Frederick Michel: With regard to development of an ideal conversion technology, we need to keep in mind that cellulose, hemicellulose and lignin are the three primary feedstocks we are working with and there are multiple processes we can apply to them and products we could make from them, whether it’s gasoline, butanol, ethanol or methanol, each with particular strengths and weaknesses. Lignin fractions have potential uses as feedstocks for energy and chemicals and as sources of carbon for reintroduction to the soil.

We also heard about the importance of the logistics of harvesting and storage, and soil management and optimizing nutrient use in the production of feedstock crops.

The ideal feedstock crop is likely to be region-specific.

One thing that I didn’t hear much about, but may be important, is modification of corn and soybean to improve their suitability as energy crops, by increasing yields of ligno-cellulose in stover and straw, for example, in addition to increasing seed yield. And the best thing I heard is that biomass is now cheaper than oil.

Dwayne Siekman: I applaud the speakers for their coverage of diversified feedstocks. It may shock you, but the Ohio Corn Growers Association does support cellulosic ethanol. We supported the Farm Bill in terms of the cellulosic ethanol industry receiving a higher blender’s credit. We see the need and we look forward to working together with the cellulosic industry. With that, I do want to caution everyone not to overstate corn
ethanol. When I hear “every kernel of corn converted to ethanol will supply 20% of the fuel” or “to make 35 billion gallons we need 69 million acres,” we need to keep it within the context of the Energy Bill. David Bransby pointed out a 15-billion-gallon cap and I think that’s where we need to focus on the corn side. The media’s treatment of food versus fuel has led to much uncertainty in Washington, DC. Governor Perry of Texas is already calling for waiver of the renewable fuel standard, whereas the renewable fuel standard is very important to the cellulosic industry. A couple of weeks ago a farmer told me that he is not obligated to plant corn or soybean or wheat. Farmers are going to plant the most profitable crop. So, land use really needs to be taken into consideration; food versus fuel will be there regardless, whether it’s corn or a dedicated energy crop.

Tom Richard: We’ve heard a lot about win-win solutions to this energy challenge. We also need to think about who the losers are in the different systems and be proactive about prepositioning what can happen for them. There are issues in this regards in certain regions in the country and the comments on the Texas-livestock industry are right on the money. It’s something for this industry to be proactive for and for the university community to be thoughtful about as well to be focusing on. There is a huge opportunity in terms of co-production of food from energy-crop systems and the conversion processes. That’s a lead in to the main thing I want to comment on. We heard a lot about dedicated energy crops, whether they be perennial grasses or sorghum and other grains. We need to think about the multifunctionality of agriculture, which is what we’ve had in this country for a long time. To some extent, we’ve strayed from that in the last few decades, but, at least in my view and many of the folks I talk with, biofuels provide an opportunity to regain some of that multifunctionality. That means not just food and fuel—although that’s got to be a starting point—but also other benefits that we expect from agriculture, including the ecosystem services that have been discussed. Along those lines, I want to elaborate on some of the comments that David Bransby made about aspects that we don’t often focus on. If you look at the landscape of this country, particularly the rain-fed regions, the dominant species of the natural ecosystem is generally forest. The prairies are there in the Midwest, but much of the east, where there’s a lot of the rain, is forested land. We don’t often focus on that, but it represents a huge opportunity. That’s one of the low-hanging fruit in this industry. We are doing work on that at Penn State. We happen to be in the hard-wood-rich region, but there is a lot of that material in many parts of the country. The numbers are impressive. The billion-ton study provided a very conservative analysis of the wood resource. The potential losers there are the timber industry and the pulp and paper industry, which are nervous about someone else going after their resources and potentially driving up their feedstock costs. They have allies in the US Forest Service, which is very conservative about making estimates about what the forest can provide, and basically have focused on byproduct wood residues and waste. There’s an opportunity to get proactive about that and to think more carefully about what can happen there.

Municipal waste is another large piece. On average, each of us produces about a ton of solid waste per year, mostly organic matter. We recycle some of it but not all. We need to think carefully about the best use for that material. It has the advantage of being already
collected. It actually has a negative value because somebody is paying to dispose of it, oftentimes in an environmentally suspect fashion; significant opportunities are worthy of exploration.

Possibly least appreciated is the opportunity to actually intensify our existing agricultural systems to provide energy crops along with food crops on the same area of land. We see hints of that, such as the discussion of co-production of corn grain and stover for energy. We've heard a little about cover crops, which represent another opportunity. If you look at the 400 million acres of crop land that we have in this country and consider a modest ton per acre of cover crops growing in winter when you don't have anything else there, helping to conserve nutrients and soil, that's almost halfway to a billion tons. You know you can run the numbers lots of different ways, but there are some big opportunities out there that we need to recognize.

I'll finish with a follow-up to David Bransby's comment about wet storage and dry storage. This happens to be my technical area, and I often have to defend wet storage, although less often than 5 or 10 years ago. Wet storage is a bit more expensive. If you look at the numbers it might be $5 to $10 a ton. We think there are some positives in terms of reduced downstream processing, at least for some conversion processes. But when you look at $250 in a ton of biomass as its energy value, we are really talking about the margins here. I worked with a company in Iowa that went bankrupt because they lost 100,000 tons of corn stover that they were trying to store dry. When you store stuff dry, it can burn. So, there are safety issues and, equally important, some security and risk-aversion opportunities that we should think about, not just in storage, but in the entire value chain because farmers are risk-adverse. Although the playing field is leveled in some ways with the cellulosic subsidies in the new Farm Bill, there are other risks that aren't protected in perennial-grass and energy-crop production. We need to be thoughtful about those and make sure that we have the right safety nets in place.

Siekman: That is one point I wanted to highlight. Traditional farm programs in the new age of bioenergy or biomass are going to have to adjust—whether it's the sugar policy, corn policy, soybean policy, etc.—to provide that safety net too. Absolutely.

William Ravlin: Very good. Thank you very much. Very thoughtful comments in a short period of time. We will open it up to some general questions.

Audience Member: Has there been much response to those articles in Science? David, you didn't talk about that.

David Bransby: There have been some responses. I don't want to get too personal, but there were responses right out of the University of Minnesota, the origin of a couple of those papers. The colleagues responded negatively to the articles. And there have been letters to newspapers and so on, but that has very little impact because, once an article is out there, the damage is done. The key response to this is “let's just get to it—get busy and do it—make it cheaper than oil and sustainable,” and then we will prove them wrong.”
Nancy Hodur (North Dakota State University): I have a question about a chicken-and-egg problem in converting to cellulosic and dedicated energy crops. A farmer will say, “If you buy this, I’ll grow it.” The conversion people will say, “If you grow this, I’ll buy it.” I think that such non-technical issues will be barriers to next-generation cellulosic ethanol production. Any comments on that chicken-and-egg problem?

Bill McCutchen: When I got to Texas A&M about 2 years ago, the first thing we did was an analysis, looking at the strengths, weaknesses, opportunities and threats to developing our program, and the one thing that we may have overlooked to this point is the logistics, the circle of economic feasibility. Unless technology changes—for example, rendering to a more-flowable form—we have a 50- to 60-mile radius for harvesting and transporting biomass to the conversion facility. We are working with a couple of co-op groups, one of them being the sugar-cane industry who work directly with producers. They know where they are planting the sugar cane and they have two different harvest fronts. They also grow cotton, soybean, corn in rotation. Sugar cane will grow for 5 to 8 years in the same ground and then they move it. But your point is exactly right. The logistics of moving all that biomass from point A to point B is a significant problem that we have to address, and we are working on it.

Bransby: I’ve had the privilege of working with a company that is going commercial now, and so I am close to the way they are thinking, which influenced a lot of what I said today. It’s a reason why I push hard that this technology needs to be flexible with respect to feedstock. If it is flexible, it will use feedstocks that are already available—such as residues and municipal solid waste, because they are cheap. In line with the chicken-and-egg problem you raise, industry people are going to say, “Where are the feedstocks now?” The industry is chaotic right now. So much is going on, it’s impossible to keep track of everything because you don’t know what you don’t know. We think we are ahead of the game. We are ahead of the conversion technologies. But I’m not certain about that. Somebody might pop out with a commercial technology within 3 months and then we’re behind. I work a lot with Vinod Khosla these days and one of his favorite sayings is, “All predictions are wrong.” We all are going to be wrong. If you want to predict the future, invent it.

Stephen Long: I’ve been surprised over the years how often farmers actually are ahead of us. When we started working with miscanthus in Illinois, where it was very out of the ordinary, a farmer wanted some to grow and we said, “Fine, but there’s absolutely no market for it.” And he said, “Well, anyway, I want to grow some.” So he grew about 2 acres. He sold it last year for about a $250,000 dollar to a company that is setting up miscanthus propagation. We saw similar models in Europe of farmers who were willing to take those risks. Actually, if you can produce a significant amount of biomass per acre there are smaller markets out there. For example, the horse bedding industry: fall-harvested switchgrass and miscanthus are apparently valuable to them. They fetch a premium price, much higher than straw, for example. I agree with David that the big opportunities will come as these cellulosic plants are placed.
Richard: We do need to look carefully at the arrangements of the refineries with the producers because biomass is not as easy to move long distances as grains are. It's a captured relationship that needs to be explicitly worked out to mutual benefit. Our grain-marketing structure is very flexible. We can move those materials around the globe. They are annual crops so farmers can adjust to the markets, not immediately but at least in a feasible time frame. And when you are asking a producer or landowner to make a multi-year, perhaps decade-long commitment to a single facility that is within a commercial hauling distance, there's got to be a strong level of trust there, reinforced by different kinds of contractual arrangements from what we have right now in most of agriculture. There are exceptions. The sugar-cane industry is one area to look at, also the pulp and paper and wood industries, where those kinds of long-term relationships have been developed.

Mitch Minarick (University of Illinois): David, you alluded to some of the properties of an ideal conversion technique and made it seem like it's a thermochemical process. Could you elaborate on whether that is gasification or pyrolysis and also some of the techniques to produce gasoline. Secondly, do any panelists disagree that a thermochemical process would be the ideal way to convert a cellulosic feedstock? In other words, does anyone think that biological would be the better way to reach viability in this market?

Bransby: It’s neither gasification nor pyrolysis. It's catalytic cracking involving particle-size reduction of the raw material down to probably between 1 and 10 microns—a fine powder—then using catalysts to break it down further into molecules and catalysts re-synthesize these into the alkanes or gasoline or diesel. You do need elevated temperature, but nowhere near what you have in gasification.

McCutchten: Based on what we’ve seen, it may be a combination of both and composition of the feedstock is going to provide byproduct opportunities beyond fuels. For example, one of the companies we are working with actually wants more lignin, so you can imagine what they might be using that for.

Long: As a plant biologist, I'm not an expert on either route, but I certainly wouldn't take the risk at this stage of ruling out either one. David mentioned grinding down to a fine powder, which means you have to put in a significant amount of work and if you are going to reduce to alkanes your catalytic process has to remove a significant amount of oxygen. There's got to be an energy cost there. On the biological route, we know, for example, that the cow’s rumen or the termite gut are efficient at releasing the sugars from cellulose and hemicellulose, but are not so good with lignin. But we do know that there are biological solutions out there that we haven’t managed to harvest. A bug in a termite’s gut can be sequenced now in a couple of hours, so biology is changing rapidly. It’s dangerous, to rule out the biology option at this stage.

David Koetje (Calvin College): Municipal waste streams have been mentioned. On the other hand, these are far more complex biologically and chemically than crop biofeed-
Richard: Landfills are a resource. It’s good that we have them and we will mine them for lots of different things. Energy is only one. Materials are there as well. And there’s some rich ore. But it’s going to be a while before we actually tackle that. Opening them will be opening a big can of worms. No pun intended there. The current organic waste stream needs to be looked at carefully. Yes, it’s diverse, but of the first-generation commercial facilities that are going to be built in this country, several are targeting low-hanging fruit in terms of consistent supply, large volume, as a concentrated low-cost resource. We are going to learn a lot more about how they will work on a practical and commercial scale in just the next few years.

Michel: There are two approaches to looking at that. Here in Columbus we have a landfill that is producing gas. Some say that the efficiency is low at 20 to 25%. Some say that that 70 to 80% can be collected. The other approach is to separate feedstocks either after collection or, better, at the source. For example, waste paper is an ideal feedstock for ethanol production; you can get higher yields than from most of the feedstocks we’ve been talking about. Waste paper does have value in the market when separated. Different grades of paper, ranging from $100 to $200 per ton, can be purchased as a commodity. So, these are opportunities. One of the difficulties is being in agriculture without experience in dealing with waste collectors. New types of government structures are involved in the waste-collection industry and landfills. How do you broach that and find a champion in that industry willing to work with you to develop new, possibly risky, technologies that will lead to production of energy and/or other bioproducts?

Bransby: Getting back to the plant that is being built. In Alabama they are starting to develop a feedstock supply. It’s in a small town that couldn’t possibly afford what has just been described as separation. Recycling costs money, but if they are getting paid for that feedstock that can pay for the whole system, and in fact that’s exactly what we are looking at. This small town already recycles paper and plastics. Wet material is more difficult, and the glass and metals have to go to the landfill. There is definitely an opportunity here. But coming back to the need for feedstock flexibility—you can operate with relatively small amounts.

Getting back to wet storage—the technology that I’m talking about needs no more than 20% moisture. So, I did see both storage and conversion technology—sorry, I am totally influenced by this technology because I think it is so good.

Ravlin: A friendly amendment on this question here and I guess I would direct it back to Tom and Fred and anyone else. We’ve talked a lot about low-hanging fruit and feedstocks we can start with that are already available and just haven’t been tapped into. If you were to rate the top three feedstocks available today, what would they be?
Richard: I would say our solid-waste stream, our native forests and our crop residues, each of which has different associated challenges, but they are all out there right now. We wouldn’t have to ask a single landowner to do anything radically different from what they are doing today.

Michel: I would definitely say paper going to the landfill. It’s a large fraction of many landfills. Also, food-processing waste. I think for anaerobic digestion it’s another low-hanging fruit we can look at especially in Ohio and other states that have diverse agriculture. And I like the energy crops like miscanthus. Twenty tons per acre sounds like a lot of biomass.

Bransby: What would you do if you had a processing plant ready for operation and flexible with respect to feedstock. You’re going to look for the cheapest. First, municipal solid waste is the cheapest. I’ve heard that clean wood chips are available in the southeast for around $30 a dry ton. So wood’s got to be next. It’s out there. But this doesn’t reflect negatively on energy crops. I’m in that business myself. The billion-ton report assumes 55 million acres of dedicated energy crops. If we were asked to plant 1 million acres of switchgrass next year, we wouldn’t have enough seed. It’s just not there. So, it’s going to take a bit of time to integrate. We will integrate it in time, but if we were to start now, those are the feedstocks.

Irwin Goldman (University of Wisconsin): I understand the drive towards an ideal crop model like a C4 grass, like miscanthus or even corn, but there’s also a desire for diversified agricultural systems and the fact that we will have to have rotation crops. Could the panel comment on root crops that might make good energy crops and whether there is potential for that kind of cropping system for biomass?

Long: Diversification was part of our initial motivation. Farmers in the region showed interest in diversification, particularly those growing corn and soybean. Of course this was when prices were lower. Putting a crop like miscanthus or switchgrass on poorer soils has the potential to boost soil organic matter levels and diversify income stream. When you then take that crop away and plough, you see considerably higher yields from your corn or soybean. At current prices, of course, farmers on the best land are going to think twice about doing that. With respect to root feedstocks, China is using cassava to make ethanol. They banned the use of grains for making ethanol although I’m not sure that cassava circumvents the food-versus-fuel issue. Syngenta has developed what they call a tropical sugar beet. It is a true Beta vulgaris, but it has proved quite productive in areas of the tropics. Obviously, it doesn’t flower. Although it doesn’t give the sugar yield of sugar cane, it’s being used in Europe for ethanol. Even in the upper Midwest, yields of sugar beet are reasonable. With the prices we are now seeing for oil, you can envisage a viable system based on sugar beet. If we can get close to 100 gallons per ton from lignocellulose, then I feel the solution is to go with the highest-yielding material to avoid the conflicts that are causing problems at the present time.
Richard: Sugar beet and fodder beet are pretty interesting for the United States. If you look at gallons per acre, they could beat corn in Pennsylvania and I suspect in Wisconsin, Ohio and Michigan as well. That’s pretty easy technology—starches and sugars. So that could happen today. I do think that the question of diversity and rotations is important, and I’m not sure that below-ground options work for the winter time. Above ground, we are interested in winter barley and winter canola, both of which we can convert with grain and oil technologies available today and with cellulosic technology coming online. I think it will open up a lot of other winter cover crops that are fast growing and high yielding, albeit not as high as a dedicated energy crop. Putting something on the ground in the winter will improve the soil, reduce erosion and make the land look pretty. Those are all things to be thinking about as we grow this industry.