far too little on more quickly available approaches. For fuel cell vehicles to be purchased by consumers, reformers (producing hydrogen from, say, natural gas) would need to be present in a large number of filling stations so that the family car could fill up with hydrogen whenever needed. But who goes first? Detroit, producing fuel cell cars, or energy companies installing reformers? Making such large and complex infrastructure changes takes a good deal of money and time. (If, in order to avoid this problem, the reformers were put in the vehicles so that consumers could fill their tanks with gasoline and then have it reformed into hydrogen to produce electricity, all inside the car, the weight and economic cost would likely be very substantial.)

Substantial fuel efficiency technologies are already available that can reduce the overall amount of transportation fuel required and thus multiply the effect of alternative fuels. For example, if we were producing ethanol from biomass and E-85 fuel (85 per cent ethanol, 15 per cent gasoline) were thus widely available, a 20-mile-per-gallon vehicle would be getting nearly 100 mpg on the gasoline it used when it burned such a fuel. But if the same fuel were used in the 60-mpg hybrid gasoline-electric car that I drove here today, that vehicle would be getting nearly 300 mpg on its gasoline. (If the capacity to burn E-85 rather than only E-10 is added to a vehicle during production, the modification and cost are both trivial – there are already millions of such flexible-fuel vehicles (FFVs) on the road.)

To obtain the amounts of ethanol that would be necessary to make a substantial dent in our oil imports, we will need to move beyond grain as a feedstock and use agricultural waste products such as rice straw and bagasse or such crops as switchgrass, a process that will require the use of genetically modified biocatalysts. Progress has been made on this technology since Senator Lugar and I wrote about it in January of 1999, and a Canadian company, Iogen, has just entered commercial production.

Another form of agricultural waste, from animal carcasses and manure, can also be used to produce vehicle fuel for the existing infrastructure: high-grade diesel fuel that can either be utilized directly or refined into gasoline. Such diesel fuel is currently being successfully produced commercially by a joint venture between Conagra and the company that developed the technology, Changing World Technologies, using over 200 tons per day of waste from a Conagra turkey processing facility in Carthage, Mo. The same technology can be used to process cellulosic biomass into diesel fuel.

I have been familiar with the work being done on the technology of these two processes for years – conversion of biomass into ethanol using genetically modified biocatalysts, and thermal conversion (involving high-pressure de-polymerization) of organic wastes of all sorts into high-grade diesel fuel – and have advised companies utilizing them. There are other processes, using other-than-agricultural waste products such as strip-mine waste, to produce diesel and other fuels; these deserve attention as well. But whatever the technology, I want to stress the opportunity, for both substantive and political reasons, provided by the prospect of utilizing waste as a feedstock for such fuel production.

First of all, capital is often a coward, particularly the first time new technologies are brought to market. If we want to encourage new technologies to be used promptly in commercially viable production facilities to produce transportation fuel, we will have to find a way to recognize the cost of waste disposal as a reduction in the cost of producing the fuel.

Farmers and others who help produce agricultural products must dispose of such wastes as rice straw and bagasse somehow, and it costs them something out-of-pocket to do this. There are other costs to society (e.g., air pollution from burning) that are often not recognized by the market. These costs make such agricultural waste ideal feedstocks for the production of transportation fuel. If the fuel producer took care of conversion of rice straw into ethanol or diesel, was paid by the farmer whatever it now costs the latter to dispose of the rice straw, and the reduction in pollution was recognized by a tax credit or in some other fashion, I believe that a number of waste-to-fuel technologies would begin to thrive.

Where such costs are monetized, the effect of bringing on line technologies that use waste as a feedstock can be dramatic. For example, in Europe, because of concern about BSE, a negative cost ("tipping fee") of well over $100/ton is recognized for some animal carcasses, since the type of disposal now required there means that such waste cannot be used to produce feed for chickens or for other such purposes. At tipping fees of that magnitude, the thermal conversion process now used at the Conagra turkey processing plant and applied to cattle carcasses would produce diesel fuel that could be given away free, and the plant operators would still make a substantial profit. Since Europe recognizes and gives credit for disposing of such waste more than is done on this side of the Atlantic, the deployment of these waste-to-fuel technologies is beginning in some cases to migrate to Europe – for example, the turkey-offal-to-diesel process at the Conagra plant is not recognized as producing "bio-diesel" as the term is defined in U.S. law and thus is not financially encouraged in this country. We are inventing in the U.S. ways to make the world less dependent on oil and watching our inventiveness migrate to Europe to be used by Europeans to reduce their oil import bill.

The volume of what we import and what we could save – while creating jobs, largely in rural America, to produce our transportation fuel – is staggering. Last year we paid the outside world about a billion dollars every three days for imported oil. Even replacing a share of this with domestic production of transportation fuel could create hundreds of thousands of jobs.

How much domestic production of fuel from waste is plausible to produce substitutes for imported oil? According to those who manage the process at the Conagra facility, EPA estimates that there are approximately 6 billion tons of agricultural (i.e., plant and animal) waste created every year. Of course major shares of this do not need to be removed from the field as must be done with rice straw and may be left there to decompose. But the overall volume of fuel that could theoretically be produced from such waste is interesting because the amount is so large that even a small share would be significant. Discounting for 50 per cent moisture content and assuming a conservative yield of 20 per cent diesel from the rest of agricultural waste, using thermal conversion our total agricultural waste would yield nearly 11 million barrels/day. Production from a new domestic source of conventional oil, such as the Alaska National Wildlife Refuge, would be dwarfed by conversion of a very small share of this agricultural waste into fuel.

Another benchmark for potential volume of production is provided in Senator Lugar's and my article, mentioned above. (Our figures are from the work of Professor Lee Lynd of Dartmouth's Thayer School of Engineering, who will be testifying later today.) If our CRP lands were planted in switchgrass (as a substantial share already is) and legislation were passed which permitted such lands to be harvested solely for the production of biomass feedstocks to produce fuel, then at the mileages being achieved by today's hybrid gasoline-electric vehicles this amount of switchgrass plus a reasonable portion of agricultural wastes would produce enough ethanol to replace all of our current gasoline consumption. Other analysts have used lower switchgrass yields than Professor Lynd in looking at the issue. Fine, halve the assumed yields, and for a fleet of hybrids we could still get enough ethanol – with no land taken out of its current uses – to replace the approximately half of our gasoline that comes from imported oil.

A Possible New Coalition

The final point I would make is a political one. Important change often requires a shock to the system of the body politic, and also the formation of coalitions that previously had not existed.

I would suggest that the shock should have been perceived long before, but for many it came on 9/11. The subsequent events described above, including the terrorist attacks in Saudi Arabia within the last week, should have supplied all that is necessary in that regard.

As for coalitions, for the past two years, I have been a member of the National Commission on Energy Policy and have served on the Advisory Council of the Energy Future Coalition.

The potential coalition here is an interesting one. Senator Lugar and I alluded to it in our article of five years ago.

First are the farmers, indeed rural America as a whole – an extremely important part of our country and a sector of the economy of great interest of course to this Committee. To have rural America be able to take over a major share of our production of transportation fuel would mean substantially enhanced prosperity for our farms, rural areas, and small towns.

The second group in the potential coalition consists of those concerned about the environment. The two technologies I have described not only get rid of noxious wastes but, unlike incineration, are themselves non-polluting. Moreover for those concerned about global warming and climate change, the production of transportation fuel from agricultural wastes essentially recycles CO_2 that has been fixed in the photosynthesis process and turns it loose again – the experts in this field agree that burning fuel produced from biomass adds essentially no net CO_2 to the atmosphere. And to the degree that using agricultural wastes to produce diesel or ethanol means that those wastes do not decay anaerobically, this prevents the formation of methane, which is more than twenty times worse as a contributor to global warming than CO_2.

The third group consists of those who are interested in promoting economic growth and stability in developing countries. Even apart from the obvious humanitarian concerns, this group should include all of us, because to the degree that such countries, say in Africa, can experience greater rural prosperity from the production of transportation fuel domestically – and can avoid the accumulation of dollar-denominated debt to pay for their imports of oil – they will be less likely to produce instability and terrorism.

Finally, there should be a substantial group under present circumstances who are quite concerned about our nation's security and who want to do everything possible to protect it – hopefully without back-breaking costs.

We might say that there is a prospect of the farmers' being joined in a political coalition to promote the use of agricultural wastes to produce transportation fuel by three other elements: the Tree-Huggers, the Do-Gooders, and the Cheap Hawks. I must admit that I personally see nothing incongruous in this since, now that my wife and I own a small farm, I regard myself as a member of all four of these groups. Such a coalition would require some compromises among its members, but I would suggest these would be neither major nor prohibitive. Cooperative efforts among these important constituencies could bring substantial new support to a vital cause.

TESTIMONY OF C. BOYDEN GRAY
ON BEHALF OF THE ENERGY FUTURE COALITION

COMMITTEE ON AGRICULTURE, NUTRITION AND FORESTRY
UNITED STATES SENATE
MAY 6, 2004

Mr. Chairman and Members of the Committee: I want to thank you for having the vision and the leadership to hold this hearing. Each morning when we pick up the newspaper and read about the latest terrorist attack in Saudi Arabia, Spain, Pakistan, or elsewhere, we're reminded of the volatility of this post-9/11 world of ours – and of the urgency of finding ways to reduce our dependence on Middle East oil.

It is a challenge directly linked to the security and well-being of our nation: to find new technologies, new efficiencies, and new natural resources that will enable us to produce more of the energy we need at home, and do so in ways that are positive for the environment and that may also be adopted by less prosperous nations. The nation's agricultural sector is uniquely positioned to respond to this challenge and to benefit from the opportunities it presents.

I am presenting these views on behalf of the Energy Future Coalition, for which I serve on the Steering Committee. This is a broad-based, independent and bipartisan initiative that seeks to address three great challenges that are directly tied to the production and consumption of energy:

- The security threat posed by the world's, and our own, dependence on oil.
- The lack of access of the world's poor to the reliable and affordable energy supplies they need to help themselves out of poverty; and
- The risk to the global environment from climate change, stimulated by over-reliance on fossil fuels.

Our coalition has worked to move beyond the predictable clashes of interests and parties. Instead, we've focused on emerging technologies, on market solutions and on both immediate and longer-term approaches that will carry us to a new, sustainable energy economy.

In recent years, U.S. energy policy has been gridlocked. We've failed to adequately address the risk to our economy, our environment and our security that stems from our dependence on oil. Oil market upheavals since 1973 have stunted the growth of the U.S. economy – by a net 10 percent of GDP, according to energy economist Philip Verleger. The question we must address today is how best to hurry along what we now recognize must be an inevitable shift in our primary energy supply.

About a quarter of the total energy consumption in the United States is for transportation, which depends almost entirely on oil. Transportation consumes roughly two-thirds of the oil we use, nearly 60% of which is imported. So if we are to move away from dependence upon imported oil, we must change the transportation sector.

We can do that, starting today, by creating and sustaining public policies that encourage a transition to cleaner and more fuel-efficient vehicles and by investment in large-scale initiatives to produce biofuels as an alternative supply source. In the process we can increase farm income and reduce the cost of government support payments, as new markets for agricultural materials steadily lift the demand for farmland and provide new revenue streams to farmers for products now thought of as "waste."

Bioenergy – growing our way out of dependence upon foreign oil – offers our country an opportunity to protect itself by doing the right thing: aiding our farmers, the environment and the nation's energy security. It also can help resolve global trade deadlocks that center on whether our support for agriculture in this country undermines the rural poor in the rest of the world.

This is not a scenario based on technological expectations that will take shape a half-century from now. Two weeks ago, a Canadian company, Iogen Corporation, announced that it had begun the commercial production of ethanol from cellulose, in the form of wheat straw – a global first. Iogen reported that it and its partners had already invested $110 million (Canadian) in this technology, of which the largest share, $46 million, came from Shell. Shell in turn predicted that "the global market for biofuels such as cellulose ethanol will grow to exceed $10 billion by 2012."

New biotech advances can enable the use of corn stalks, wheat straw, rice hulls, grasses and other "waste" products to be the new crude for "biorefineries." Starch from corn and other grain crops has been the principal feedstock for ethanol production and will continue to be for some time. This pathway has been an essential first step toward developing an ethanol infrastructure, and government support for continued growth of the industry is vital as a bridge to the future. The efficiencies of crop production and ethanol conversion continue to increase.

Using cellulose will increase the amount of ethanol that can be produced from grain because more of the plant will be used. Obtaining energy and other products from cellulose also avoids the consumption of food crops for industrial applications. Thermochemical processes have the potential of converting a still wider range of biomass feedstocks, including abundant animal wastes and sewage, to clean renewable fuels – even gasoline.

Starch-based ethanol has limited benefits in terms of oil displacement and greenhouse gas emissions, due to the substantial fossil fuel inputs required to grow grain and convert it to alcohol. The benefits of cellulose conversion are dramatically larger; indeed, a conventional internal combustion engine operating on cellulosic ethanol produces fewer greenhouse gas emissions on a life-cycle basis than a fuel cell operating on hydrogen derived from fossil fuels. The use of sustainably produced bio-derived fuels and products contributes little in the way of net greenhouse gas emissions because the carbon dioxide released during combustion is offset by the carbon dioxide absorbed by the biomass as it is grown.

There would be also a significant air quality benefit from the increased use of biofuels, at a time when much of the country is having difficulty complying with new ozone standards, by reducing gasoline aromatics, such as benzene, toluene and xylene. These materials are highly toxic, the largest single contributors to fine-particle pollution, highly photochemically reactive to sunlight (and thus large contributors to ozone), hard on catalytic converters, and the most carbon-intensive portion of a gallon of gasoline. The health benefits alone of eliminating these air toxics potentially run to billions of dollars.

The potential contribution of biofuels to our energy supply is quite large. A study for the Energy Future Coalition by the Battelle Memorial Institute produced a near-term scenario in which 50 billion gallons of cellulosic ethanol could be manufactured annually, without a significant disturbance to our agricultural economy. (This compares to last year's record production of nearly 3 billion gallons of ethanol from corn and overall U.S. consumption of more than 110 billion gallons of gasoline.) A copy of this study is attached for the record.

Large-scale demand for ethanol feedstocks would also raise prices of other crops, both here and abroad. Economist William Cline of the Center for Global Development and the Institute for International Economics estimates that U.S. production of 50 billion gallons of ethanol would have the indirect effect of lifting more than 40 million people out of poverty in the developing world. In the U.S., a new domestic fuels industry would be a major economic stimulus to the rural economy, creating new jobs, increasing farm income by billions of dollars, and reducing the need for government support. It would also make a dent in our enormous trade deficit: Fully one-quarter of our $489 billion imbalance of payments is attributable to petroleum.

A substantial shift to biofuels would also have a significant benefit for our national security. In response to a request by Dr. Andrew Marshall, Director of Net Assessment in the Office of the Secretary of Defense, the Arlington Institute last year produced a report entitled "A Strategy: Moving America Away from Oil." A summary is attached for the record. In short, the report recommended a three-step strategy for the nation:

1. Vast improvements in efficiency must be made, mainly through hybrid gasoline-electric vehicles and new lightweight designs.
2. The U.S. should invest in a new large-scale initiative to produce biofuels as an alternative supply source, mainly through cellulosic biomass.
3. In the longer term, these biofuels can be used as a feedstock for fuel cells.

So what needs to happen next?

Congress should create a well-focused program to make bioenergy a low-risk commercial option, funded at a level that reflects its value to enhanced national security, trade and the environment. We recommend that the Federal Government authorize and conduct a one-time procurement "fly-off," aimed at building 5 to 10 commercial-scale demonstration plans over five years to test the viability of different conversion processes, using different resources and producing different end products. The risks of this kind of scale-up are substantial – beyond the scope of the private sector to manageably finance alone – but the benefits of success are far larger. The Department of Defense is well suited for this sort of competitive technology demonstration program.

Second, federal expenditures for bioenergy research and development need to be increased to reflect the magnitude of the problem – in national security terms. Thanks to Senator Lugar's leadership, Congress passed and the President signed in 2000 the Biomass Research and Development Act to establish an intensive and focused national R&D program – authorizing $245 million over five years. But this additional money hasn't been appropriated.

Once the technology for the conversion of biomass to fuels is well demonstrated, financial incentives may be needed to stimulate production and ensure a fair return to farmer until demand becomes reliable and profits can be fairly certain. We recommend that the National Research Council assess the impacts of shifting domestic farm subsidies from food and fiber crops to conservation, energy crops, and the bioenergy industry and report back to Congress. This report would evaluate the effect of such action on energy supply, national security, and the environment, as well as on economic conditions in rural America and the developing world.

Mr. Chairman, the full report of the Energy Future Coalition contains additional recommendations, and a summary of that report is attached for the record. The Coalition's Bioenergy and Agriculture Working Group was ably chaired by Brent Erickson, Vice President for Industrial and Environmental Biotechnology at the Biotechnology Industry Organization.

In our judgment, these and other well-considered steps can hurry this country into a more secure future in which our economic survival is not so directly linked to the unstable nations that supply our oil. Biofuels are the future America deserves, and we need to begin on that future today.

Testimony of

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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.

Testimony before the Senate Committee on Agriculture, Nutrition, and Forestry

Biomass Use in Energy Production: New Opportunities for Agriculture

May 6, 2004

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Introduction

Chairman Cochran and members of the committee, thank you for convening this panel, and for the opportunity to share some of the exciting possibilities for expanding biomass energy production in the coming years.

With the encouragement of this committee's hard work over many years, and particularly the Biomass Research and Development Act of 2000, and the landmark Energy Title of the Farm Security and Reinvestment Act of 2002 (FSRIA), the promise of biomass energy is beginning to be realized. Evidence of these first steps toward a bio-based economy includes rapidly increasing numbers of ethanol and biodiesel plants converting corn and soybeans to transportation fuels, anaerobic digesters producing electricity from manure, and the development of a host of innovative technologies to produce biomass energy and complementary products from lignocellulosic feedstocks. This evidence underscores the fact that biomass energy is a real alternative, and that agriculture can play a significant role in America's energy future.

Although these current activities are important, they are not enough to achieve the full potential that exists. Efficient and competitive biomass energy requires new agricultural production strategies, to provide cost-effective biomass feedstock while protecting and enhancing the natural resource base. Conversion technologies must be developed that can transform these feedstocks into diverse product streams, and these technologies must be scaled so they can be implemented on farms and in local communities. And these feedstock production and conversion technologies need to be integrated in value-chains that reward all participants, from farmer to processor to consumer, across the United States.

Biobased production has the potential to provide secure domestic energy, invigorate agricultural enterprises, and catalyze robust rural development. But it will take strong partnerships and serious investments by industry, government, and academia to achieve that vision. Today I would like to discuss some of these emerging partnerships, and identify some of the areas where greater investments in fundamental knowledge and technical innovation are critical to making these opportunities real.

Strategic Partnerships

The opportunities to convert agricultural crops and residues into biobased products and bioenergy present entirely new value-added pathways for agriculture and industry. Coordinated business, government, and university partnerships can greatly accelerate the emergence of these new pathways and facilitate their success. Many of the opportunities for Iowa have been detailed in the October 2002 report titled "Biobased Products and Bioenergy Vision and Roadmap for Iowa[1]." This report is the result of the Iowa Industries of the Future project, involving over 500 Iowa stakeholders in discussing the opportunities and challenges for the BioEconomy for Iowa. This report outlines potential markets for Iowa's biomass resources and sets realistic goals for progress. The report also outlines the science and technology focus areas that need to be addressed to assure advancement of the BioEconomy and Iowa's position within it.

The BIOWA™ Development Association, an association composed of representatives from production agriculture, industry, environmental interests and academe, has been formed to support and promote the growth and development of Iowa's BioEconomy. BIOWA is working closely with the Iowa Department of Economic Development to structure Iowa's economic development portfolio so that it focuses on the opportunities and challenges provided by biobased businesses.

While state-level initiatives can leverage local opportunities and resources, the federal government can also play a catalytic role. By establishing standards and stimulating market demand, the federal Biobased Product Preferred Procurement Program will help biobased businesses achieve the economies of scale needed to compete. This program, initiated by Section 9002 of FSRIA and managed by the USDA Office of Energy Policy and New Uses, is modeled after a similar program the EPA developed to encourage procurement of recycled materials. By defining a suite of designated biobased products, this program will provide not just improved access to federal procurement processes, but also a benchmark for state and local procurement policies, as well as encourage private sector demand.

While near-term biobased agricultural and economic development opportunities are being nurtured by business and government, research investments will drive the next generation of innovation needed for the bioeconomy to flourish. The joint USDA-DOE Biomass Research and Development Initiative, which previous panelists Mark Rey and David Garman co-chair, illustrates the groundswell of interest in this area. I know many members of this committee are working hard to secure funds for the Sun Grant Initiative, which will provide another major boost to university research. These research efforts need to span both basic and applied sciences, and also be widespread and diverse. One of the distinguishing features of successful biomass energy strategies is a close coupling with local agricultural production systems, which vary greatly across this nation.

Iowa State University provides an example of active university engagement with these challenges. In 2002 our University President, Gregory Geoffroy, approved a Bioeconomy Initiative[2] to provide a central focus for biomass research and education on campus. An interdisciplinary graduate program has been established in Biorenewable Resources and Technology, including advanced training in the plant science, production, processing, and utilization areas identified as critical barriers to biobased production by the U.S. Dept. of Energy[3]. Coordinated teams of faculty and students are focused on six research platforms: biobased products from vegetable lipids, expression and purification of recombinant proteins, metabolic engineering of new fermentation products, natural fiber utilization, syngas fermentation, and lignocellulosic feedstock development. This research is supported by a range of university, industry, state and federal funds, including competitive grants from the USDA, DOE, and NSF. Platform teams have strong linkages with industry, including such companies as Cargill, Genencor, West Central Cooperative, John Deere, and Alliant Energy. The BIOWA effort already mentioned provides a mechanism for these partnerships to flourish and develop critical mass. Similar combinations of university research expertise, industry innovation, and governmental support are proving both powerful and effective engines for bioenergy development throughout the U.S.

Near-term Opportunities

Even with effective partnerships and significant investments, the development of a biobased economy will not happen overnight. Extensive analysis of a range of feedstocks has identified several opportunities for near-term progress[4, 5, 6]. Two of the feedstocks of particular interest are livestock manure and crop residues. These materials are attractive because they are byproducts of existing agricultural production systems, are potentially available in very large quantities, and, in the case of manure, can benefit from certain types of bioenergy use. Other organic residues and byproducts, including wood and paper wastes, agroprocessing wastes, and biotechnology byproducts, also represent immediate opportunities to pursue[4, 5].

Manure

Although often viewed as a problematic waste, livestock manure also represents a considerable resource. Much of the energy and nutrients fed to the animals is not absorbed, and passes out with the manure. This residual value has long been recognized by farmers, particularly in the use of manure for crop production and soil tilth. Unfortunately, these nutrients may also contaminate surface or groundwater, while some of the energy is lost as methane. Methane is a potent greenhouse gas if lost into the atmosphere, but is also the principal component of natural gas, with obvious renewable energy ramifications.

Although anaerobic digestion has been used to capture and use manure generated methane for decades, the number of operating facilities on farms has until recently remained quite low. Most of the farm-scale anaerobic digestion plants that were installed during the 1970's and 1980's failed, due to a combination of technical, managerial, and economic weaknesses[6]. However, advances in anaerobic digestion technology, and increased environmental awareness to reduce greenhouse gas emissions, have improved the outlook for the installation of farm-scale systems[7].

Processing manure through an anaerobic digester extracts much of the available energy, while preserving the nutrients for subsequent crop utilization. Side benefits of digestion include increased availability of nitrogen for crop utilization, and significant reductions in odor released.

Despite these benefits, anaerobic digestion is not for every livestock operation. Manure must be easily collected, and of intermediate consistency so that it will readily flow. Excess moisture increases processing costs, both by increasing the size of digester vessels, and by increasing heating requirements during winter operation. But the primary limitation to anaerobic digestion today is economic. Unless farms have significant on-farm demand for heat and electricity, excess power production will be sold to the grid. And while some utilities have implemented green power procurement programs that pay a premium for renewable energy, many in rural areas have not. The outlook for dairies is most promising, as many have compatible manure handling systems and significant on-farm demand for heat and power. In regions where green power premiums are available, anaerobic digestion can break even for farms of only a few hundred cows[8]. For swine operations, with limited on-farm energy demand, favorable conditions are rare[8].

For beef and poultry operations with drier manure, there has been increasing interest in combustion, gasification and other thermochemical conversion processes. These technologies are also being applied to plant biomass, and can play a very promising role. Depending on the configuration, thermochemical systems can convert biomass energy to many useful forms, including heat, power and even hydrogen fuel, while retaining P, K, and mineral elements in the ash. But nitrogen, the most valuable nutrient in manure, is typically not conserved, and instead is lost as NO_x and other gaseous emissions. In agricultural systems we presume this lost manure nitrogen is compensated for by increased nitrogen fertilizer demand, which requires significant amounts of energy to produce. Nitrogen fertilizer production requires one of the major energy inputs to agriculture, accounting for about one third the energy required to produce our crops. If we consider N losses from manure in the context of the entire crop production – livestock – manure – energy cycle, the net energy benefits of manure combustion will be considerably reduced. This example points up the need for comprehensive life cycle analysis of biomass production, processing, and utilization, to insure that the complete systems achieve the intended goals.

Corn Stover

Crop residues are an agricultural byproduct with even greater energy potential than manure. Among the many straws and crop residues produced at present, corn stover is widely recognized as the most promising high volume, low cost lignocellulosic feedstock on which to base a range of biobased energy, chemical, and material industries for the next several decades[4, 5, 10]. With a sustainable harvest estimated at 100 million dry metric tons per year[4], this resource contains over 1.7×10^9 GJ of energy annually. Because stover is a crop residue, the incremental energy, nutrient and cost inputs for collection are relatively small, offering corn producers the potential for a valuable new co-product from existing acreage. Since corn is widely grown across the United States, biorefineries based on corn stover can provide an important new economic engine for rural development in many regions of the country.

However, several significant challenges must be addressed before this vision can be achieved. First, stover biomass must be supplied at a price that is competitive with petroleum, profitable for producers, and favorable for the growth of the rural agroindustrial economy. To achieve these economic objectives new technologies must be developed and optimized for stover harvest and storage. As stover becomes a significant feedstock commodity, the genetic potential of corn must be exploited to increase both stover yield and biomass conversion rates. And as these new technologies and varieties are developed and optimized, they must be implemented in ways that are sustainable with respect to soil, the environment, and rural communities[9, 10].

Current stover harvest systems rely on multiple passes across each field (for grain harvest, stover windrowing, baling, and bale collection) followed by dry storage of stover bales. This system has been used for decades for livestock bedding and hay production, but for the biomass industry is problematic with respect to soil contamination, space requirements, and transportation costs, not to mention occasional catastrophic losses due to fire. Overall biomass harvest and delivery costs of this multi-pass, dry storage system have been estimated at $43 to $60/dry ton, including a $10 to $11/dry ton return to the farmers that are involved [11, 12]. The price target for corn stover biomass is $30/dry ton, as estimated in the DOE's *Roadmap for Agricultural Biomass Feedstock Supply in the United States*[13]. This target is considered competitive with petrochemical feedstocks for many commodity chemicals and transportation fuels, and is thus essential for widespread biobased industrial development in rural America[5].

An alternative system, coupling single-pass, simultaneous harvest of grain and stover with ensiled stover storage, has recently been shown to reduce centralized delivery costs by 26% relative to the multi-pass, dry storage approach[14]. These savings are possible with first generation prototype equipment, and further breakthroughs are expected as equipment manufacturers invest and optimize next-generation designs. Single-pass harvest has been estimated to reduce harvest energy requirements by 33%, while reducing harvest related soil compaction and erosion by 50%[5]. Coupling these harvest strategies with ensiled storage can provide a safe, scalable, and cost-effective year round stover supply. Ensiled storage can also function as low-cost pretreatment for cellulose and hemicellulose hydrolysis[15], increasing biomass value at the farm or co-op storage site. Additional economic gains can be achieved using selected corn varieties with improved genetics for specific stover feedstock applications. With targeted research and demonstration of these new strategies, as well as effective implementation, corn stover biomass appears poised to become the high volume, price-competitive biorefinery feedstock many had hoped.

Integrating the entire feedstock supply system and taking advantage of the complementarities and interoperability between the unit processes can maximize overall system performance. Due to trade-offs among feedstock supply processes, it is important to consider the full feedstock supply system so that opportunities for economic and environmental improvements can be identified and exploited. As with manure, iterative life-cycle assessment and economic analysis of the resulting integrated corn stover feedstock systems will ensure that the strategies developed are both economically rewarding and environmentally sustainable.

Achieving Long Term Sustainability

While manure, corn stover, and other agricultural residues represent immediate opportunities for biomass energy, long term growth of the bioeconomy will require additional feedstocks as well. A number of strategies have been proposed to increase biomass production in both productive and marginal lands, including cover crops, switchgrass and other native warm season grasses, and grass-legume mixes. With new conversion technologies for lignocellulosic biomass, one can even imagine plantings mimicking native prairie being harvested for biomass use. Such dedicated biomass crops offer intriguing opportunities to both increase agricultural productivity while addressing critical sustainability concerns.

Increased use of perennials and cover crops in agricultural systems has a number of environmental advantages. By increasing vegetative cover and root biomass, soil erosion is reduced and soil quality enhanced. Even with removal of most of the surface vegetation for biomass feedstock, the root biomass sequesters carbon to address global warming concerns. Extending the growing season through the use of perennial species also allows plant uptake of nutrients during spring and fall rain events when nutrients would otherwise leach or erode, providing one of the most effective strategies for alleviating water quality concerns.

The Conservation Title of FSRIA 2002 provides a mechanism for encouraging greater use of cover crops and perennial species to conserve our working lands. While this mechanism exists on paper, implementation of the Conservation Security Program has not proceeded as quickly as hoped. The potential synergies with biomass feedstock production provide additional motivation for making sure that this conservation program gets stronger support.

Decentralized Value Chains

Much has been made of the need for biobased production to mimic some of the efficiencies of the well established petrochemical industry in order to compete. The biorefinery concept is certainly part of this, with multiple processes and products taking advantage of every feedstock component and byproduct stream. But biomass production, especially from agriculture, must recognize some unique attributes which argue for a somewhat different strategy than the centralized and concentrated petrochemical approach.

One of the distinct characteristics of biomass as an industrial feedstock is its low energy density relative to fossil fuels, and this is especially true of non-woody plants. As a result, transportation costs to large centralized conversion facilities generate significant diseconomies of scale. Optimum sizing of bio-based facilities thus requires a decentralized infrastructure, with many loci of bioindustrial development.

While a decentralized mode of development has obvious advantages for rural development, it faces particular challenges as well. One of these is the need to generate and tap different types of investment capital than is normally the case. Many of the initial business successes have found new markets for products with unique value and high enough margins to justify capital investment. But as we move toward high volume, relatively low value commodities like energy and transportation fuels, the requirements for capital will increase. Venture capital is scarce in rural communities, and debt markets view unproven business enterprises with understandable concern. As a result, state and federal programs need to help generate the considerable investment capital needed to nurture and grow the bioeconomy and its infrastructure.

Perhaps one of the most critical issues that needs to be addressed as we ramp up the development of biobased businesses is *the business models* for the supply chains. It is critical that the business models be sustainable (economically, socially, and environmentally) over the long term. Like any other economic entity, sustainability means that the every link of the supply chain (including the producer link) receive enough return to pay their fixed and variable costs and some reasonable profit.

The current paradigm for agricultural-based supply chains is for contract production. These contract arrangements typically do not meet the definition of sustainability. In general, the contracts are designed to cover the producer's fixed costs (i.e. , the mortgage payment to the lender), and some part of the variable costs, but provides no level of profit. For producers, this type of "value chain" results in the producer using the equity built in other parts of the business, sometimes over generations, to sustain the viability of the value chain. In essence, the value chain is mining the equity of the producer.

We need to find ways recognize and reward the farmers that are the foundation of bioeconomy value-chains. One proposed solution is for producers to use their equity to vertically integrate up the value chain, as has been done with many of the ethanol plants in the Midwest. However, given the size of the capital investments that will be required for establishing integrated biorefineries, and because of intellectual property protections, it is likely that the "ethanol" model will be rare. So, new types of business relationships need to be evaluated so that the new systems do develop to meet the definition of sustainability.

Some biobased enterprises are finding creative solutions for including farmers in a central role. Partnerships between utilities and farmers are addressing capital and management barriers to expand distributed energy generation from anaerobic digestion. In Oregon, a cluster of dairies now supplies manure to a centralized digester, gaining economies of scale that many individual farmers could not achieve. In Iowa, an industrial lubricants company engages farmers in the initial processing steps, reducing the biomass transportation requirements and shifting processing income to the farm. This partnership is off to an excellent start, already capturing 20% of product market share.

The United States is not alone in considering ways to encourage and reward farmer-based value chains. The European Community is moving ahead aggressively in this area. Denmark alone has over 10,000 straw-fired boilers producing energy on farms, and almost 60 straw-fired district heating plants [16]. These systems are producing local energy from local biomass, and reinvesting in their own communities for local economic development.

A decentralized biobased industry can take advantage of these innovative strategies, and others yet to unfold. But the effort to organize and reward farmer involvement in these value chains is not a trivial task. Management support, technology assistance, and access to capital are all necessary to ensure that the farmer foundation of biomass value chains is durable and strong.

Closing Remarks

I hope these remarks have provided both some insights into present opportunities, as well as the future potential that biomass energy and agriculture share. With strategic partnerships fostering both innovation and implementation, increasingly competitive conversion technologies, and efficient, sustainable feedstock strategies, the emerging bioeconomy has tremendous potential. Nonetheless, there are still many challenges to overcome, and the federal government and this committee will need to play a key role in making that vision real.

As integrated biobased production systems develop, with value chains from farm to biorefinery to consumer, it will be crucial to ensure we achieve both productivity and sustainability. The Energy Title of FSRIA provides several important mechanisms to help us on that path. Synergies with the Conservation Title of FSRIA are particularly important, with the potential to simultaneously address biomass feedstock, carbon sequestration, and water quality concerns. Full funding of the Biomass Research and Development Act of 2000 will help accelerate the trajectory of discovery and innovation that still needs to occur. These and other complimentary federal policies can provide the necessary framework for what may be the most important industrial transformation of the century.

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Testimony Before the Senate Committee on Agriculture, Nutrition, and Forestry
Hearing on Emerging Opportunities for Utilizing Agricultural Biomass to Enhance Future Energy Production and Security
May 6, 2004

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Focus of my remarks. Thank you for the opportunity to offer my perspectives on using agricultural biomass to enhance future energy production and security.

I suggest that the following three points be among those you leave this hearing with:

1. There are foreseeable and realizable solutions to the security and sustainability challenges that we face in the United States, and biomass - particularly cellulosic biomass - has increasingly evident potential to play a major role in such solutions.

2. Widespread energy production from cellulosic biomass could transform American agriculture, providing a potent response to the overcapacity that has undermined the health of rural economies throughout most of the last hundred years.

3. The United States could do much more than it is doing now to enable and accelerate realization of the benefits of biomass energy production. In particular, I believe that an expanded and revised effort could substantially compress the time required for large-scale biomass energy production to be cost-competitive. For example, I consider pilot-scale demonstration of technology that can produce ethanol from cellulosic crops at prices competitive with that of gasoline today on an unsubsidized basis to be a realistic 5-year goal if we are prepared to change the way we do business.

Since my expertise is deepest with respect to points one and three, I will leave it to other speakers to elaborate the very large and important benefits of expanded biomass energy production for American agriculture and the communities that depend on it.

The sustainability and security challenges faced by the United States arise primarily from energy conversion and utilization. Fossil fuel utilization in all sectors is the primary concern from the standpoint of sustainability. Oil utilization, particularly in the transportation sector, is the primary concern with respect to energy security. Among various forms of biomass, cellulosic materials – including perennial grasses, short rotation woody crops, and various agriculture and forest industry residues – have the greatest potential for energy production. Hence my remarks will focus on energy production from cellulosic biomass. I note that the recommendations presented herein have broadly been endorsed by the Energy Future Coalition.

The "Brave New World" of Biomass Energy. My perspective is shaped by over 20 year's experience doing research and analysis pursuant to biomass utilization, and most recently by an in-progress project entitled "The Role of Biomass in America's Energy Future" which I co-lead with Nathanael Greene of the Natural Resources Defense Council and John Sheehan of the National Renewable Energy Laboratory. Technology-related analysis associated with the "RBAEF" project is sponsored by the Department of Energy Office of Energy Efficiency and Renewable Energy. Environmental and policy analysis is supported by the Energy Foundation and the National Commission on Energy Policy. Participating institutions include, in addition to Dartmouth, the NRDC, and NREL include Princeton University, Michigan State University, the University of Tennessee, the Union of Concerned Scientists, Argonne National Laboratory, Oak Ridge National Laboratory, and the USDA Agricultural Research Service. I acknowledge the contributions of my colleagues in the RBAEF project to the remarks that follow, but at the same time take full personal responsibility for the opinions expressed herein.

The RBAEF project seeks to identify and evaluate paths by which biomass can make a large contribution to meeting future demand for energy services, and to determine what can be done to accelerate biomass energy use and in what timeframe associated benefits can be realized. There would appear to be substantial overlap between these goals and those of this hearing. This project is unprecedented with respect to the breadth of technologies considered and the diversity of participants involved - representing the technical, environmental advocacy, and policy communities. Perhaps most importantly, the project is differentiated from prior studies by adopting a "high beam" perspective focusing on mature technology that can reasonably be expected in the future given a concerted effort. I believe that this project is redefining understanding of what is possible with respect to biomass energy production, and that it is appropriate to consider an expanded and revised governmental effort in response to the expanded and revised vision that is emerging from our analysis.

Although the RBAEF project is not yet complete, our results are providing increasing evidence for an exciting set of working hypotheses that I expect will ultimately be supported by our work:

1. *Large increases in the productivity and environmental efficacy of cellulosic energy crops can reasonably be expected to result from an aggressive and sustained R&D effort focused on these goals.* For example, analysis led by Sandy McLaughlin – whose testimony follows mine - anticipates that such an effort would likely double the average productivity (in tons of biomass produced per acre per year) of switchgrass over the next two to three decades. We anticipate that similarly large productivity gains can also be made for other cellulosic crops, although we have not analyzed these in detail.

2. *Very large increases in the cost-competitiveness and efficiency of technology for biomass conversion can reasonably be expected to result from an aggressive and sustained R&D effort focused on these goals.* The RBAEF project is analyzing industrial facilities incorporating foreseeable R&D-driven advances that process cellulosic biomass to a mix of light duty and heavy duty fuels with co-production of commodity chemicals, just as oil refineries do today. Along with these products, future processes based on cellulosic biomass can be configured to also co-produce significant quantities of animal feed and electrical power. The potential for high overall process efficiency and simultaneous contributions to energy and other needs in multiple sectors becomes much more apparent when mature technology is considered.

Because cellulosic biomass at a price of $50/tonne is equivalent on an energy basis to oil at ~$14/barrel, biomass is a more than cost-competitive raw material compared to petroleum. Thus the key challenge is to reduce processing costs. I am confident that processing technologies can be developed with a concerted effort that can produce on a large scale fuels, power, and coproducts at competitive prices, and that this can be achieved in much shorter timeframes than currently forecast via an expanded and effective governmental R&D program. I also expect that the RBAEF project will lend more detailed support for this view than has hitherto been available.

3. *Analysis underway as part of the RBAEF project supports the proposition that an amount of fuel sufficient to provide for current levels of vehicular mobility in the United States could be produced from biomass, and that this could be accomplished within the existing agricultural land base while dramatically increasing the value contributed to the overall economy from the agricultural sector.* RBAEF scenarios with this outcome involve high productivity cellulosic energy crops, a high-efficiency vehicle fleet, advanced conversion technology, and integration of feedstock production into existing agricultural operations. In short, these scenarios require both innovation and change, as do all paths to a sustainable and secure energy future whether based on biomass or other resources. We would do well to remind ourselves that it is fruitless to look for paths to a sustainable and secure energy future by extrapolating trends associated with our non-sustainable and insecure present.

4. *Overall, the RBAEF project has identified to date some very large environmental benefits accompanying greatly expanded biomass energy production, and no environmental show-stoppers.* Environmental consequences associated with scenarios in which biomass plays a large energy supply role are being critically evaluated as part of the RBAEF project by the Natural Resources Defense Council, the Union of Concerned Scientists, Argonne National Laboratory, and other members of the project team. Some conclusions are already quite clear, while other issues are still under investigation. Prominent in the former category is the observation that production and utilization of fuel and power derived from cellulosic crops such as switchgrass involves near-zero net emissions of greenhouse gases, and large contributions of carbon to the soil. Such near-zero or negative emissions are a direct result of the decidedly favorable process energy balance accompanying energy production from cellulosic biomass, particularly for mature technology. The propensity of switchgrass to increase soil carbon gives rise to major benefits in terms of soil fertility, as well as potential carbon sequestration, which do not diminish under intensive harvest.

In light of these considerations, I believe that fuel produced from cellulosic biomass is a legitimate option as a primary energy carrier for the U.S. transportation sector for the indefinite future. Let me be clear that I am not talking about biomass being limited to a bit player, and I am not talking about an intermediate option that will play a necessarily transient role on the way to some other ultimate solution. Consistent with these sentiments, and based on the RBAEF analysis, the NRDC and UCS – both long-time supporters of the hydrogen economy – issued a statement in February that: "Cellulosic ethanol is at least as likely as hydrogen to be an energy carrier of choice for a sustainable transportation sector."

We could do much more than we are doing now. Sustainability and security are poorly reflected in market prices, the market provides only limited incentive to overcome obstacles associated with first-of-a-kind technology, and reinvestment of profits from a nascent cellulose processing industry will result in but a small flow of funding for innovation-focused R&D during the critical early growth phase. For all these reasons, and regardless of one's political leanings, it is appropriate that the government play an active role in enabling and advancing biomass energy production. In particular, it is very likely that the growth of biomass energy will be much more rapid with substantial and well-directed governmental support than without it.

How well is the government doing at providing the needed support?

Let us assume for a moment that sustainability and security challenges are deemed important to respond to, and that biomass could play a very important part in such a response, as I have argued. When viewed from these premises, the effort the United States is expending to enable and accelerate biomass energy production is far short of what it should be. The modest size of current R&D investment in biomass energy lowers the rate of progress compared to what it could be, prevents alternative technological approaches from being pursued in a parallel fashion, and is a significant impediment to aggressively pursuing both innovation and pioneer plant deployment at the same time. Moreover, the trends are not encouraging. Funding after earmarks for biomass R&D by the DOE has declined yearly for the last several years and the world's leading research program on cellulosic feedstocks, coordinated by Oak Ridge National Laboratory, has been discontinued. The creative potential of the U.S. research community is not being brought to bear on problems relevant to biomass energy as effectively as it could be, in part because of highly specified research solicitations, little funding for work at the intersection of applications and fundamentals, and discontinuities in the amount and focus of research funding. As one illustration of this, compare the extent of engagement of the U.S. research community in R&D related to health care as compared to sustainable energy production. John Holdren, former Chair of the Energy R&D Panel of the President's Council of Advisors on Science and Technology, noted in *Science* in 2001:

> Current levels of public and private investment in energy R&D and demonstration are not remotely commensurate with the long-term challenges and opportunities, either in the United States or any other country. U.S. federal expenditures on applied energy technology R&D are about what they were, in real terms, just before the oil price shock of 1973-1974, although the country's economy is more than twice as large. U.S. private sector investments in energy R&D have been falling since the mid-1980s.

Legislation has been enacted to accelerate R&D-driven progress in biomass conversion technology and to more fully engage the academic research community but with limited success. A case in point is Senate Bill S.935, introduced as the "National Sustainable Fuels and Chemicals Act" in April of 1999 by Senate Lugar (R-IN) when he was Agriculture Committee Chairman Richard Lugar (R-IN) (see inset "S.935 – a cautionary tale").

Simply put, we are not acting as if we have a lot at stake and an important solution at hand.

What might we do differently if we were to mount a more aggressive effort in the biomass energy area? In brief, I suggest:

a. Increase by several-fold the amount of funding for biomass energy R&D, with clearly demarcated support for both precommercial research devoted to innovation and applied fundamentalsp as well as cost sharing for first-of-a-kind pioneer plants. The amounts required are small on any reasonable scale and insignificant relative to both the overall national budget and the potential benefits that could be realized. Consider: Tripling funding for bioenergy R&D would cost about $500 million annually. The cumulative cost of a focused R&D effort to develop technology for producing cellulosic ethanol at a cost competitive with gasoline has been estimated at less than one year's expenditure associated with the current ethanol tax incentive*, and pales in comparison to funding for health care, space exploration, or other efforts directed at achieving meaningful goals in short timeframes.

b. Commit to pursuing increased biomass energy production in ways that expand opportunities for farmers, and that realize sustainability, security and environmental benefits. It is important that these features characterize both periods of transition as well as targeted end-points.

c. Allocate research funds among technical topics and evaluate proposals in a way that is responsive to potential for sustainability and security benefits, reliant to a significant extent on open solicitations, and based on technical merit. High priority should be placed on fundamentals-inclusive and innovation-focused work related to overcoming the recalcitrance of cellulosic biomass by a variety of approaches, and to development of energy crops and cropping systems that maximize productivity and environmental efficacy. Open solicitations with evaluation based on potential to advance biomass energy technology as judged by peer-reviewed technical merit would significantly increase the effectiveness with which America's research community is engaged. If we are serious about realizing the potential of biomass energy for the national interest in the most productive and cost effective way, extensive earmarking needs to be curtailed.

Much can be done within legislative mechanisms that are already in place. For example, by adding new funding authorized by the Biomass Research and Development Act to funding levels of preexisting programs, and by fully funding the biorefinery development grants portion of the Farm Bill.

Mr. Chairman and distinguished committee members, as current events make clearer the urgent need for sustainable and secure energy sources and as analyses such as the RBAEF project make clearer the potential of biomass to serve these needs in a meaningful way, the case for business as usual in the biomass energy arena becomes progressively more weak. I urge your committee and the U.S. Congress to take decisive action.

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* "Report to the President of the Interagency Steering Committee on the Outcome of the Deliberations of the Policy Dialogue Advisory Committee to Assist in the Development of Measures to Significantly Reduce Greenhouse Gas Emissions from Personal Vehicles," (1996). The White House,

S.935. A cautionary tale. Senator Lugar's explicit goal in proposing S.935 was to establish an intensive and focused R&D program, national in scope, to reduce processing costs for producing fuels, chemicals, and electricity from biomass to the point that these technologies become cost-competitive with conventional fossil resources. The legislation identified fundamentals-inclusive, innovation-targeted research as the sole viable means of addressing the technological challenges of biomass conversion and use. National laboratories, universities and industry were eligible to compete for grants, although emphasis was given for partnership efforts led by universities. After being renamed the "Biomass Research and Development Act", S.935 was signed into law by President Clinton in June of 2000 as part of the Crop Insurance Bill. The Act authorized $49 million/year over a five year period.

The story of what happened to this $49 million authorization is reminiscent of the progress of the Colorado River on its way to the Pacific Ocean in the face of demands for irrigation. Although $49 million per year was authorized, only $18 million per year was appropriated in the 2000 (H.R. 2605), 2001 (H.R. 4635), and 2002 (H.R. 2311) fiscal years. Moreover, the appropriation language directed that funding be derived from existing power and transportation programs. Thus what was intended to add a major influx of new funding in fact largely resulted in putting a new name on already allocated funds within programs that had only modest growth in gross funding. Whereas S.935 as originally proposed featured awards based on technical merit as determined by peer review, the lion's share of funding has in fact been claimed by earmarks. In the fiscal year ending September 2001, all but approximately $2 million of the intended $18 million was absorbed by Congressional earmarks. What starts as a strong river of funding is reduced to a trickle as a result of Congress' failure to match appropriations with authorization and the excessive use of earmarks.

This text is taken from Lynd, L.R., H. Jin, J.G. Michels, C.E. Wyman, and B. Dale. 2003. Bioenergy: Background, potential, and policy. Center for Strategic and International Studies, Washington, DC. http://www.csis.org/tech/Biotech/. One of the authors of this paper is Joe Michels, a former member of Senator Lugar's staff who had day-to-day responsibility for S.935.

Written Testimony for Hearings by The United States Senate

Committee on Agriculture, Nutrition, and Forestry

May 6, 2004

Biomass Use in Future Energy Production: Demonstration and Commercial Application for Agricultural Bioproducts and Cellulosic Biomass Use

Testimony of:

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Summary Points:

- Cellulosic biomass produced on American farms can contribute significantly to the nation's energy self sufficiency and to both its economic and ecological health.

- The American farmer and the American consumer should both benefit economically from increased reliance on biomass derived fuels

- The costs of biomass - derived fuels to society both now and in the future are likely to be much lower than costs of fossil-derived fuels.

- A focus on the biomass utilization that minimizes net usage of imported energy, maximizes net reduction in greenhouse gas emissions, and gives credit for reduction in societal costs of energy production would accelerate near term incorporation of cellulosic biomass into a US energy strategy.

Thank you Mr. Chairman and the members of this committee for the opportunity to speak before you today. The research and production issues related to the use of cellulosic biomass for bioenergy production have been a major focus of my work at Oak Ridge National Laboratory(ORNL) for the past 12 years as a member of the Bioenergy Feedstock Development Program. The Department of Energy (DOE) supported this work at ORNL for more than 24 years. Its purpose was to identify and develop bioenergy crops and to evaluate their potential to contribute to biomass energy and bioproducts for national needs. I can tell you that there is tremendous enthusiasm among both researchers and farmers for the opportunity to utilize economically viable bioenergy crops and to contribute in a significant way to this nation's energy needs and its energy security.

Today I will share with you some of what we have learned about production and economic potential of a model bioenergy crop, switchgrass, a highly productive and resource-efficient perennial grass native to the Eastern two-thirds of the country. Switchgrass is a cellulosic feedstock that was selected to be grown as a dedicated bioenergy crop in the immediate vicinity of industry that would use it for bioenergy or bioproducts. This distinguishes it from other types of cellulosic feedstocks such as forestry and mill residues, urban wood wastes, and agricultural residues for which feedstock availability is linked to the distribution and intensity of the industries that produce these waste streams.

As this nation implements strategies to improve its energy self sufficiency we will need to use many types of feedstocks and deploy many types of technologies to displace significant amounts of fossil fuels and to reduce emissions of greenhouse gases that they produce. In this process it would seem that several criteria would help guide the direction in which we proceed and measure the efficacy of our efforts. Below are some criteria which may prove useful. I will use them in following sections to measure progress that our research suggests can be made using switchgrass as a test case.

Some Criteria/questions for Evaluating the Bionergy Production Potential of Energy Crops:

1. What is the net fossil energy displacement potential per unit of land area used to produce the crop?

2. What is the net reduction in greenhouse gas emissions associated with energy produced through using the crop as a feedstock?
3. Are the economic benefits of producing the crops sufficient to attract growers at prices that industry is willing to pay?
4. Is production agriculture for the crop compatible with existing agricultural practices across a broad region?
5. Are there ecological benefits that make the crop valuable to land management systems at a local and regional level?
6. Are there secondary products that can be derived from the feedstock to improve its production/conversion economics?
7. What are the net societal values of incorporating the energy crop production into the national energy and agricultural production strategy?

While questions 1, 2 and 7 are the most critical measures of meeting the need to reduce the level of our dependency on fossil fuels, questions 3-6 address characteristics that determine whether a crop is even viable as a candidate for bioenergy production. The landowner/producer is a key player in cellulosic crop production and ecological and economic compatibility with existing farming practices is a prerequisite for widespread acceptance of a crop by the farming community.

Switchgrass was chosen as a model crop based on preliminary research that showed it to produce very high yields (5-10 tons/acre) with low requirements for both water and fertilization. Because it is a perennial forage species that can produced and harvested like a hay crop, the management intensity and energy requirements for producing switchgrass are low and the equipment to plant and harvest it is already widely available. There are currently 60 million acres of hay, 14% of total US cropland, produced in the US and much of the same equipment can be used to harvest switchgrass. Switchgrass is in fact an excellent forage species for cattle and its relatively high leaf protein content is leading to its being considered as a source of animal feed protein.

From a land management perspective, switchgrass has an extremely deep and active root system which anchors the soil against erosion losses while adding approximately one ton of carbon per year to the soil profile. Soil carbon is extremely important to soil stability, soil quality, and retention and supply of nutrients through root turnover. In many cases we find that the total root mass maintained by switchgrass is equivalent to the annual aboveground biomass harvested for forage or energy. Growing switchgrass will be most favorable to eroded croplands where decades of annual crop production has often reduced soil organic matter by as much as 25%. Under these conditions growing deep-rooted perennial species like switchgrass can help restore soil fertility and the capacity for soils to hold and supply water and nutrients. For this reason switchgrass is among the preferred species planted in the Conservation Reserve Program to protect and restore the productivity of our nations agricultural lands. Approximately 30 million acres, 7% of this nation's crops land is in this program.

When ORNL/BFDP began intensive research on switchgrass in 1992, we were able to build on decades of research on this species based on its value as a forage grass (see review by Moser et al, 1995). Evaluation of biofuels potential however entails somewhat different criteria than management for forage production. From, 1992 until 2002, significant progress was made in characterizing the breeding biology of switchgrass, developing new cultivars for energy production, and defining management strategy and costs, ecological benefits, and the potential for biotechnology applications.

Research on switchgrass production biology, ecology, and management potential to date has reinforced early projections that this species could play an important role as an energy crop. However, since deployment of energy crops in this country has been very slow, we have had to rely on models to project what we know to the larger scale where production economics and competitiveness with other crops are critical features. An enormously useful tool in this regard has been POLYSYS, a regional econometric model developed jointly be a team of scientists at ORNL/BFDP, the US Department of Agriculture, and the University of Tennessee (Ugarte et al., 2003). POLYSYS is an agricultural policy simulation model of the US agricultural sector that considers national demand for crops, their regional supply and established prices, and their potential impact on farm income. Thus POLYSYS can be used to characterize regional production amounts and the impact of crop introduction or alterations on the agricultural economy.

Since large scale markets for bioenergy crops like switchgrass do not presently exist, POLYSYS, allows one to use what we know about production costs of any energy crop to ask how profitable and hence how competitive it would be at various entry prices into agricultural markets – Would it be grown and where and what would the impacts on agricultural markets and farm income be at various entry prices?

Initial simulations with POLYSYS were directed towards comparisons among three leading energy crop candidates: switchgrass and two short rotation woody crops, hybrid poplar and willow. Results indicated that at present production costs, switchgrass would be the most economically competitive of these energy crops on 99% of available crop lands when maximum production potential was sought. A summary of the acreage of cropland and CRP land projected to convert to switchgrass, average yields on those lands, and impacts on the agricultural economy at three prices are shown in Table 1.

Table 1. Projected production characteristics for land planted to switchgrass as a function of prices offered to farmers at the farm gate.[1]

	Production Characteristics		
Farmgate price ($ per ton)	27.58	40.04	47.65
Area planted (millions of acres)	7.62	21.3	52.4
Average yield (tons per acre)	4.88	4.14	3.96

[1]From McLaughlin et al., 2002.

In addition, POLYSYS, because it is linked to agricultural policy options, including government price supports for crop prices or land allocation to CRP, simulations can provide perspectives on changes in both government support of agriculture as well as prices of other crops and, most importantly, changes in net income to farmers. A summary of these parameters for the same three switchgrass prices included in Table 1 is provided in Table 2 below.

Table 2. Projected changes in farm income and government costs at three farmgate prices for switchgrass produced as an energy grop.[1]

	Farmgate price ($ per ton)		
	27.8	40.04	47.65
	Economic Benefits ($ millions)		
Increased Farm Revenue			
From switchgrass	150	2272	4437
From other crops	1161	3653	3312
Total Revenues	1311	5925	7745
Reduced Government Subsidies	1253	4035	5770
	Total Economic Benefits ($ Billions)		
	2.5	9.9	13.5

[1]See McLaughlin et al. 2002 for a more complete cost accounting.

Table 2 represents a simplification of total societal costs and benefits, which are projected to include both increased prices for crops displaced by switchgrass and reductions in the very substantial societal costs that stem from use of fossil fuels. However the data shown here indicate that substantial acreages of switchgrass would be expected to be produced at these prices and that the level of production can be greatly influenced by rather small increases in farm gate prices. For example, the price shift from $40 to $47 per ton as shown above would increase projected acreage planted to switchgrass by over 30 million acres.

To produce large acreages of switchgrass a given price is meaningless however if the associated price of switchgrass isn't competitive with the fossil fuels it is intended to supplant. McLaughlin et al.(2002) have compared the price of switchgrass as both a fuel to the energy industry and as an energy provider to society. The former considers only the energy contained in the feedstock, while the latter includes secondary market values, such as reductions in greenhouse gases (valued at $25 per ton of carbon emissions reduction), increased farm income, and reduced levels of government subsidies needed to support farm income. Even without including major components of societal value such as reduced health effects and economic impacts of oil price shocks, McLaughlin et al (2002) found that societal costs of energy derived from switchgrass would be well below current prices paid for both oil and natural gas.

In fact society does not now do a full cost accounting of its energy supplies and new energy sources must compete with fossil fuels on a very uneven playing field, which includes substantial subsidies to the fossil fuel industry. One must ask " how effective could government policy be in helping promote more equitable valuation of US energy options?" As a case in point McLaughlin et al. (2002) calculated that a very modest price support of $10 per ton value at the $27/ton production level would cost $1.58 billion annually and provide an annual increase in farm income of about $4.7 billion: a benefit:cost ration of about 3:1. Projected reductions in government subsidies not required as a result increased farm income could totally pay for this infusion of funds into the farm economy.

At present corn ethanol is the major source of transportation fuels derived from renewable energy in the US. Despite the relatively high energy costs of producing corn ethanol, it has been responsible for an extremely important beginning in the production of renewable energy from biomass and should continue to play an important role. In the mean time highly efficient cellulosic feedstock such as switchgrass coupled with corn offer a way of substantially improving the net energy returns and the rate of reduction of greenhouse gas emissions per unit of land and per unit of cost in resources. In addition the inclusion of perennial crops like switchgrass in the feedstock supply structure will allow a much more regionally distributed cross section of farmers to participate in this nation's search for improved energy self sufficiency. This includes notably depressed farm economies in the eastern US, where corn is much less important than in the Mid-west.

It is hoped that the vital role of the American farmer will be promoted and recognized as a vital part of the energy supply industry and that the farm community can share fully in the economic benefits that will be associated with its efforts. What is vitally needed is a strategy to bring these and other renewable feedstocks into to the nation's energy supply structure so that the benefits to society at local, regional, and global scales can be realized. I thank the committee again for allowing me to share these thoughts with you.

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DOCUMENTS SUBMITTED FOR THE RECORD

MAY 6, 2004

"The New Petroleum"

By Richard G. Lugar and R. James Woolsey
Foreign Affairs, January/February 1999

WHY CHANGE?

Oil is a magnet for conflict. The problem is simple – everyone needs energy, but the sources of the world's transportation fuel are concentrated in relatively few countries. Well over two-thirds of the world's remaining oil reserves lie in the Middle East (including the Caspian basin), leaving the rest of the world dependent on the region's collection of predators and vulnerable autocrats. This unwelcome dependence keeps U.S. military forces tied to the Persian Gulf, forces foreign policy compromises, and sinks many developing nations into staggering debt as they struggle to pay for expensive dollar-denominated oil with lower priced commodities and agricultural products. In addition, oil causes environmental conflict. The possibility that greenhouse gases will lead to catastrophic climate change is substantially increased by the 40 million barrels of oil burned every day by vehicles.

Ethanol has always provided an alternative to gasoline. In terms of environmental impact and fuel efficiency, its advantages over gasoline substantially outweigh its few disadvantages. But until now it has only been practical to produce ethanol from a tiny portion of plant life – the edible parts of corn or other feed grains. Corn prices have fluctuated around $100 a ton in the last few years, ranging from half to double that amount. Ethanol has thus been too expensive to represent anything but a small, subsidized niche of the transportation fuel market. In spite of recent reductions in the expense of ethanol processing, the final product still costs roughly $1.50 a gallon, or about double today's wholesale price of gasoline.

Recent and prospective breakthroughs in genetic engineering and processing, however, are radically changing the viability of ethanol as a transportation fuel. New biocatalysts – genetically engineered enzymes, yeasts, and bacteria – are making it possible to use virtually any plant or plant product (known as cellulosic biomass) to produce ethanol. This may decisively reduce cost – to the point where petroleum products would face vigorous competition.

The best analogy to this potential cost reduction is the cracking of the petroleum molecule in the early twentieth century. This let an increasingly large share of petroleum be used in producing high-performance gasoline, thus reducing waste and lowering cost enough that gasoline could fuel this century's automotive revolution. Genetically engineered biocatalysts and new processing techniques can similarly make it possible to utilize most plant matter, rather than a tiny fraction thereof, as fuel. Cellulosic biomass is extremely plentiful. As it comes to be used to produce competitively priced ethanol, it will democratize the world's fuel market. If the hundreds of billions of dollars that now flow into a few coffers in a few nations were to flow instead to the millions of people who till the world's fields, most countries would see substantial national security, economic, and environmental benefits.

PAYING FOR ROGUES

Energy is vital to a country's security and material well-being. A state unable to provide its people with adequate energy supplies or desiring added leverage over other people often resorts to force. Consider Saddam Hussein's 1990 invasion of Kuwait, driven by his desire to control more of the world's oil reserves, and the international response to this threat. The underlying goal of the U.N. force, which included 500,000 American troops, was to ensure continued and unfettered access to petroleum.

Oil permeates every aspect of our lives, so even minor price increases have devastating impacts. The most difficult challenge for planners, policymakers, and alternative-energy advocates is the transportation sector, which accounts for over 60 percent of U.S. oil demand. The massive infrastructure developed to support gasoline-powered cars is particularly resistant to modifications. It precludes rapid change to alternative transportation systems and makes America highly vulnerable to a break in oil supplies. During a war or embargo, moving quickly to mass transit or to fuel-cell or battery-powered automobiles would be impossible.

For most countries, excluding only those few that will be the next century's oil suppliers, the future portends growing indebtedness, driven by increasingly expensive oil imports. New demand for oil will be filled largely by the Middle East, meaning a transfer of more than $1 trillion over the next 15 years to the unstable states of the Persian Gulf alone – on top of the $90 billion they received in 1996.

Dependence on the Middle East entails the risk of a repeat of the international crises of 1973, 1979, and 1998 – or worse. This growing reliance on Middle Eastern oil not only adds to that region's disproportionate leverage but also provides the resources with which rogue nations support international terrorism and develop weapons of mass destruction and the ballistic missiles to carry them. Iraqi vx nerve gas and Iranian medium-range missiles show how such regimes can convert oil revenues into extensive and sophisticated armament programs.

IS OIL RUNNING OUT?

Optimists about world oil reserves, such as the Department of Energy, are getting increasingly lonely. The International Energy Agency now says that world production outside the Middle Eastern Organization of Petroleum Exporting Countries (OPEC) will peak in 1999 and world production overall will peak between 2010 and 2020. Influential recent articles in *Science* and *Scientific American* support this projection. Some knowledgeable academic and industry voices put the date that world production will peak even sooner – within the next five or six years.

The optimists who project large reserve quantities of over one trillion barrels tend to base their numbers on one of three things: inclusion of heavy oil and tar sands, the exploitation of which will entail huge economic and environmental costs; puffery by OPEC nations lobbying for higher production quotas within the cartel; or assumptions about new drilling technologies that may accelerate production but are unlikely to expand reserves.

Once production peaks, even though exhaustion of world reserves will still be many years away, prices will begin to rise sharply. This trend will be exacerbated by increased demand in the developing world. As Daniel Yergin, Dennis Eklof, and Jefferson Edwards pointed out in these pages ("Fueling Asia's Recovery," March/April 1998), even assuming a substantial recession, increased Asian needs alone will add enough demand by 2010 (9 million barrels per day) to more than equal Saudi Arabia's current daily production.

The nations of the Middle East will be ready to exploit the trend of rising demand and shrinking supply. The Gulf states control nearly two-thirds of the world's reserves; the states bordering the Caspian Sea have another several percent. Barring some unforeseen discoveries, the Middle East will control something approaching three-quarters of the world's oil in the coming century.

A WHOLE NEW WORLD

If genetically engineered biocatalysts and advanced processing technologies can make a transition from fossil fuels to biofuels affordable, the world's security picture could be different in many ways. It would be impossible to form a cartel that would control the production, manufacturing, and marketing of ethanol fuel. U.S. diplomacy and policies in the Middle East could be guided more by a respect for democracy than by a need to protect oil supplies and accommodate oil-producing regimes. Our intrusive military presence in the region could be reduced, both ameliorating anti-American tensions and making U.S. involvement in a Middle Eastern war less likely. Other states would also reap benefits. Ukraine, rich in fertile land, would be less likely to be dominated over time by oil-rich Russia. China would feel less pressure to befriend Iran and Iraq or build a big navy to secure the oil of the South China Sea. The ability of oil-exporting countries to shape events would be increasingly limited.

The recent report by the President's Committee of Advisers on Science and Technology (PCAST) predicted that U.S. oil imports will approximately double between 1996 and 2030, from 8.5 million barrels per day, at a cost of $64 billion, to nearly 16 million barrels per day, at a cost of $120 billion. They estimated, however, that with concentrated efforts in fundamental energy research and investment in renewable fuel technologies, this could be reduced to 6 million barrels per day in 2030. The report concluded,

"A plausible argument can be made that the security of the United States is at least as likely to be imperiled in the first half of the next century by the consequences of inadequacies in the energy options available to the world as by inadequacies in the capabilities of U.S. weapons systems. It is striking that the Federal government spends about 20 times more R&D money on the latter problem than on the former."

FUEL FARMERS

Cellulosic ethanol would radically improve the outlook for rural areas all over the world. Farmers could produce a cash crop by simply collecting agricultural wastes or harvesting grasses or crops natural to their region. Agricultural nations with little to no petroleum reserves would begin to see economic stability and prosperity as they steadily reduced massive payments for oil imports. Even more striking would be the redistribution of resources that would occur if farmers and foresters produced much of the world's transportation fuel. We know from the positive results of micro-credit institutions and other such programs that even small increases in income can be a major boost to a subsistence-level family's prospects. If family income is a few hundred dollars a year, earning an extra $50-$100 by gathering and selling agricultural residues to a cellulosic ethanol plant could mean a much improved life. Such added income can buy a few used sewing machines to start a business or a few animals to breed and sell. It can begin to replace despondency with hope.

There are likely to be even larger effects on rural development if biomass ethanol production can lead a shift toward using plant matter for other products as well, such as biochemicals and electrical energy. The cleanliness of renewable fuel technologies makes them particularly attractive to countries that lack a sophisticated infrastructure or network of regulatory controls. At least some facilities that process carbohydrates should lend themselves to being simplified and sized to meet the needs of remote communities. If such towns can produce their own fuel, some of their fertilizers, and electricity, they will be far better positioned to make their way out of poverty and to move toward democracy and free enterprise. Local economic development can promote political stability and security where poverty now produces hopelessness and conflict.

A major strength of the new technologies for fermenting cellulosic biomass is the prospect that almost any type of plant, tree, or agricultural waste can be used as a source of fuel. This high degree of flexibility allows for the use of local crops that will enrich the soil, prevent erosion, and improve local environmental conditions.

Finally, as recession and devaluations overseas move the American balance-of-payments deficit from the 1998 level – $1 billion every two days – toward nearly $1 billion every day, there will be increased calls for protectionism. The best way to avoid the mistakes of the 1930s is to have a solid economic reason for increasing U.S. production of commodities now bought abroad. The nearly $70 billion spent annually for imported oil represents about 40 percent of the current U.S. trade deficit, and every $1 billion of oil imports that is replaced by domestically produced ethanol creates 10,000-20,000 American jobs.

EASY BEING GREEN

To be politically and economically acceptable, changes in fuel must be understood by the American public to be affordable and not disruptive. Most other countries require the same tough criteria – U.S. difficulties in convincing developing nations to reduce greenhouse gas emissions are directly related to the cost and the damage this would have on their development plans. But if one of the most effective ways to reduce greenhouse emissions also produced an improved balance-of-payments deficit and opportunities for rural development, economic benefits would suddenly far exceed the costs. The political acceptability of reducing emissions changes substantially when the economics change. A shift to biomass fuels stands out as an excellent way to introduce an environmentally friendly energy technology that has a chance of both enjoying widespread political and economic support and having a decisive impact on the risk of climate change.

Renewable fuels produced from plants are an outstanding way to substantially reduce greenhouse gases. Although burning ethanol releases carbon dioxide into the atmosphere, it is essentially the same carbon dioxide that was fixed by photosynthesis when the plants grew. Burning fossil fuels, on the other hand, releases carbon dioxide that otherwise would have stayed trapped beneath the earth.

If one looks at the complete life cycle of the production and use of ethanol derived from feed grains, the only addition of carbon dioxide to the atmosphere results from the use of fossil fuel products in planting, chemical fertilizing, harvesting, and processing. But this fossil fuel use can be substantial – up to seven gallons of oil may be needed to produce eight gallons of ethanol. When ethanol is produced from cellulosic biomass, however, relatively little tilling or cultivation is required, reducing the energy inputs. It takes only about one gallon of oil to produce seven of ethanol. There is a virtual consensus among scientists: when considered as part of a complete cycle of growth, fermentation, and combustion, the use of cellulosic ethanol as a fuel, once optimized, will contribute essentially no net carbon dioxide to the atmosphere.

According to a 1997 study done by five laboratories of the U.S. Department of Energy, a vehicle powered by biomass ethanol emits well under one percent of the carbon dioxide emitted by one powered by gasoline. More surprising, however, is that ethanol produced from biomass emits only about one percent of the carbon dioxide emitted by battery-powered vehicles, since the electricity for those is commonly produced by burning fossil fuels at another location. Although local air quality is improved, total carbon dioxide emissions are not curtailed; they are merely exported – for example, from Los Angeles to the Four Corners. Unless the electricity to charge the car's batteries is produced by renewable fuels or nuclear power, electric vehicles are only 20 to 40 percent better as carbon dioxide emitters than gasoline-powered cars. Biomass ethanol beats both by a factor of about 100, fundamentally changing the global-warming debate.

FRINGE BENEFITS

Cellulosic ethanol is the only alternative fuel that requires, at most, very modest changes to vehicles and the transportation infrastructure. One need not spend money retooling Detroit, nor spend years awaiting the gradual replacement of older vehicles by those with new technology. Nor does one need to modify or construct pipelines and storage tanks to hold hydrogen as an alternate to petroleum. This compatibility with today's infrastructure saves billions of dollars and not just years, but decades. Moreover, there is nothing incompatible between using ethanol now in internal combustion engines and using it later in more efficient power systems, such as hybrids or fuel cells.

Essentially all automobiles currently on the road can use fuel containing up to ten percent ethanol. But strict fuel economy standards have encouraged the development and production of flexible fuel vehicles (FFVs) that can use up to 85 percent ethanol. FFVs are already in dealers' showrooms, containing (at no added cost to the consumer) the minor engine modifications – a computer chip in the fuel system and a fuel line made out of slightly different material – that make large-scale ethanol use possible. Even pure ethanol vehicles are quite practical. Brazil has 3.6 million on the road.

Corn ethanol will continue to serve an important role as ethanol production shifts to cellulosic biomass. Commercialization of corn ethanol has provided a base of industrial experience, talented people, and infrastructure from which a much larger cellulosic ethanol industry may be launched. For corn farmers, biomass is no threat; it will probably be a boon. Indeed, there is likely to be a continuing, perhaps even an expanding, market for corn ethanol because of the value of its byproducts, such as animal feed. In general, the transition from corn to cellulosic biomass and from a few producers to many is likely to expand opportunities for American farmers.

BIOENGINEERED BUGS

Ethanol's economic viability depends on making it cheaper to produce. This can be achieved by making it out of cellulosic biomass, which includes essentially anything that grows or has grown: agricultural and forest residues, prairie grass, kudzu, waste wood, used paper products, even much of urban waste. Last year, about 95 percent of the ethanol produced in the United States came from corn. But agricultural residues and other wastes have low or even negative cost – some you are paid to haul away – while crops like prairie grass cost only a few tens of dollars a ton. This represents a substantial savings in the raw material used in ethanol and puts it within the range of oil, even inexpensive Persian Gulf oil.

Only recently have scientists developed the means to convert cellulosic biomass efficiently into ethanol. The edible portions of corn and other grains easily ferment into ethanol because of their chemical make-up. Most biomass, however, consists of more recalcitrant hemicellulose and cellulose, requiring both the breaking up of these two fibers as well as the fermenting of both five- and six-carbon sugars. This all happens in nature, but two parts of it – fermenting five-carbon sugars and breaking up cellulose quickly – are technically challenging. The first is now done by genetically engineered microorganisms; this tool and other new techniques are now being brought to bear on the second problem.

How far along are these developments? The current efficiency of ethanol processing is somewhat analogous to that of petroleum refining in the early 1900s: after the invention of thermal cracking made it possible to use a major share of the petroleum molecule for gasoline production but before the invention of catalytic cracking opened up an even larger share of petroleum to exploitation. In short, we have come a long way, but still have some inventing to do. The new, genetically engineered microorganisms have already taken us far toward the fermentation of ethanol from a wide range of plant material, laying the groundwork for reductions in processing costs as well.

The new microorganisms, combined with other improvements in processing, fundamentally change the equation for considering ethanol a major transportation fuel. According to a recent study by Dartmouth engineering professor Lee Lynd, utilizing only some of the nation's agricultural and forest residues, with no additional land use, could supply over 15 billion gallons of ethanol a year – more than ten times the amount now produced from corn, and enough to replace around eight percent of the nation's gasoline. (Not all residues would be used, of course, since some must be left for long-term fertility.) Lynd also calculated that taking a little over half of the 60 million acres of cropland historically idled by federal programs for conservation and other purposes, and using for ethanol production the mown grasses with which much of this acreage is ordinarily planted, would produce enough ethanol to fulfill around 25 percent of the country's annual gasoline needs. These calculations use current automobile mileage. Lynd notes that further mileage improvements, achieved through a shift to hybrids or fuel cells, could obviate the need for gasoline entirely, without taking land from food crops or nonagricultural uses. The coproduction of animal feed and biomass residues from alfalfa and switchgrass is especially promising. There is, in short, no basis for the argument that America does not have the land to produce enough ethanol to make a very large dent in U.S. gasoline consumption.

Biofuels must be produced in ways that enhance overall environmental quality. Sound land-use policies certainly must be followed, to protect wildlife habitat and address other environmental concerns. But professional land-use techniques should readily accomplish this. Alternative fuels are often seen as an unpalatable necessity representing a retrenched standard of living, forced upon us in an age of limits. The opposite may be true. Utilization of renewable fuels will make it possible for us to continue enjoying the freedom afforded by private cars, even as the production of petroleum begins to decline.

THE RIGHT STUFF?

Early this century, Henry Ford expected that ethanol, not gasoline, would be the fuel of choice for automobiles. His reasons are evident. The two fuels can be compared by examining three basic parameters – energy content, octane, and vapor pressure. Pure ethanol contains 69 percent of the energy of gasoline. A lower energy content translates into fewer miles to the gallon; in order to travel the same range, about a 30 percent larger fuel tank is needed (as is used in Brazil). Many scientists believe that optimizing engines for ethanol use will largely compensate for this difference, in part because ethanol is a simple combination of carbon, hydrogen, and oxygen. It is vastly less complex than gasoline, which means that fine-tuning an engine to squeeze every last drop of energy from ethanol is potentially easier.

Octane is the measure of a fuel's ability to oxidize hydrogen and carbon molecules within a fraction of a second. When the reaction is not simultaneous, "engine knock" and inefficient combustion result. Ethanol has an octane rating 15 percent higher than gasoline's. In the 1920s ethanol was briefly considered as a large-scale additive to gasoline to stop the knocking of the new higher compression engines. However, to the detriment of public health, ethanol lost out to highly toxic tetraethyl lead, for three reasons: in contrast to ethanol, only a small amount of lead was needed as an additive; some were concerned that corn-derived ethanol would compete for land and threaten the feed grains market; and since Prohibition was in effect, many were also worried about the security problems associated with maintaining large volumes of what is essentially 200-proof vodka. Ethanol's ability to be an effective fuel, however, was never an issue.

A third important fuel measurement is vapor pressure, or how readily a liquid evaporates. A fuel's vapor pressure is directly linked to the quantity of vehicle emissions, since over 40 percent of automobile emissions result from evaporation, not tailpipe emissions.

Substituting ethanol for gasoline in any amount reduces tailpipe emissions and thus reduces urban smog. Pure ethanol, and any gasoline-ethanol mixture that is more than 22 percent ethanol, has a lower vapor pressure than gasoline and would therefore reduce the amount of evaporative emissions.

Somewhat confusingly, however, blends of ethanol and current gasoline have a slightly higher vapor pressure than pure gasoline when the mixture contains less than 22 percent ethanol, because of the unique mixing properties of the liquids. Some studies show that low-level blends of ethanol and gasoline (like gasohol, which is ten percent ethanol) can actually worsen local air pollution, especially the formation of low-level ozone. Consequently, in cities in the Northeast and California, proposals to encourage the use of ethanol blends have often fallen on deaf ears. Some environmentalists see them as camouflaged subsidies for Midwestern corn growers at the expense of the cities.

But although low-level ethanol blends present complex issues, blends with more than 22 percent ethanol – which can be used in FFVs – do not have the vaporization problem. Moreover, with different approaches to refining and blending gasoline, a solution to the vaporization problem may well exist even at mixtures below 22 percent. Finally, ETBE – an oxygenate made from ethanol that improves gasoline combustion – improves air quality both in tailpipe emissions and vaporization, although its use means the fuel contains five to ten percent ethanol.

Choosing to use cellulosic ethanol is not a choice to forsake more advanced automobile propulsion technologies, such as hybrids and fuel cells. Ethanol is compatible with both. Jeffrey Bentley, vice president of Arthur D. Little, Inc., a company recently honored by the U.S. government for its novel fuel-cell technology, stated that "ethanol provides higher efficiencies, fewer emissions, and better performance than other fuel sources, including gasoline.... Where ethanol is available, it will be the fuel of choice by consumers." As both hybrids and fuel cells continue to improve, automobiles powered by them may dramatically reduce air pollution. Ethanol's compatibility with both makes moving toward cellulosic ethanol as a transportation fuel much more desirable.

If government policies promote FFVs, moreover, a large fleet of ethanol-compatible vehicles will be available much earlier than would otherwise have been feasible. This is because FFVs can burn gasoline now but can use cellulosic ethanol as it becomes available. Introducing FFVs into the national fleet differs radically in timing from other changes in transportation. Even if an ideal hybrid or fuel-cell vehicle came on the market, the slow rate of turnover in the nation's cars would mean that it would be many years before its introduction would make a dent in overall fuel use. But moving now to substantially increase the number of FFVs being produced would create the capability to shift to cellulosic ethanol as soon as it is available at attractive prices.

In addition, insofar as U.S. security and environmental concerns are more with the consumption of problem-causing petroleum fuel than with fuel in general, substituting cellulosic ethanol for gasoline improves relevant "mileage" radically, even in internal combustion engines. For example, an average automobile gets approximately 17 miles per gallon and is driven approximately 14,000 miles per year, thus using 825 gallons of gasoline annually. Suppose that same automobile were an FFV using a mixed fuel containing 85 percent cellulosic ethanol. Because of ethanol's lower energy content, it would use about 1,105 gallons of fuel, but only 165 would be gasoline. Such a vehicle could be said to be getting, in a sense, over 80 miles per gallon – of national-security-risk-increasing, carbon-dioxide-producing gasoline.

The one remaining barrier to widespread replacement of gasoline with ethanol is production cost. Relying on feed grains makes this cost comparatively high and volatile, since corn is subject to the caroming behavior of feed markets. In 1995, its price of $100 a ton nearly doubled, forcing a sharp curtailment in ethanol production. A partial shift to biomass should circumvent such instabilities. Over the past 15 years, the cost of producing a gallon of ethanol has been cut in half, to just over $1 a gallon wholesale. If, as predicted, the new biocatalysts, low and steady raw material costs, and improved processing let costs fall another 50 percent or so, ethanol could compete with gasoline at today's prices. If oil prices rise in the next century, gasoline could actually be at a substantial price disadvantage.

Such a reduction of ethanol cost is entirely plausible for two reasons. First, a simple comparison of energy content reveals that a dry ton of biomass crops – $40 is a reasonable current average cost – is comparable to oil at $10-13 a barrel. Agricultural wastes, in many cases, are considerably cheaper than either: many are free or have negative cost. So the overall costs of cellulosic biomass are likely to at least be in the same ballpark as those of crude oil. Second, further reductions in the cost of processing seem quite achievable. The current cost of processing ethanol is significantly higher than the equivalent price per barrel for oil. But this discrepancy reflects the maturity and sophistication of the petroleum industry, developed over the past century, as compared to the fledgling biofuels effort. Producing ethanol is not inherently more complex than refining petroleum – in fact, just the contrary. The world has simply invested far more effort in the latter.

JUMP-START

While the private sector will provide the capital and motivation to move toward ethanol, the federal government has a vital role to play. Market forces seldom reflect national security risks, environmental issues, or other social concerns. The private sector often cannot fund long-term research, despite its demonstrated potential for dramatic innovation. Hence, the federal government must increase its investment in renewable energy research, particularly in innovative programs such as genetic engineering of biocatalysts, development of dedicated energy crops, and improved processing. The very small sums previously invested by the Departments of Energy and Agriculture have already spawned dramatic advances. Every effort should be made to expand competitive, merit-based, and peer-reviewed science and to encourage research that cuts across scientific disciplines.

Research is essential to produce the innovations and technical improvements that will lower the production costs of ethanol and other renewable fuels and let them compete directly with gasoline. At present, the United States is not funding a vigorous program in renewable technologies. The Department of Energy spends under two percent of its budget on renewable fuels; its overall work on renewable technologies is at its lowest level in 30 years. Because private investment often follows federal commitment, industrial research and development has also reached new lows. These disturbing trends occur at a time of national economic prosperity when America has both time and resources for investing in biofuels. The United States cannot afford to wait for the next energy crisis to marshal its intellectual and industrial resources.

Research alone will not suffice to realize cellulosic ethanol's promise. The federal government should also modify the tax code to spur private investment. The existing renewable alcohol tax credits have recently been extended by Congress through 2007 – which will help the growth of the new biofuels industry and offer some protection in the transition from grain to cellulosic biomass. But the tax credit structure should facilitate the gradual adoption of cellulosic ethanol – in time, it should not need subsidies. Government incentives to produce FFVS should also be increased.

Finally, there must be a coordinated effort across the many different federal agencies that oversee government laboratories and regulatory agencies. The analogy to the semiconductor industry is instructive. In 1987, Congress authorized the creation of a government-industry partnership, the Semiconductor Manufacturing Technology Association (SEMATECH). Under the direction of the Department of Defense's Advanced Research Projects Agency, SEMATECH pursued fundamental research in semiconductor components and manufacturing processes. Private firms with innovative ideas were encouraged to devote research dollars to transform the idea into a commercial reality. The few domestic semiconductor manufacturers were brought together in forums where the companies could discuss technical hurdles without sacrificing competitive advantage. Today, the success of SEMATECH is evident, as the high-technology sector demonstrates. Biofuels offer a similar opportunity.

Cellulosic ethanol is a first-class transportation fuel, able to power the cars of today as well as tomorrow, use the vast infrastructure already built for gasoline, and enter quickly and easily into the transportation system. It can be shipped in standard rail cars and tank trucks and is easily mixed with gasoline. Although somewhat lower in energy content, it has a substantially higher octane rating than gasoline, allowing for more efficient combustion. It can radically reduce the emission of global warming gases, help reduce the choking smog of our cities, and improve air quality. It is far less toxic than petroleum, far less likely to explode and burn accidentally, and far simpler physically and chemically, making possible simpler refining procedures. If a second Exxon Valdez filled with ethanol ran aground off Alaska, it would produce a lot of evaporation and some drunk seals.

Our growing dependence on increasingly scarce Middle Eastern oil is a fool's game – there is no way for the rest of the world to win. Our losses may come suddenly through war, steadily through price increases, agonizingly through developing-nation poverty, relentlessly through climate change – or through all of the above. It would be extremely short-sighted not to take advantage of the scientific breakthroughs that have occurred and that are in the offing, accelerate them, and move smartly toward ameliorating all of these risks by beginning to substitute carbohydrates for hydrocarbons. If we do, we will make life far less dangerous and far more prosperous for future generations. If we do not, those generations will look back in angry wonder at the remarkable opportunity that we missed.

Defeating the Oil Weapon

By R. James Woolsey
Commentary, September 2002

The wealth produced by oil is what underlies, almost exclusively, the strength of three major groups in the Middle East—Islamists, both Shiite and Sunni, and Baathists—that have chosen to be at war with us. Our own dependence on that oil, and the effect this has had on our conduct over the last quarter-century, have helped encourage each of these groups to believe that we are vulnerable. Each group is anchored in a leading oil-producing state.

In Iran, the anti-American radicalism of the Ayatollah Khomeini and his Shiite followers was greatly emboldened by their success in seizing hostages in our embassy in 1979 and holding them for over a year while we, for our part, responded with yellow ribbons and a botched rescue attempt. In 1983, affiliates of the Khomeini regime in the Hizbullah movement drove us from Lebanon, and ever since then, Hizbullah and other Shiite terrorists have continued to campaign against us. To this day, the Iranian regime paints us as a diabolical threat in order to justify its repression of moderates and its increasingly hated rule at home.

The case of Saudi Arabia is no less clearcut. There, particularly in the aftermath of the Iranian revolution and of a massive attack by fanatics on the Holy Mosque in Mecca in 1979, the Saudi royal family has subordinated important aspects of its rule to the demands of the Wahhabi sect, accommodating—and promoting—the sect's hatred of the modern world and of infidels. Islamist immigrants to Saudi Arabia from Egypt and elsewhere essentially joined forces with the Wahhabis, producing an even nastier combination. In the mid-1990's, under the influence of Osama bin Laden, the target of Wahhabi- and Islamist-inspired terror shifted from regional governments like Egypt ("the near enemy") to us ("the Crusaders and the Jews"). If, in the coinage of Judith Yaphe, the Saudis have indeed struck a Faustian bargain with the Wahhabi sect, we have in a sense been assigned the role of Gretchen, the exploited party, in what is by now a long-running production.

In Iraq, the Baathists—modeling themselves after the European fascist parties of the 1930's—likewise came to regard us with implacable enmity, despite our having given them intelligence and other assistance in their war with Iran. This enmity only increased when, in 1990-1991, we decided not to permit Saddam Hussein's conquest of Kuwait to stand. Having been spared in the ensuing Gulf war, Saddam has spent the last decade developing weapons of mass destruction and ballistic missiles. He tried to assassinate former President Bush in 1993, and he explicitly, publicly, and continuously characterizes the U.S. as his country's enemy. Recently he has begun to work closely with his fellow Baathists in the government of Syria, a country historically more aligned with Iran.

In dealing with these three groups and other assorted Middle Eastern predators over the years, we have occasionally acted forcefully, as in Ronald Reagan's strike against Tripoli in 1986 or George H.W. Bush's conduct of the Gulf war up until the cease-fire. But generally, and until we deposed the Taliban and chased most of al Qaeda out of Afghanistan in 2001, we seemed inclined to respond to attacks on us by temporizing, retreating, or, at most, launching a few air strikes from afar.

To our enemies, the reason for our timidity has seemed plain enough. Holding only 3 percent of the world's proven remaining oil reserves, and consuming 25 percent of the world's annual production, we appear to care most of all about maintaining our reliable access to Middle Eastern oil. Our behavior at the very end of the Gulf war is frequently cited as an example of how we arrange our priorities. In the course of that war, we had encouraged the Iraqi Kurds and Shiites to rise up against Saddam Hussein, but once our own access to Kuwaiti and Saudi oil was secure, we signed a cease-fire, stood aside, and permitted hundreds of thousands of these rebels to be slaughtered by Saddam's Republican Guard.

Such is the perceived power of the oil weapon in the hands of our enemies, and such is our predicament.

II

The Middle East, including the Caspian Ba sin, is the home of nearly three-quarters of the world's proven oil reserves and about the same share of the world's "swing" capacity. The former establishes our underlying dependence, but the latter is what creates tactical power.

That power lies largely with Saudi Arabia. Although the Saudis have long been unable to increase their basic production capacity, which in mid-2002 stood at around 7.4 million barrels a day, they control almost 3 million barrels a day of the world's reserve production capacity, a figure that exceeds the total exports of all other oil-producing countries except Russia. When a crisis of some kind creates a spike in the oil spot market, the only way to increase supply quickly and keep prices stable is for the Saudis to activate this spare capacity. Thus it is they and they alone who, with their leverage over spot prices, have the power to assuage Western fears of another oil crisis—and it is a power they know how to use, not only against consumers but against other competing producers. In the apt words of the energy analysts Edward L. Morse and James Richard, this Saudi leverage is "the energy equivalent of nuclear weapons."

We had a working partnership with the Saudis for much of the cold war, offering them protection against the Soviets (and Soviet client states) in exchange for a reliable supply of cheap oil. But as Victor Davis Hanson has recently reminded us ("Our Enemies, the Saudis," Commentary, July-August), this relationship has frayed badly over time. Not only has the royal family accommodated extremist Wahhabi views about the application of Islamic law, it has effectively turned over education in the kingdom to the Wahhabis and, more momentously, enabled their expansion into the rest of the world. It is well known that the religious schools of Pakistan that educated a large share of the Taliban and al Qaeda are Wahhabi. But the Wahhabis' reach has spread as far as Malaysia and Indonesia and indeed into a substantial number of organizations, lobbies, mosques, and Muslim schools in Europe, Britain, and the UnitedStates.

An analogue for Wahhabism's role in the world today might be the part played during the period after World War I by extremist forms of German nationalism. Not all German nationalists, not even all the extreme ones, became Nazis. But this form of German nationalism was the fertile soil in which Nazism grew—just as, today, Wahhabi and Islamist extremism are the soil in which al Qaeda and its sister terrorist organizations are flourishing.

There are, obviously, issues on which we must continue to work with the royal family and matters on which it is in our interest to maintain formally cordial relations. But in light of the direction taken by the Saudis for nearly a quarter-century now, it is also imperative that we take steps to reduce their hold over us. If doing so forces them and others to explore alternative ways of supporting themselves—in the mid-1990's, oil aside, the 260 million people of the Muslim Middle East exported less than the 5 million people of Finland—so much the better. Genuine economic development in that region is long overdue, and the world hardly owes anyone a living for being lucky enough to sit on top of so much its oil.

What, then, to do about our dependence? In order to be effective, a plan to overcome our vulnerability must be both decisive and coherent. Although the result of such a program will inevitably be to improve air quality, reduce greenhouse gas emissions, and bring down our trade deficit, this is not and should not be conceived of as an energy plan for its own sake but rather as the energy component of our strategy for the war we are in. As such, it must be realistic, and it should take effect promptly. That means discarding two approaches to the problem that have enjoyed substantial support in the U.S. but whose implementation would have, at best, a negligible effect.

For one thing, we will not come anywhere near being able to break our dependence by producing more oil domestically. As I noted earlier, we now hold only 3 percent of the world's proven reserves. Three-quarters of the oil wells that have been drilled in the world since the mid-19th century are in the lower 48 states: we are not going to find much more there than has already been found. Even exploiting Alaska's National Wildlife Refuge would increase our share of world reserves to only 3.3 percent. Offshore exploration may yield something, but surely not enough to make a real dent. In the end, our appetite for oil will still be eight times more gluttonous than what we can satisfy from our own resources—and as oil fields in other regions become depleted and more and more expensive to exploit, this gluttony will give the Middle East growing leverage over us.

For another thing, it will not do us any good to increase our production of transportation fuel by means of exotic processes that will result in prices substantially above the equivalent of oil at $30 a barrel. As they have done before, the Saudis can undercut all such technologies by using their swing capacity to increase supply and lower prices until our thirst forces us to capitulate—at which point they can raise the price again.

The Saudis' swing capacity must be, indeed, the ultimate target of our strategy. But if protection against their use of this capacity is our ultimate goal, pursuit of that goal must be combined with three other, underlying changes: reducing our overall demand for oil; bringing major new production from outside the Middle East into the world market; and moving toward affordable alternative fuels for transportation. Accordingly, the approach I propose has four complementary elements. Each of them has independent merit, but each is insufficient on its own, if not actually risky. Implemented as a package, however, the four individual elements can augment each other's effectiveness and, together, overcome inevitable snags and delays.

III

First, any serious effort to block the use of the oil weapon must reduce the demand for oil generally. We need to improve efficiency—a better term than "conservation," since we are talking not just about using less but about doing more with less.

The last time we traveled down this road, we actually acquitted ourselves quite well. In the six years after the 1979 oil shock, Americans cut oil use by 15 percent and Persian Gulf imports by 87 percent—while our economy grew by 16 percent. In the early and mid-80's we improved gas mileage in new domestic cars by 7 miles per gallon (mpg). By 1987, OPEC's share of the world market had dropped from 52 to 30 percent.*

Technology has moved far in two decades, but we do not seem to have gotten the message nearly so clearly as we did in 1979. Much of the public is averse to increased gasoline taxes, and also demonstrates a marked preference for large cars, trucks, and SUV. But we need not push for smaller vehicles per se; we need only care about gasoline consumption. This means encouraging the widespread use of hybrid gas/electric vehicles—the first hybrid SUV's now coming on the market should get over 30 mpg—and adopting other fuel-efficiency improvements through such means as lower aerodynamic drag, lighter materials, better tires, and so forth. We do not have to resort to tiny cars—or even mandated fuel-efficiency standards as such—in order to effect a huge difference in oil consumption.

A whole range of steps is available on this front. Twelve years ago, the California legislature voted financial incentives to reward purchasers of efficient cars. (Unfortunately the measure was vetoed.) Today we should be able to devise Detroit-friendly incentives like tax credits and rebates to encourage the scrapping of older, less efficient vehicles and promote the buying of hybrids, a technology that has much to recommend it over other solutions (like automotive fuel cells) whose affordable production is still years off and/or whose implementation would require substantial changes in our transportation infrastructure.

In the meantime—and here is the second component of the strategy—we should be helping Russia substantially improve its share of the world's oil market.

The level of oil production in Russia is already high, but, thanks to the country's vast untapped reserves, it could be substantially higher; Jeffrey E. Garten of the Yale School of Management has estimated that the current output of 6.9 million barrels per day could expand by at least 50 percent. The main obstacle here is the deplorable state of the country's pipelines, most of which (unlike the Russian oil companies themselves) are still government-owned. In many places, pipelines are lacking altogether. We should therefore help Russia obtain Western investment to modernize and expand its pipeline network while urging Europe to import more Russian oil and, by means of incentives, encouraging American oil companies to cooperate with Russian companies in the Middle East and elsewhere.

There are, admittedly, constraints on Russia's ability to provide a Saudi-style reserve capacity that could be "surged" as needed. (One such constraint is the Russian winter.) But as a supplier, Russia is likely to prove much more reliable than any regime in today's chaotic Middle East, and a steady shift of much of the world's oil purchases toward that country would thus have an overall stabilizing effect. It would also provide a tangible quid pro quo for the recent statesmanship of President Putin, who in more than one way has seemed definitively to cast Russia's lot with the West. And it would offer a nicely bracing reminder to the Saudis and other members of OPEC that their cartel's days may be numbered.

Another reason to take this step is more broadly strategic: to give Russia time to diversify its economy. We have a real interest in encouraging Russian prosperity, since this is the best way to foster the growth of a middle class and the kind of stability that can give solid roots to political liberalization and the development of the rule of law. Russia has serious problems: corruption, criminality, proliferation of nuclear and missile technology, brutality in Chechnya. But at this point it looks far more likely to develop democratically than does Saudi Arabia, and it would be decidedly to our benefit that it do so.

The third element consists of taking immediate steps toward replacing petroleum-based transportation fuels with domestically produced alternatives, especially those derived from wastes generally and more particularly from cellulosic biomass, otherwise known as plant material. Senator Richard Lugar and I assessed the case for doing this over three years ago,† and that case has since grown much stronger. The intervening years have seen the further development both of genetically modified biocatalysts to produce ethanol from cellulosic biomass and of other promising waste-to-fuel technologies such as thermal depolymerization that, unlike incineration, create no pollution and leave no streams of secondary waste.

We are not talking about your father's ethanol—corn-derived fuel that requires substantial energy to produce and will never cover more than a tiny share of our needs. By contrast, fuels produced from waste and cellulosic biomass can be much cheaper to manufacture and, being fashioned from very inexpensive and widely available material, would likely be competitive with gasoline even if the price of petroleum should move as low as $10 to $15 a barrel. Nor would large-scale production of ethanol from cellulosic biomass require introducing marginal land into cultivation or replacing existing crops on existing farmland. Lee Lynd of the Thayer School of Engineering at Dartmouth estimates that, by using a little over half of the prairie grass growing naturally on cropland now idled by federal conservation programs, we could produce enough biomass-derived ethanol to fill a quarter of our annual gasoline needs, even at present vehicle mileages.

The vehicles most of us own today can already use biomass-derived ethanol, if only in proportions of up to 10 percent. But there are at least two million flexible-fuel vehicles on the road that can burn up to 85-percent ethanol, and it would be a very simple and cheap matter to adapt the technology to all new cars, the only requirements being a differently programmed computer chip in the fuel system and a different kind of plastic in the fuel line. (Virtually all cars sold in Brazil already have this modification.) To get a feel for the results: a 20-mpg vehicle using 85-percent ethanol would realize well over 100 mpg of gasoline.

There are added benefits. Any fuel mixture above 22-percent ethanol burns more cleanly in all respects than gasoline, and both the production and use of cellulosic ethanol add essentially no new carbon to the atmosphere. Then, too, using domestically produced fuels from biomass and waste can substantially reduce our huge trade deficit.

Finally, consider the use of biomass- and waste-derived fuels in higher-mileage vehicles, like hybrids. Using 85-percent ethanol, a full-sized hybrid passenger car that gets 40 mpg would be realizing the equivalent of about 250 mpg of gasoline. The combined effect on our oil use from improved fuel efficiency and the use of biomass- and waste-derived fuels might thus be staggering indeed.

Which brings us to the fourth and most crucial component of the strategy. Even as we implement the rest of the program, an aggressive use of our Strategic Petroleum Reserve (SPR) is essential. Otherwise, the Saudis can try to use their swing capacity and the threat of economic recession to prevent us from reducing our use of oil.

The Saudis do not enjoy infinite flexibility in wielding their oil weapon. The kingdom has been living beyond its means for many years: the government has run deficits since 1983, domestic debt substantially exceeds gross domestic product, and in spite of runaway spending, the per-capita standard of living has dropped by half since 1980. The royal family rightly fears severe social unrest if there are further reductions in its welfare programs. So lengthy cutbacks or reductions in basic output are not really tolerable. And there are also logistical problems: much Saudi infrastructure, including electricity and desalination plants, requires a steady supply of the natural gas that is produced in association with the production of oil.

All of these factors enhance the utility of our SPR as a counterweapon. By selling from it and then replenishing it in a timely fashion, we could limit the Saudis' ability to use their own reserve capacity to manipulate the market. We could, for example, sell SPR oil on the spot market to counter any actual Saudi cut, or any refusal to increase production in a crisis (when the spot price typically rises). More: a number of energy experts have pointed out that if we sold oil drawn from the SPR to offset Saudi cutbacks, we could use the funds received to buy oil futures, which are ordinarily priced below the current spot market.

Thus, if a crisis caused the spot price to rise to $39 a barrel and we sold 10 million barrels, the proceeds from this sale might purchase as much as 15 million barrels for delivery two years later at, say, $26 a barrel. Alternatively, we could replace exactly the amount we had sold and use the remaining cash for some other purpose. It is true that spot oil prices cannot be kept completely stable, but aggressive management of the SPR nevertheless holds out the possibility of denying to the Saudis the ability to cause severe recessions here as they did in 1973-74 and 1978-80.

We could exercise even greater leverage if we added several hundred million barrels to the current SPR or, following Jeffrey Garten's advice, doubled its size to a billion barrels, perhaps giving Russia a preference in selling us the oil and proposing that other energy importers like China, India, and Brazil accumulate substantially larger reserves as well. A total reserve in oil-consuming countries approaching 2 billion barrels would constitute about two years of Saudi swing production and effectively deprive the Saudis of their principal oil weapon.

To be sure, the Saudis and their OPEC partners would oppose any such use of the SPR or other reserves, no doubt claiming to be shocked—shocked—that we would ever consider letting politics affect oil prices. The short answer to this is that we are at war. The somewhat longer answer is that in any case the oil market is hardly the model of a classical free market.

OPEC has its own mechanisms for administering its cartel, and the Saudis have their weapon. Under current circumstances, we can and should do what is necessary to counter their continuing politicization of the market, including by means of a reasonable international framework in which representatives of major oil-importing nations can meet in a crisis and agree to manage their reserves according to certain criteria. Even if it should prove too difficult to do this internationally, we can do much on our own, especially with the advantage of a billion-barrel reserve.

IV

But we must act, for the consequences of not acting are dire indeed. Consider a parallel dilemma, in a hypothetical world. Suppose Torquemada and the clique of Dominicans around him who managed the Spanish Inquisition had survived unreconstructed to exercise powerful influence within a 21st-century Spanish monarchy that was as enduringly unreceptive to democratic values as the real Spanish monarchy of the 15th and 16th centuries. Suppose that this reactionary monarchy controlled 25 percent of the world's oil. Suppose further that a portion of the rest of the Spanish-speaking world—in governments heavily influenced by Spain's power and by organizations reflecting Torquemada's attitude toward Jews, Muslims, and heretics—controlled an additional 40 percent of the world's oil reserves.

Torquemada and his Dominicans were given to the auto-da-fé. The Wahhabis are more given to lopping off limbs and heads—and smashing passenger aircraft into skyscrapers. Those differences aside, the problem posed both to non-Wahhabi Muslims and to the rest of the world today is not unlike the problem that would be posed by such a hypothetical

21st-century, Torquemada-backed monarchy reinforced by oil. If we do not forge a strategy and act now, we will leave major aspects of our national fate in the hands of a regime that was once our ally but has fallen increasingly under the sway of fanatics who have chosen to spread hatred of us, indeed of freedom itself.

This hatred fires and sustains those who make war on us with the intention of destroying our way of life. Their power derives from their oil, and it is time to break their sword.

* Hunter and Amory Lovins, "Mobilizing Energy Solutions," *American Prospect*, January 28, 2002.
† "The New Petroleum," *Foreign Affairs*, January-February 1999.

TESTIMONY OF C. BOYDEN GRAY
ON BEHALF OF THE ENERGY FUTURE COALITION

COMMITTEE ON AGRICULTURE, NUTRITION AND FORESTRY
UNITED STATES SENATE
MAY 6, 2004

ATTACHMENTS:

1. Recommendations of the Energy Future Coalition
2. Summary: *"A Strategy: Moving America Away From Oil"*
3. Report by Battelle Memorial Institute:
   "Near-Term US Biomass Potential:
   Economics, Land-Use, and Research Opportunities

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Challenge and Opportunity: Charting a New Energy Future
Recommendations of the Energy Future Coalition

Energy is the linchpin of our economic future – at home and throughout the world. Our economic health, the stability of global markets, the capacity of developing countries to meet the aspirations of their growing population, the health of the Earth's environmental systems, and our children's quality of life – all is affected by how we produce and use energy.

Much is at stake in getting energy policy right.

America needs a bold vision to chart a new energy future. Our old energy ways cannot be sustained if we are to meet the world's future needs responsibly. Whether the long-pending energy bill is enacted or not, American leadership, innovation, and investment are needed to develop and deploy the next generation of energy solutions that will create new jobs and economic growth, improve our security, and protect the global environment. The Energy Future Coalition seeks to accelerate this transition and set a new course for energy policy.

This new course must address three overarching challenges:

- We must reduce the world's dependence on oil, helping to free consumers from the economic, political and environmental risks that such dependence entails.

- We must take steps to control the emissions from the burning of coal, oil and natural gas that are adversely impacting the global climate.

- And we must recognize that helping developing nations to grow can be both a boost for them and in the best interest of the United States. Extending access to modern energy services to poor people around the world can demonstrate American leadership and create new markets at the same time.

Specifically, the following elements should be part of an energy policy for the future.

1. The U.S. should alleviate the transportation sector's dependence on oil and reduce its carbon emissions, using technology to increase automobile efficiency and make greater use of alternative fuels, starting with sustainably produced biofuels and ultimately converting to hydrogen-based fuel cells. The Energy Future Coalition recommends:
    - Tax incentives for manufacturers to build and consumers to purchase high-efficiency advanced technology vehicles.
    - Commercialization of new technologies to produce fuels for these vehicles that are derived from biomass – widely abundant organic material from farm and forest wastes and low-cost crops like switchgrass.
    - Development of low-cost hydrogen fuel cells that eventually will power most cars and trucks.

2. The electric utility and coal industries should position themselves to respond creatively and efficiently to the challenge of climate change. The Energy Future Coalition recommends:
   - Rapid modernization of the U.S. electric power grid to improve its reliability and to permit use of advanced renewable generation and energy efficiency technologies.
   - Increasing reliance on renewable energy sources, especially wind, for additional electric power supply.
   - Dramatically increasing the efficiency of generation, transmission and use of electricity – lowering consumers' electric bills and reducing carbon emissions at the same time.
   - Demonstrating the commercial viability of technologies to capture carbon emissions from coal-fired power plants, and permanently sequester that carbon underground.

3. The U.S. should jump-start new bioenergy technologies and the production of biofuels. The Energy Future Coalition recommends:
   - A competitive demonstration of new commercial-scale technologies to convert cellulosic biomass – going beyond the current use of corn and other food crops – into ethanol and other petroleum substitutes.
   - Redirecting U.S. and other countries' export subsidies away from currently supported commodity crops and toward the development of a new industry based on agricultural wastes and crops grown for energy.

4. The U.S. should take the lead in extending modern energy services to the billions of the world's people who now lack them, using private-sector investment and creative international partnerships. The Energy Future Coalition recommends:
   - Creation of a new international financial instrument – the global development bond.
   - Longer repayment terms and standard financing protocols for low-carbon and energy efficiency projects.
   - Transferring advanced energy technologies internationally, with subsidies where necessary, to reduce the projected growth of fossil fuel use.

The steps recommended by the Coalition will reduce U.S. oil consumption by an estimated 3 million barrels per day – about 15% of current use – and carbon emissions by 180 million tons per year – about 10% of today's level – over the next 25 years. This is a larger impact, at far less cost, than the energy bill would have. They will also lead to economic growth and create hundreds of thousands of new jobs. More importantly, they will lay the groundwork for more dramatic policy shifts in the years to come – shifts that will not occur without intervention and that will be much more painful if we do not begin today.

We know that change will not come easily, nor will it occur overnight. But vision and leadership can move the U.S. economy toward the next generation of energy technologies, the technologies of the 21^{st} century.

Summary
"A Strategy: Moving America Away From Oil"
The Arlington Institute

This report was commissioned by Dr. Andrew Marshall, Director of Net Assessment in the Office of the Secretary of Defense. The authors were John L. Petersen, Dane Erickson, and Humera Khan.

Recent terrorist events have raised new questions about the security of U.S. energy supplies. In light of Middle East regional instability, it is fair to ask: Are there any alternatives to the status quo? How might the U.S. hurry the inevitable shift to a more stable, clean alternative to oil?

This project examined historical transitions to new energy sources, catalogued the present situation, considered the global oil peak, and envisioned possible future alternatives. We recommend a strategy for changing the shape of transportation energy use in the U.S. and the world over the next 15 years.

About 26% of the total energy consumption in the United States is used for transportation. Oil, 60% of which is imported, provides nearly all that energy. To solve the problem of dependence on imported oil, changes must occur in the transportation sector.

Pessimists say the world is running out of conventional supplies of crude oil; optimists point to unconventional sources as being adequate for years to come. Recently the Pew Center on Global Climate Change commissioned the development of a set of detailed energy scenarios that represent a well thought-out spectrum of possible energy futures. They are:

- "Awash in Oil and Gas" – a market-driven scenario in which abundant supplies of oil and natural gas are available to U.S. consumers, and cheap energy remains a staple of the U.S. economy.

- "Technology Triumphs" – a scenario driven by market forces, technological innovations, and policy interventions.

- "Turbulent World" – an event-driven scenario, characterized by severe stresses and broad challenges, with constant dislocations, ubiquitous conflicts, and historically low levels of global cooperation.

We developed our recommended energy strategy by testing it against these three scenarios. If "Awash in Oil and Gas" prevails, no significant change in direction is needed in U.S. energy policy. "Technology Triumphs" demands an evolutionary strategy, and "Turbulent World" a revolutionary one. Our strategy therefore combines an evolutionary initiative with elements that would allow it to respond to revolutionary changes if needed.

Based on current technology trends, we posit a desired future end point – an "all-electric" world, based on low-polluting energy sources, increasingly decentralized power generation, and increased efficiency in the production and use of electricity. Our transportation strategy is designed to be consistent with that vision.

Using the Think Tools™ Options Evaluation tool, we arrayed different configurations of fuels and vehicles against a comprehensive set of metrics relevant to this assessment, including technological maturity, levels of public / private investment, infrastructure transition time, geopolitical influences, and environmental impact – over three time periods: 1-5 years, 5-10 years, and 10-15 years, in order to determine which options presented the best near-, mid-, and long-term benefits.

We conclude that the U.S. must:

- Take advantage of existing technological alternatives to wean itself from oil before fuel cells and hydrogen come on board.
- Find a way to facilitate the transition to hydrogen and fuel cells in the longer term.

To achieve these needs, a three-phase strategy is needed to revamp and renew the U.S. transportation sector. Within this strategy are three main ideas:

1. Vast improvements in efficiency must be made, mainly through hybrid gasoline-electric vehicles and new lightweight designs.
2. The U.S. should invest in a new large-scale initiative to produce biofuels as an alternative supply source, mainly through cellulosic biomass.
3. In the longer term, these biofuels can be used as a feedstock for fuel cells.

Our strategy envisions a near-term emphasis on hybrid and flexible-fuel vehicles (vehicles that can use gasoline or ethanol interchangeably) as a transition to a future based on fuel-cell vehicles using hydrogen from renewable sources. Specifically:

By the end of 2008, we recommend as broad objectives that all replacement vehicles off the assembly line be hybrid or flexible-fuel vehicles, the fuels used are gasoline and ethanol, and major efficiency improvements come from the increased penetration of hybrid vehicles. Toward that end, we suggest the use of substantial tax incentives and increased fuel taxes.

In phase 2, flexible-fuel hybrids should be entering the replacement-car market by 2010, the major fuel consumed should be ethanol, and major efficiency improvements should come from hybrid and Hypercar® lightweight designs. To achieve this, research and development funding should focus on cellulosic biomass technology (for ethanol), flexible-fuel hybrids, and Hypercar® designs. Additionally, incentives will be needed to promote needed infrastructure changes, along with subsidies and promotion of ethanol.

In 10-15 years, our strategic objectives include making fuel-cell vehicles mainstream, enabling most of the feedstock fuel to be biofuels, and achieving efficiency gains from hybrid fuel cell vehicles and Hypercar® designs. Needed policy steps include: R&D on fuel cells that run on biofuels, on fuel-cell hybrid vehicles, and on hydrogen refueling stations, together with incentives for fuel cell deployment.

There are numerous benefits to this strategy: It uses existing infrastructure to move the U.S. away from oil, fast; it uses renewable fuels and creates jobs in rural areas, benefiting the politically strong agricultural lobby; it reduces the U.S. trade deficit; it will contribute no net carbon dioxide to the atmosphere; and it is flexible enough to allow for new technologies and discoveries to arise in the next decade that will alter or accelerate this transition.

A combination of technology, fuels, and efficiency that makes oil obsolete could have profound positive impact on the U.S. military forces. Major benefits include increased range, increased capabilities for surprise and reconnaissance purposes, increased agility of forces, and decreased costs.

Weaning ourselves away from oil in the short term is both necessary and possible. The benefits would be profound, and there are existing technologies that can start the process immediately with broad-reaching options on the near horizon to complete it – if only our government decides that such a fundamental change is in the national interest.

"A Strategy: Moving America Away From Oil" can be found on the Arlington Institute's web site at: http://www.arlingtoninstitute.org/whatsnew.html.

PNWD-3285

Near-Term US Biomass Potential:
Economics, Land-Use, and Research Opportunities

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Introduction

This report discusses the potential for the production of biomass energy in the United States over the next few decades. By potential we mean the possible use of biomass energy given expected evolutionary developments in biomass production and transformation over this time period. While biomass can be used as a direct energy source or as an energy feedstock in many sectors of the economy, our focus in this report is on the production of cellulosic (or "woody") biomass for conversion to ethanol. The emphasis on ethanol is motivated by the promise of emerging cellulosic fermentation techniques to provide ethanol as an alternative to gasoline derived from imported petroleum as a fuel for vehicle transportation.

This report provides a summary of current US biomass energy use, a comparison of ethanol production from corn grain feedstock versus cellulosic switchgrass feedstock, and a comprehensive near-term supply curve of U.S. primary biomass production from both wastes and the growing of energy crops. Currently, the largest potential source of biomass energy is by-product, or "waste" flows, such as agricultural residues, wood residues, and municipal wastes. A near-term scenario for producing an additional 10 EJ/year of biomass energy in the US is discussed (enough to produce about 50 billion US gallons of ethanol per year). This level of expansion would be a large increase over current biomass use, but would not result in large impacts on the agricultural system. In order for the biomass energy supply to expand significantly beyond the 10 EJ/year level, extensive production of dedicated biomass energy crops would be required, with implications for the cost of cropland and competition with food crops. The report concludes with an outline of the major areas where performance improvements and research are needed that would allow biomass to be used on a wider scale.

Background

Figure 1 illustrates the potential pathways for the use of biomass energy. Biomass can be used directly by end-use sectors for space heating and process heat, or transformed to provide electricity,

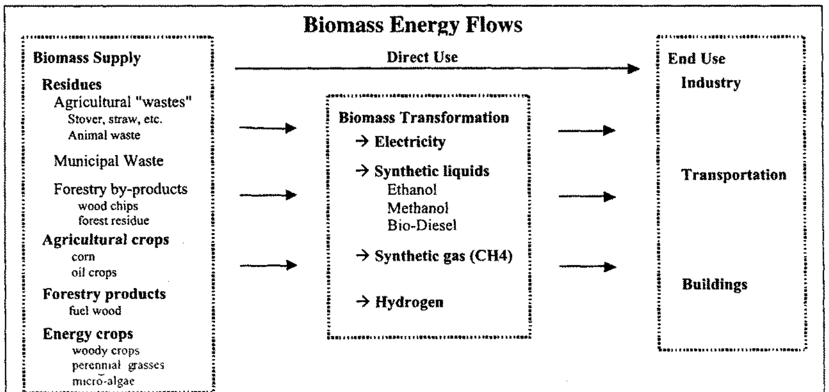

Figure 1. Pathways for Biomass Energy.

liquid, or gaseous fuels. Today, most biomass in the US is used directly by end-use sectors, primarily in the form of wood and wood wastes used to generate process heat by the industrial sector. Biomass is also used to heat buildings and to generate electricity.

US 2000 Biomass Use (EJ)

Sector	Wood & Wood by-products	Waste/Other	Total
Industry	1.7	0.2	1.9
Buildings	0.5	0.0	0.6
Transportation	-	0.1*	0.1
Electric Generation	0.1	0.3	0.5
Total Biomass Energy	2.4	0.6	3.0

*Ethanol used in transportation

Table 1 — Summary of US biomass consumption. Totals may not sum due to independent rounding. Source: EIA (2002).

Table 1 summarizes US biomass use in the year 2000. Substantial expansion in biomass consumption will likely require transformation to either electricity or liquid and gaseous fuels. The largest use of biomass at present is in the pulp and paper industry, primarily for use as process heat. The most common biomass transformation practiced at present is the use of biomass to generate electricity, with relatively little biomass used as a liquid fuel feedstock (Table 1). For comparison, about 20 EJ of coal were burned to produce electricity in the US in the year 2000 (EIA 2003).

To put these US biomass consumption figures into context, total US petroleum imports were 25 EJ (net) in the year 2000 (about 11 million barrels per day), and are projected to increase (EIA 2003) to about 40 EJ by 2020. Ground transportation in the United States currently consumes 21 EJ of fuel, of which 16 EJ (352 million gallons per day or 130 billion gallons per year) is motor gasoline. Due in part to the phase-out of MTBE, 2003 was a record year for US ethanol production with about 2.8 billion gallons or 0.2 EJ produced (RFA 2003).

See Table 2 for some ethanol and biomass conversion factors. An important fact to note is that one gallon of ethanol contains only 66% of the energy content of a gallon of gasoline. For consistency, net energy contents (or LHV) units

Energy and Biofuel Conversion Factors

Ethanol
energy content (LHV) = 75700 Btu/gallon = 80 MJ/gallon = 21 MJ/liter
energy content (HHV) = 84000 Btu/gallon = 89 MJ/gallon = 23 MJ/liter
density (average) = 0.79 g/ml
1 GJ ethanol = 12.5 gallons (LHV)

Gasoline
energy content (LHV) = 115000 Btu/gallon = 121 MJ/gallon = 32 MJ/liter
energy content (HHV) = 125000 Btu/gallon = 132 MJ/gallon = 35 MJ/liter
density (average) = 0.73 g/ml
1 GJ gasoline = 8.2 gallons (LHV)

Biomass
biomass energy content: 15-19 GJ/tonne (6450-8200 Btu/lb)
switchgrass energy content (dry-HHV): 19 GJ/tonne
switchgrass energy content (dry LHV): 17 GJ/tonne
switchgrass energy content (20% moisture content LHV): 16.5 GJ/tonne

Units
1 US gallon = 3.79 liters
1 kilogram = 2.205 pounds
1 short ton (US) = 0.9072 metric tones
1 Hectare (Ha) = 2.47 acres
1 BtU = 1.055 kJ
1 exajoule (EJ = 10^{18} J) = 1 billion gigajoules (GJ) = 0.95 Quads (quadrillion, 10^{15} Btu) = approximately 163 million barrels of oil equivalent (boe)
1 (EJ) = 8.2 billion US gallons gasoline (LHV) = 12.5 billion US gallons ethanol (LHV)
1 \$/GJ gasoline (LHV) = 12 cents per gallon gasoline
1 \$/GJ ethanol (LHV) = 8 cents per gallon ethanol

Table 2 — Energy conversion factors. Energy values are commonly provided in two types of units, HHV (gross) or LHV (net) and both sets of values are given for reference. LHV figures are used in this report. HHV = Higher Heating Value (also gross heat content) which is all energy released during combustion. LHV = Lower Heating Value (also net heat content) where the energy used to vaporize water contained or released during combustion is subtracted. Sources: http://bioenergy.ornl gov/papers/misc/energy_conv.html; switchgrass HHV from: http://www.ott.doe.gov/biofuels/properties_database.html; LHV derived assuming 6.5% Hydrogen content.

are used throughout this report. Not all sources state their unit assumptions, however, so some values are approximate.

Future Biomass Transformations

Before considering liquid fuels derived from biomass sources, it is important to note that there is significant potential for expansion of the direct use of biomass even without advances in the transformation of biomass to liquid or gaseous energy forms. In addition to using biomass in direct end uses such as process heat, biomass can be burned to produce electricity. Biomass can be co-fired with coal, combusted in a dedicated plant, or gasified for use in a combined-cycle plant (or even as a hydrogen feedstock). If biomass is used to generate electricity, the energy content of the biomass as produced (taking into account water content) can be compared directly to the energy content of fossil fuels used for electric generation (with an allowance for the energy used in biomass production).

When liquid fuels are considered, then the comparison between fuels is slightly more complicated because conversion losses and the energy needed to transform biomass into a liquid must be considered. The most common biomass-to-liquid transformation currently practiced is the production of ethanol using corn grain as a feedstock. Using current technology for ethanol production from corn, 10 EJ of energy embodied in corn results in about 4.5 EJ of ethanol. The energy needed to transform corn is significant, however, and accounting for the energy used to grow corn and manufacture ethanol, the net output of 10 EJ of corn energy is about 1.4 EJ (LHV; Shapouri, Duffield, and Wang, 2002; Table 3).

For biomass fuels to have a significant net contribution to the supply of liquid fuels, new transformation technologies will be needed. Table 3 presents a comparison of the current technology for corn grain to ethanol and estimated *future* (year 2010) parameters for a technology to produce ethanol from a switchgrass energy crop, which provides cellulosic biomass. From a net energy standpoint, switchgrass is superior as a feedstock as compared to corn grain due to lower energy needs during production and the contribution that the switchgrass-processing residue can make toward process energy needs, since the portion of the switchgrass that cannot be transformed into ethanol (primarily lignin) can be burned for process heat and, if there is a surplus, to produce electricity. The net process energy requirement, accounting for surplus

Energy Balance For Ethanol Production (EJ)

	Feedstock	
	Corn	**Switchgrass**
Harvest	**10**	**10**
Handling Losses	1.0	1.0
Ethanol Out	**4.5**	**4.3**
Biomass to Ethanol Conversion %	**45%**	**43%**
Energy Inputs		
Farm Energy	1.3	0.6
External Process Energy	2.5	0.0
Transport to Market	0.1	0.1
Co-product credit	-0.8	-
Net Energy Inputs	3.1	0.6
Net Energy Out	**1.4**	**3.7**
(Net Energy Out = Ethanol Out – Net Energy Inputs)		
Net Conversion %	**14%**	**37%**
(Net Energy Out/Harvested Biomass)		

Table 3 — Energy flow comparison of current corn grain to ethanol technology to future technology (circa 2010) for switchgrass to ethanol production (Shapouri, Duffield, and Wang, 2002; ANL 1999). Values are in EJ (Table 2). A nominal 10% processing and storage loss was assumed for both crops. For reference, 10 EJ of primary biomass corresponds to 25,000 million bushels of corn (630 million tonnes) or 600 million dry tonnes of switchgrass (LHV). The assumed yield was 103 gallons of ethanol per dry tonne of switchgrass.

electricity sold to the grid, is roughly zero (assuming technology and biomass production advances as described in Shapouri *et al.* 2002).

The net effect is that we expect that about 40% of the energy contained in a modern biomass energy crop will be available as an end-use fuel. The difference between converting a starch (corn) and a cellulosic feedstock is summarized in the last two lines of Table 3. While the rate of conversion from biomass to ethanol is similar for the two technologies, the net energy consequences are substantially different. No co-products were assumed produced from ethanol (see discussion below). The production of co-products could further improve the net energy balance (and economics) of the ethanol production process.

While the net energy consequences for cellulosic ethanol are far better than current ethanol processes, the process efficiency is less than that for petroleum, where approximately 85% of the energy contained in crude oil is output as product (Wang 2001). This means that, as compared to petroleum products, about twice as much biomass must be produced to create the same amount of usable liquid fuel. Also, this means that – if the costs of the input feedstock and conversion were equal – the final product produced using biomass would be more expensive than a petroleum product since more feedstock must be processed.

Potential US Biomass Supply

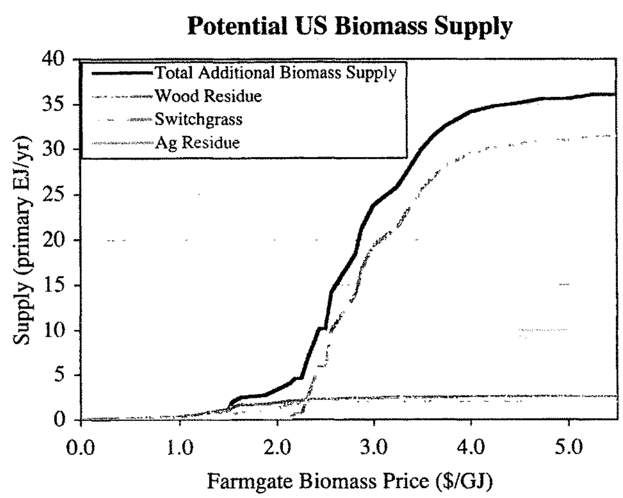

Figure 2 — Supply curves for new US biomass by source (left axis, adapted from Graham *et al.* 1996; and Walsh *et al.* 2000a as updated by EIA). Supply is given in terms of primary biomass energy at the "field gate" before any transformations or transportation (see text). The top dark line is the sum of the sources shown. Costs are in year 2000 dollars. Energy production from municipal wastes and landfills is not included in the above curves. The effect of competition between food crops and biomass energy crops for land is not included, which would increase the cost of biomass (see text). Most of the current US biomass consumption of about 3 EJ/yr (fuel wood and "waste" consumption in the pulp and paper industry) is not included in the above curves. Use of forested land for biomass production would add to potential biomass supply and is not included here.

The consideration of biomass supply must consider both the amount of biomass that can be supplied and its cost. The utilization of so-called "waste" biomass for energy is practiced today, and this experience can be used to estimate the ultimate potential of these biomass residue streams. Note that not all biomass residues can be considered waste. Some portion of forest and agricultural residues, for example, must be left in place in order to maintain cover for protection against wind and water erosion and to maintain good soil conditions and fertility. There is less experience, however, in the production and use of crops grown specifically for biomass energy. The potential supply here must be estimated using biomass or agricultural production models.

An important consideration for both the potential biomass supply and its cost is geographical heterogeneity. Use of a single average value for either yield or cost can lead to large errors. The potential yields of biomass through the US vary significantly, and this variation must be taken into account. For biomass crops, we use the results of Graham *et al.* (1996), who calculated the potential biomass supply for each county in the continental United States. For "waste" biomass streams we use the estimates of Walsh *et al.* (2000a) as updated and used in the NEMS model (Haq 2002).

We present the combination of biomass supply and cost as a set of supply curves. Figure 2 presents a supply curve for primary energy from biomass in the United States. At low prices only "waste" biomass sources are available as biomass fuels or feedstocks. Once the price for raw biomass increases beyond about $2.0 per GJ (about $30 per dry metric tonne of switchgrass) the production of biomass energy crops would be expected to expand significantly. Some production, particularly from CRP lands, of bioenergy crops would be expected before this point (Walsh *et al.* 2000b). In this figure, switchgrass is used as an example cellulosic biomass crop. The costs given in this figure are used in the next section to estimate how much biomass energy could be competitively produced.

We note that the costs given here are general estimates only, particularly since competition between bioenergy and traditional crops has not been considered. In a model that includes such competition Walsh *et al.* (2000b) found a lower production of bioenergy crops (3 EJ/year) than that given in Figure 2 for a farmgate price of about $3/GJ with an increase in corn prices of 9% due to the competition with biomass. While the estimates used here (Figure 2) may, therefore, be somewhat optimistic regarding biomass production costs given current yields, we would expect that ongoing research efforts would result in yield increases over the next couple decades.

Figure 3 shows the fraction of US cropland that would be used by the amount of switchgrass production as indicated on the bottom axis. Note that is only an illustration; more research on biomass production is required to produce improved estimates of biomass productivity. In addition, at high biomass production levels, the static assumptions used in the detailed calculations of Graham *et al.* (1996) would change as biomass production competes for land with food crops, resulting in an increase in land values. This would act to increase the production costs, and ultimate price, of both biomass and crops (Walsh *et al.*

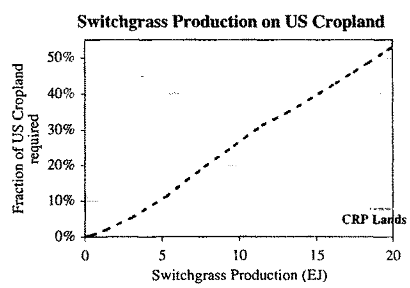

Figure 3 — Fraction of US cropland required to produce the given amount of biomass assuming yields for currently available varieties (data from Graham *et al.* 1996); and Walsh *et al.* 2000 as updated by EIA). The blue bar on the right-hand axis indicates the amount of land in the conservation reserve program (CRP) in 1996. This bar is only for reference of total land area, it this does not indicate the amount of switchgrass that CRP land would produce. Note that this figure includes cropland only, Figure 2 also include potential biomass production on pasture lands.

2000b). We confine our further analysis here to a level where the effect of land competition will be small.

An indication of the amount of biomass that might be produced without a significant effect on US food crop production is shown by the amount of conservation reserve program land (blue line in Figure 3). Taking all the sources shown in the graph together we see that around 10 EJ of biomass could be produced, at an intermediate price, without a substantial impact on US agricultural production. This would translate into around 4.3 EJ per year of ethanol (LHV; Table 3), or 50 billion gallons (35 billion gallons of gasoline equivalent).

A larger role for biomass, beyond this level, will require either use of significant amounts of cropland, or use of land not currently used for agriculture. Much of the land in the US that is not used for agriculture is not highly productive without significant inputs of nutrients and/or water, which may significantly reduce the potential net energy contribution of biomass crops. Not included in the above calculations, however, are biomass crops such as hybrid poplar grown on forested lands (although at a cost of potentially competing with land used for the production of forest products).

Note that the costs of shipping biomass to the processing facility have not been included. These costs will depend on the configuration of the biomass supply and processing system. The EIA, for example, adds a $10/dry ton processing charge to their biomass supply curves. This translates to an additional cost of $0.6 per GJ (or about 11 cents per gallon of ethanol produced[1]). Inclusion of transportation charges would increase the cost of biomass. For simplicity, given that transportation costs will vary with situation, we have omitted them for the purposes of this discussion.

Near-term Expansion to 10 EJ Primary Biomass Energy

The first phase of expansion would likely be dominated by the use of biomass "waste" streams.

We consider here a scenario where near-term biomass energy supply in the United States expands to 10 EJ per year of primary energy supply beyond the present level, representing about a four-fold increase in biomass use, or enough to produce an estimated 50 billion gallons/year of ethanol. This level was chosen for illustration because, to move beyond this level, the estimates shown here (Figure 2) indicate that interactions between biomass and agricultural production would need to be considered (see below). Note that while the estimates here were calculated using the sources referenced above, they may well change with further real-world experience and research. For simplicity, we will associate 10 EJ of production with $2.5 per GJ in the example below ($2.5 per GJ is equivalent to about $40 per metric tonne of switchgrass). This results in about 2 EJ produced from agricultural residue, 2.5 EJ from wood wastes, and the remaining 5.5 EJ from energy crops.

The first phase of expansion would likely be dominated by the use of biomass "waste" streams. Corn stover and wheat straw are often mentioned as likely candidates as potentially low-cost feedstocks that are available in large quantity. The higher costs of the initial ethanol production plants will be somewhat offset by the use of low-cost biomass "waste" streams. In addition to further developing cellulosic biomass-to-ethanol conversion technologies, preparation for further production expansion using dedicated biomass crops can occur at the same time. As ethanol production expands, however, biomass feedstock costs will increase since the total amount of low-cost biomass available is limited (Figure 2). As feedstock costs increase, production costs will need to decrease to maintain the same end-use price.

In summary, 10 EJ of primary biomass supply would consist of various "waste" biomass streams plus production of energy crops (Figure 2). If 10 EJ of primary biomass energy were provided entirely by switchgrass production, this would correspond to about 600 million dry tonnes (LHV).

Using the projected performance of advanced technologies for conversion of cellulosic biomass to ethanol, 10 EJ per year of biomass could be converted into about 4.3 EJ per year of ethanol (Table 3), or more than 50 billion US gallons per year. In energy terms, this is equivalent to 35 billion gallons of gasoline per year (LHV). The net energy production, taking into account fuels (largely liquid) used to produce biomass (Table 3), is 30 million gallons per year of gasoline equivalent. This would represent about 17% of current US consumption of ground transportation fuels (gasoline + diesel).

Assuming an 85% conversion efficiency in petroleum refining (for all products), the use of 4.3 EJ per year of ethanol would reduce net crude oil consumption by about 2.2 million barrels per day. This compares to current gasoline use of about 8.8 million barrels per day and total crude oil use of about 15 million barrels per day. This would reduce 75 million metric tonnes of carbon emissions per year: 10% of the AEO 2003 projected US transportation emissions in 2020, or 4% of the projected total US carbon emissions in that year.

While a $2.5/GJ feedstock cost of biomass is lower than current expected world crude oil prices in primary energy terms, the lower energy efficiency of refining biomass to ethanol relative to the energy losses incurred in refining petroleum presents a cost hurdle for biofuels. For example, the crude oil price forecast for the year 2010 from the AEO 2003 of $24/bbl translates to a cost of approximately $4/GJ of crude oil. The feedstock portion of the cost of gasoline is, therefore, approximately $4.70/GJ assuming an 85% energy conversion efficiency for petroleum refining. For a biomass-derived fuel the feedstock portion of the final cost would be $5.80/GJ (or 70 cents per gallon of gasoline equivalent) for a feedstock costing $2.5/GJ, assuming a conversion efficiency of 43% (Table 3).

At this time, there is insufficient experience with biomass refining on a commercial scale to have a good understanding of the costs of a mature refinery process.

The cost of ethanol derived from biomass will be determined by the feedstock costs plus the cost of the conversion process. At this time, there is insufficient experience with biomass refining on a commercial scale to have a good understanding of the costs of a mature refinery process. As a lower bound we consider gasoline refining, which is a mature and widely practiced technology. A wholesale gasoline price of about $0.90/gallon and a net 85% energy conversion efficiency implies a cost of $2.50/GJ for current crude oil refining costs. This cost can be compared to the cost of a current corn-based ethanol plant, estimated to be $4.00/GJ for capital and operating costs excluding utilities (McAloon *et al.* 2000).[2] The technology for cellulosic conversion is more complex than that for conversion of a starch feedstock (*i.e.*, corn) so costs are likely to be higher than for current corn-based ethanol plant. Given that further improvements are potentially possible for starch-based ethanol plants, a processing cost of $2.5/GJ would appear to be a liberal lower bound for the long-term cost of ethanol processing.

Taking the cost of petroleum refining as a lower bound, a $2.50/GJ biomass feedstock cost would result in a wholesale ethanol cost of about $8.30/GJ, or $1/gallon of gasoline-equivalent. Under these lower-bound conditions for refinery costs, ethanol would be competitive with gasoline at a break-even crude oil price of approximately $36/bbl. Conversely, under these lower bound refinery cost conditions, the farmgate biomass cost would have to be $1.75/GJ (or about $30 per dry metric tonne) to break even with crude oil at $24/bbl. At this price, about 2.5 EJ of biomass would be available (Figure 2), enough for about 12.5 billion gallons per year of ethanol using advanced cellulosic technology, an amount roughly equivalent to the upper bound of the market for ethanol in the US if it were used as a gasoline additive in blends up to 10 percent.

This lower-bound cost estimate is likely to be overly optimistic, however, given several factors. First, the larger amount of biomass feedstock that must be processed per unit output as compared to petroleum processing, not to mention the processing of a solid (biomass) as compared to a liquid (crude oil) feedstock, means that refinery costs per unit output will tend to be higher. Second, the near-term capital and operating costs of a biomass refinery are likely to be higher than those for a petroleum refinery given the greater global experience in petroleum refining technology. Engineering estimates of processing costs for cellulosic biomass conversion using current technology are several times the lower-bound estimate assumed above (Lynd 1996a, Wooley *et al.* 1999). The cost estimates in Wingren *et al.* (2003) are even higher. These estimates are made for an "Nth plant", that is, assuming that sufficient demonstration and development projects have been completed to work out implementation issues. Costs would decline if anticipated technological advances are realized; however, engineering estimates that assume such further advances are still higher than the value assumed above (Wooley *et al.* 1999). Some speculative estimates suggest process costs that are on the order of the $2.50/GJ assumed here could be possible in the long term (Lynd *et al.* 1996b).[3] A number of technologies are proposed to lower the cost of biomass conversion. These will need to be developed and then demonstrated at a commercial scale. Ultimately, the cost of biomass conversion will need to be determined through actual operation of cellulosic biomass-to-ethanol plants.

Ultimately, the cost of biomass conversion will need to be determined through actual operation of cellulosic biomass-to-ethanol plants.

A complete cost comparison must also take into account not only the potentially higher capital costs of biomass conversion relative to petroleum, but also larger transportation costs (due to the lower energy density of ethanol as compared to gasoline). Because of higher feedstock requirement for ethanol as compared to petroleum fuels, lowering biomass production costs and increasing ethanol yields will be key factors for decreasing the cost of biomass-derived liquid fuels to a level more competitive with petroleum products.

The production of co-products could reduce the net cost of producing ethanol from a cellulosic feedstock. For example, the protein portion of the feedstock could be extracted for use as animal feed (de la Rosa *et al.* 1994). The protein content for common feedstocks such as woody biomass or switchgrass at the end of the growing season ranges from 2-5%. Higher protein contents for switchgrass occur at early stages in its growth (Hintz *et al.* 2002), which could make feed by-product extraction economically attractive, but would reduce the amount of biomass available as an ethanol feedstock. Note that extracting a protein-rich animal feed from a cellulosic feedstock would require more effort than the animal feed by-product produced from the current corn-to-ethanol process. Various other co-products could be produced in so-called biorefineries (Lasure and Zhang 2004). The economic and energy-balance tradeoffs from by-product (or co-product) production would need to be examined further to determine their potential role in improving the economics of ethanol production. Co-products are most likely to significantly contribute to economic vitality of an ethanol plant if co-product demand is larger than the total capacity for co-product production in a large-scale ethanol production system.[4]

Future Expansion of Biomass Supply

Substantial expansion of biomass energy supplies will require a number of significant changes in the agricultural system. The initial expansion of biomass supply may be through use of agricultural residues. Experience to date indicates that the collection of residues, particularly corn stover, is feasible once a market exists (Hettenhaus 2000). New infrastructure for the collection and processing of biomass crops will need to be constructed. The processes for this will need to develop in tandem with the growth of the biomass conversion industry. In the beginning, current agricultural practices and equipment will probably be adapted to service the biomass with specialized practices and machinery developing as the industry matures.

Expansion beyond "waste" and residue sources will require large-scale changes in the agricultural system. Techniques for growing specific biomass energy crops will need to be field tested over the range of soil and climatic conditions where biomass crops would be grown, although some of this work has already taken place. This information will need to be disseminated to farmers. One significant change is that a perennial biomass crop system cannot use crop rotation, which is a key strategy in many areas for controlling pests and disease in annual crops. Perennial crops, however, have benefits of their own, including reduced erosion and increased carbon sequestration in the soil. The necessary changes could take place over time, in parallel with the initial likely growth of an industry primarily fueled by "waste" streams. Some switchgrass is currently grown on CRP lands and, as demand for biofuels expands, this production may expand as well.

If an ethanol production plant can use many different feedstocks, this would provide additional flexibility.

If an ethanol production plant can use many different feedstocks, this would provide additional flexibility. It would appear that the use of a different feedstock would require changes in operating conditions and, perhaps, different enzymes or other biological reagents. This issue would need to be explored. Standards and methods for characterization and handling of biomass feedstocks will need to be developed.

One way to address the probable rate of such a shift is to examine historical analogies. One analogy can be made to the expansion of no-till agriculture over the last decade. From 1990 to 2002 the average rate of expansion of land under no-till cultivation has been 1.3 million hectares/year (Fawcett and Towery 2003), although the expansion rate has slowed in recent years to under 1 million ha/year. The expansion of no-till agriculture is the result of 30 years of research and field testing. The analogy to no-till agriculture may be a lower limit to the potential expansion rate for a switchgrass bioenergy crop, which can be grown with essentially the same techniques as those used for hay production.

If all the CRP lands in the US could be planted with switchgrass, then the gross biomass yield would be approximately 1.6 EJ, or 0.7 EJ of ethanol (9 billion gallons per year).[5] However, at an expansion rate of 1 million ha/year it would take 15 years, or until almost 2020, to convert this amount of land to biomass production. This may be a lower limit to the expansion rate, however, because expansion of no-till agriculture occurred under a combination of technological, economic, and policy forces. A large market for energy crops is likely to spur the necessary expansion, provided sufficient technical support is provided. A program of field testing with specific crop types may be needed to support such an expansion.

In summary, one of three factors could limit the rate of cellulosic ethanol production: production and collection (initially the collection of "waste", eventually the production of energy crops); ethanol processing and distribution (particularly the time needed to first demonstrate and then build numerous ethanol production plants); or ethanol demand. While not discussed in detail here, there is a relatively large market for ethanol blended with gasoline; however, this market has an eventual upper limit until vehicles that can operate using higher fractions of ethanol (or pure ethanol) become widespread.

Research Goals for Expanding the Use of Biomass Energy

These results lead to four research goals that would improve the potential of biomass energy, particularly liquid fuels for use in transportation.

1) *Reduce production costs for ethanol.* Reduction in the cost of ethanol production from cellulosic feedstocks has long been a research goal. Reductions can occur by increasing overall conversion efficiency, which also increases the potential contribution of a given amount of biomass, and by simplifying the conversion process.

2) *Reduce the cellulosic biomass-to-ethanol process energy requirements.* A reduction in the process energy requirements for the ethanol conversion process would reduce the cost of ethanol and improve the overall net energy balance of the system. At higher conversion efficiencies this could also result in more ethanol produced from the same amount of biomass.[6] Any such improvement could be applied to both "waste" biomass streams and dedicated energy crops. It may also be possible to develop processes with lower energy requirements that are optimized for specific biomass energy crops.

3) *Reduce the cost of biomass energy crops.* A reduction in the production cost of biomass crops such as switchgrass or hybrid poplar could enable the large-scale expansion of biomass energy supplies without a large increase in prices. Efforts in this direction include past efforts of the Department of Energy's former Bioenergy Feedstock Development Program (BFDP). Such a reduction would be particularly needed once biomass demand exceeds the amount of supply available through lower-cost "waste" biomass streams. Given that much less effort has gone into improving bio-energy crops, as compared to food crops, the potential for improvement may be quite large.

4) *Increase the productivity per unit land of biomass energy crops.* An increase in the amount of biomass that could be produced on a given amount of land would likely reduce biomass costs and, perhaps most importantly, increase the total amount of biomass energy available. This is likely to be a challenging research goal. While modest increases in biomass productivity may be feasible with current technologies, a substantial increase in biomass productivity, without a corresponding increase in energy-intensive inputs, may take some time to achieve.[7] In the long term, however, such increases are likely to determine the ultimate contribution of biomass energy to the national (and world) energy supply.

There are several areas of research opportunities behind each of these four main goals. Any improvements that reduce the cost or increase the output or efficiency along the line from producing and refining biofuels would translate directly into improved competitive economics for biomass energy.

For example, improving the biomass-to-ethanol conversion efficiency would both decrease the feedstock cost component of ethanol and reduce the amount of raw biomass input needed to get to the 4.3 EJ figure discussed above. As an illustration, a conversion efficiency of 55% (compared to our assumed 43%) would decrease the refined ethanol cost by about 5% by itself, and it would also require 25% less biomass input. At higher levels of ethanol use, where the supply cost curve is steeper, the reduction in input requirements will have a further effect of lowering costs for a given level of output by moving feedstock costs to a lower point on the supply curve (Figure 2). Conversely, for a given market price for ethanol, a higher conversion efficiency means that a larger amount can be supplied at that price.

Genetic engineering is likely to be able to contribute to both productivity increases and cost decreases, and potential bioenergy crops should be sequenced (Tuskan *et al.* 2004). Crops could also be engineered with a higher cellulose-to-lignin ratio, thus increasing ethanol yield.

Summary

Current use of biomass-based energy in the United States amounts to about 3% of total US energy consumption. Most of the use of biomass energy can be classified as "opportunities of convenience" where a biomass source, often a waste or by-product, is located near an energy user or producer. Compared to current use, a larger resource base exists for both "waste" biomass and dedicated biomass production (Figure 2).

The first phase of expansion of biomass energy would likely make fuller use of "waste" biomass sources. These "waste" streams are estimated to be capable of contributing an additional 4-5 EJ of primary biomass energy (Figure 2). Expanding biomass production beyond this level would require dedicated energy crops. The large-scale expansion of energy crops would likely require significant additional work in terms of field demonstrations. A large expansion of total biomass production, beyond perhaps 5-10 EJ from dedicated energy crops (Figure 3), will result in competition for land between biomass and conventional crops. The level at which this would occur will depend on future improvements in bioenergy crop productivity, the potential of bioenergy crops to replace existing crops (*e.g.*, for the production of animal feed), and the potential for biomass production in lands not currently used for agriculture.

Reducing the cost of growing, harvesting, and conversion of energy crops is necessary to expand the economic potential beyond that available from residue streams. As discussed above, given the present-day estimated production costs for biomass energy crops, the near-term cost of ethanol derived from energy crops is not economically competitive with crude oil as a liquid feedstock (at current prices). A reduction in overall production costs is necessary for biomass-derived ethanol *produced on a large scale* to become cost-competitive with petroleum. Such reductions could well occur. In particular, the costs of a cellulosic ethanol plant will remain speculative until such plants are built and tested. Further, the cost of bio-energy crop production could also significantly improve given that less effort has been expended in research in this area.

The analysis presented here illustrates the level of probable costs and the potential scale of biomass production in the United States. To gain a fuller picture of biomass, however, the full energy system must be considered. As mentioned previously, low-cost biomass would not be exclusively used for the production of liquid fuels. Other energy users would also use this resource where it is cost-effective. Further, at high levels of biomass production, biomass must compete with food and fiber products for land, and an integrated analysis is necessary to capture these effects.

Again, substantially increasing the productivity of growing biomass per unit of land is likely to be a challenging research goal. Such an improvement would directly provide more biomass at each cost level. Although increased crop productivity is essential in the long run, this appears to have less potential impact for the next few decades than the goal of reducing crop production costs.

Acknowledgements

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Notes

1 Assuming the biomass was used to produce ethanol using the conversion rate from Table 3.

2 The cost of process energy is a significant portion of the operating costs of a corn-ethanol plant. These costs are excluded for this comparison since a cellulosic biomass plant would not require significant external energy input (Table 3).

3 The cost estimates cited previously are based on detailed engineering cost models (Wooley *et al.* 1999, Wingren *et al.* 2003). We use the term "speculative" estimates here to indicate estimates based on more general extrapolations, including the assumption of significant R&D developments.

4 If the capacity for co-product production from all ethanol plants is much smaller than the total market for a given co-product then the price of the co-product will not be significantly changed by ethanol production. In the converse case, however, where the potential co-product production from ethanol plants is comparable to the size of the market for a given co-product then a high production level from ethanol plants will tend to drive the price received for the co-product down, thus reducing the economic benefit to ethanol plants in general.

5 Assuming CRP lands produce switchgrass using the median yield for each county from the ORECCL database (Graham *et al.* 1996). 1.6 EJ of primary biomass would produce 0.7 EJ ethanol (using the conversion from Table 3), equal to almost 9 billion gallons per year (LHV) or slightly less than 6 billion gallons of gasoline equivalent.

6 As the biomass-to-ethanol conversion efficiency increases, some configuration may require that some of the input feedstock be consumed to supply process energy (Wooley *et al.* 1999).

7 Much of the increase in food crop production, for example, has occurred due to genetic changes that shifted biomass production into the edible portion from the rest of the plant (*i.e.*, an increase in the "harvest index"). This is not a useful methodology for biomass productivity enhancement.

QUESTIONS AND ANSWERS

MAY 6, 2004

QUESTIONS AND RESPONSES OF MARK E. REY
UNDER SECRETARY FOR NATURAL RESOURCES AND ENVIRONMENT
UNITED STATES DEPARTMENT OF AGRICULTURE
BEFORE THE
SENATE COMMITTEE ON AGRICULTURE, NUTRITION AND FORESTRY
May 6, 2004

Question 1: What plans are in place to ensure that the rule for Section 9006 is finalized in the near future? Please provide a detailed timeline with your best estimates for key milestones to be reached for 9006.

Response 1: A proposed rule that provides permanent instructions for the implementation of a loan, loan quarantee and grant program authorized under Section 9006 of the 2002 Farm Bill has been submitted to the Office of Management and Budget. Since this is a significant rule, OMB will need to review it prior to publication as a proposed rule in the Federal Register. We anticipate publication by end of July 2004. A 60-day comment period is included in the proposed rule.

Question 1b: Similarly, what plans do you have to ensure that the 9002 effort moves forward more expeditiously?

Response 1b:

USDA has made significant progress on a number of fronts in implementing Section 9002 of the Farm Security and Rural Investment Act of 2002 (FSRIA). These include the following accomplishments.

USDA has published a proposed rule in the *Federal Register* with a 60 day public comment period. Two hundred and seventy one public comments on the proposed rule were received. Those comments have been reviewed, policy issues raised by the comments have been identified, and a Senior Policy Group within USDA has made decisions regarding four major policy issues identified in the comments. We are in the process of finalizing the draft final rule and are circulating it within USDA for clearance. After clearance within USDA and review by the Office of Management and Budget (OMB), the final rule is expected to be published in the *Federal Register*.

USDA has, through its cooperative agreement with the Center for Research and Industrial Service (CIRAS) at Iowa State University, been developing an electronic information system to provide on-line information on the Federal Biobased Products Preferred Procurement Program (FB4P) and specialized information on biobased products that fall within items (generic groupings of biobased products) designated by rule for preferred procurement. This online system:

- Will be available at www.biobased.usda.gov at USDA's National Information Technology Center at the end of July, 2004;
- Will provide specialized information on designated products to federal purchasing agencies that is product specific and provides manufacturer contact information; and
- Will allow biobased manufacturers/vendors to post specific information by the end of August, 2004.

Additionally, CIRAS currently is working with manufacturers of twenty-seven items (generic groupings of biobased products)to gather material for testing, and conduct testing to access the statutorily required information necessary to designate these items. By July, CIRAS will have developed test information sufficient to support a proposed rule designating from several of these items for preferred procurement.

USDA also has committed additional resources to the task of implementing Section 9002 of FSRIA. USDA's Chief Economist has made available $220,480 to support a contract for rule writing support for the purpose of drafting proposed and final rules designating the first tranche of items for preferred procurement and for drafting proposed and final rules establishing a voluntary labeling program. In addition, the contractor will provide a detailed management plan for completing the designation rule making and the labeling program rule making will be developed. Currently USDA is reviewing contract proposals.

In addition, USDA's FY 2005 Budget request includes a request for $2.5 million to support operation of the preferred procurement and labeling programs, testing of biobased products, designation of items (generic groupings of products) by rule for preferred procurement, interagency biobased product procurement efforts and operational expenses for a procurement program operated within USDA, with the program to serve as a model for other Federal agencies in cooperation with OMB's Office of Federal Procurement Policy.

Question 1c: Please provide a detailed timeline with your best estimates for key milestones to be reached for both 9006 and 9002?

Response 1c: USDA has the following priorities in implementing and operating the preferred procurement, labeling, and model procurement programs of Section 9002:

- Issue a final rule establishing the Federal Biobased Products Preferred Procurement Program during 2004.

- Issue a proposed rule, with a 30-day public comment period, designating from one to several items (generic groupings of products) for preferred procurement under the program by the close of the current fiscal year with a final rule to follow prior to the end of calendar year 2004.

- Issue a proposed rule, with a 60-day public comment period, establishing the voluntary labeling program provided for under Section 9002 of FSRIA, by the end of calendar year 2004.

- Issue a final rule establishing the voluntary labeling program by the end of June 2005.

- Issue subsequent proposed and final rules to designate items (generic groupings of products) for preferred procurement as expeditiously as test data can be developed, in cooperation with manufacturers/vendors of biobased products, to satisfy the statutory consideration requirements for designation.

For Section 9006, a proposed rule that provides permanent instructions for the implementation of a loan, loan guarantee and grant program authorized under Section 9006 of the 2002 Farm Bill has been submitted to the Office of Management and Budget. Since this is a significant rule, OMB will need to review it prior to publication as a proposed rule in the Federal Register. We anticipate publication by end of July 2004. A 60-day comment period is included in the proposed rule."

Question 2: The 2002 farm bill added for the first time significant funding for the Biomass Research and Development Act of 2000. Although part of this funding is granted in cooperation with the Department of Energy, most of these funds are provided by USDA. Given that your missions are different, how does USDA's process for evaluating and making funding recommendations differ from that of DOE? How, for example does USDA take into account the impact and benefit of projects on rural development and farmer income?

Response 2: Because USDA's mission is different than DOE's, USDA has developed programmatic review factors specific to our department that focus on rural development and self-sufficiency for rural communities. In the 2004 solicitation, program policy factors will give precedence to projects that:

1. Emphasize near-term implementation and application to commercially viable biomass production, management, handling, processing, and manufacturing.
2. Involve consortia that include Tribal entities.
3. Address methods for biomass production, harvesting, handling, and utilization that are environmentally beneficial and cost effective.
4. Exhibit mobility and adaptability of economically viable and relatively small-scale biomass utilization technology.
5. Improve rural-based processing and manufacturing of biobased products and power from biomass, including those that demonstrate the potential to stimulate revenue streams and economic improvement in rural areas.
6. Develop, diversify, and expand renewable biomass products systems, leading to self-sufficiency for rural communities, including farmers, ranchers, rural communities and institutions, Tribes, local governments, and businesses.

Question 3: When do you anticipate furnishing us with your latest report on the progress of the Biomass Research and Development Initiative?

Response 3:

The report on project funding for fiscal year 2004 is currently in draft stage with edits being made by both departments. Our goal is to deliver the report as expeditiously as possible once funding decisions have been made by early July, 2004. We are also planning to submit a report during the summer on the status of the projects underway.

Department of Energy
Washington, DC 20585

September 13, 2004

The Honorable Thad Cochran
Chairman
Committee on Agriculture, Nutrition, and Forestry
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

On May 6, 2004, David Garman, Acting Under Secretary for Energy, Science and Environment, testified regarding emerging opportunities for utilizing agricultural biomass to enhance future energy production and security.

Enclosed are the answers to three questions that were submitted by Ranking Member Tom Harkin for the hearing record.

If we can be of further assistance, please have your staff contact our Congressional Hearing Coordinator, Lillian Owen, at (202) 586-2031.

Sincerely,

Rick A. Dearborn
Assistant Secretary
Congressional and Intergovernmental Affairs

Enclosures

QUESTIONS FROM RANKING MEMBER TOM HARKIN

Q1. Following up on our discussion at the hearing, please provide at your earliest convenience further details about the Department's changed cost estimates for making cellulosic ethanol.

Previously the DOE has provided detailed cost estimates for cellulosic ethanol. As we had discussed, just a short time ago DOE estimated its cost at $1.40 per gallon. However, you now say that number was off the mark. My understanding is that DOE recently determined that it should have been $5.50 and that now production may only cost $2.50 to $2.75 a gallon because of research and development advances.

In light of the Iogen announcement that it has sold cellulosic ethanol commercially, a global first, do the DOE cost estimates still make sense? Presumably the ethanol produced by Iogen is price competitive with that of corn-based ethanol.

A1. The Department's ethanol cost estimate in the FY 2004 budget submission (developed in 2002) was $1.40 per gallon, assuming niche situations where feedstock cost was as low as $15 per dry ton feedstock ($0.21 per gallon of ethanol). Significant efforts over the last few years have greatly increased our understanding of the costs of feedstocks, enzymes, and other components associated with large scale ethanol production, as well as better overall plant designs, resulting in the current estimate of $2.50 per gallon.

The Department has not seen Iogen's estimated cost for the ethanol produced in their demonstration plant. However, Iogen has communicated to us that from a cost accounting perspective, the company is not including the cost of construction of its production facility in its ethanol product costs. Therefore, the selling price of the company's ethanol under these circumstances only needs to cover operating and delivery costs, plus profit, excluding all capital costs on their income sheet.

This situation is unique and makes comparison to the broader ethanol market challenging.

It is also difficult to view the Iogen plant as a commercial entity because of its size. Iogen's current rated production is approximately 250,000 gallons per year, which represents only 0.009% of 2003 domestic production. An average farmer-owned, corn-to-ethanol plant is 120 times larger, with a capacity of 30,000,000 gallons per year. It is difficult to ascertain how the small size of the Iogen plant could lead to a profitable and cost-competitive situation under normal accounting methods.

Q2. Now that you are the Acting Undersecretary for Energy, Science and Environment what are the Administration's plans to fill your position of Assistant Secretary for Energy Efficiency and Renewable Energy?

If there are no plans in place to fill that position, will you continue to maintain two jobs? How might this affect DOE's work to aggressively promote renewable energy and energy efficiency?

A2. As the Acting Under Secretary, I am committed to advancing the goals in the Department's Strategic Plan and the implementing the recommendations in the Administration's National Energy Policy. In each of these documents, renewable energy and energy efficiency technologies play important roles in enhancing the nation's energy security and improving environmental quality. I feel the experience I have gained the last three years serving as the Assistant Secretary of the Office of Energy Efficiency and Renewable Energy, in combination with the opportunity I have been given to be the Acting Under Secretary, will act to strengthen the Department's work to aggressively promote renewable energy and energy efficiency.

Q3. It is my understanding that DOE no longer has a biomass power program and little to no biomass feedstock research being done. Why?

Is lowering the cost of cellulosic feedstock collection and transport necessary and important? If so, what is DOE doing in this area? What should the role of DOE and USDA be in cellulosic collection and handling?

A3. The Administration's priority on reducing the Nation's dependence on oil imports and the reduction in resources available for program goals caused by congressionally-directed activities forced the program to make difficult choices.

Although biomass power is not a main focus area of program R&D, electricity may indeed be derived from a biorefinery. In FY 2005, in collaboration with industrial partners, the biomass program will demonstrate the continuous production, cleanup and conditioning of biomass syngas. Various aspects of this work are applicable to the production of both bio-based products and power.

Lowering the cost of cellulosic feedstock collection and transport is important. Most of the Federal research aimed at developing additional feedstock supplies is conducted by the Department of Agriculture (USDA) through its bio-energy crops activities, while DOE's Biomass Program remains more intensely focused on conversion of biomass feedstock to energy, fuels, and products, in alignment with its mission. However, DOE and USDA continue to coordinate and collaborate on developing technologies for harvesting, transporting and storing agricultural residues in order to reduce the cost of feedstock delivered to future biorefineries. For example, in a FY 2004 joint USDA/DOE solicitation, USDA requested proposals on biomass production, collection, handling, processing and transportation.

Committee on Agriculture, Nutrition and Forestry

United States Senate

May 6, 2004 Hearing

Questions for Tom Ewing

Q1: As the chair of the Biomass R&D Act Advisory Committee, are you and the other Committee members getting the information necessary to carry out your legislative mandate? Are USDA and DOE providing you, for example, with cogent and transparent programmatic and budgeting information? Based on information provided by USDA about the solicitation process for section 9008 funds, are you and the Committee able to independently evaluate whether the funds have been distributed consistent with the Act and the missions of USDA? If not, what can we do to help make that information available?

A: The answer to the first three questions is "Yes". Both DOE and USDA have within the parameters of the Biomass Research and Development Act and the Federal Advisory Committee Act provided the necessary information needed to carry out our legislative mandate. In regard to budgeting and programmatic information, we have received numerous presentations over the course of our meetings from both DOE and USDA. Although the USDA efforts in the biomass arena are less centralized than DOE's, (in a variety of agencies), and therefore tougher to aggregate and analyze, USDA has in my estimation successfully compiled data requests for the committee's use. With two years of solicitations completed, we have evaluated and offered suggestions as to how the Section 9008 funds should be distributed differently. Many of those suggestions given in the summer of 2003 were in fact incorporated into the joint USDA/DOE Fiscal Year 2004 solicitation. We have also asked the departments to develop a matrix of all past projects so that we can continue to monitor comparisons of the successful proposals with the missions of the departments and the intent of the legislation. USDA and DOE are jointly working on this endeavor.

Q2: Please elaborate for us on two of your key recommendations. Do you believe the $60 million for three cellulose to ethanol facilities ought to be cost-shared through a competitive solicitation process? Presumably that level of funding will be insufficient to cover the full plant construction costs, but serve as an important signal to private sector about our commitment to ethanol production.

And on your second point having to do with procurement and incentive policies, what specific programs are you referring to? Are you recommending that we craft new policies and programs to bring about dramatic increases in the production of bioenergy and biobased products?

A: The recommendation for the three ethanol plants should be based on a competitive solicitation with a minimum of a 50% cost share, possibly more. DOE's objective of the first two solicitations under this act, FY 2002 and FY 2003, and the next is to have projects, that when completed, will result in processes and design specifications for biorefineries. These biorefineries, that will use existing wet or dry mill starch based ethanol plants as a starting point, will be able to produce cellulose to ethanol as well as high value chemicals and products, including heat and power. This biorefinery concept will make it possible for the enterprise to be more competitive than a stand alone ethanol plant. When these current projects are completed over the next few years it will be time to commit ourselves to the more costly phase of actually building facilities. Since there will still be considerable risk, the private sector will still need the government to be a partner in order to get financing. The level of risk should determine the level of cost share.

While Committee members were pleased with much of the work the agencies are undertaking in the areas of economic analysis, education and outreach, and federal procurement, they found significant gaps in the area of policy support for biomass, which they believe will seriously jeopardize the prospects for successfully achieving the goals set forth in the Vision. In particular, the Committee has recommended a substantial increase in efforts to commercialize proven biomass technologies and remove regulatory barriers to their widespread adoption.

Efforts to commercialize proven biomass technologies are an essential element of the Roadmap, but at present they are woefully under-funded. Small piecemeal efforts such as those included within the State Technologies Advancement Collaborative will do little, if anything, to make these promising technologies commercially viable.

Both departments, but particularly DOE, should give much greater attention to public policy measures that can dramatically increase the commercial viability of biomass technologies at relatively low cost. The Committee's Roadmap outlines strategies and recommendations on federal incentives, financial incentives to support existing facilities, and a public benefits fund. The Roadmap also includes measures to foster procurement of biomass energy and biobased products including federal procurement, performance standards, renewable portfolio standards, and other measures. Incentives available from the Commodity Credit Corporation in FY 2004 should not be reduced from FY 2003 levels. In addition, federal incentives for methane-to-electricity generation should be allotted per ton of manure disposed of rather than per kilowatt-hour generated. A discussion of these and other policy initiatives are discussed in further detail in the Roadmap available at:

http://www.bioproducts-bioenergy.gov/pdfs/FinalBiomassRoadmap.pdf

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