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OPPORTUNITIES FOR BIOBASED PLASTICS

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Good afternoon, and thank you. It is a pleasure to be here and share with you my thoughts on opportunities for biobased plastic products in the chemical industry. Looking at the effect of biotechnology on our industry, five major thoughts come to mind:

1) If history repeats itself, biotechnology, like other new sciences in the past, will not evolve exclusively in a life sciences mode. Instead, it will converge seamlessly with other sciences to create new applications and even new industries.
2) This technology is potentially disruptive. It will compete with existing chemical technologies at a low level for some time and then roll forward in a groundswell.
3) Evidence for this evolution exists already. There are many examples of biotechnology's ability to create innovative new products and processes.
4) This technology is not mature; it has many missing links that need to be worked on.
5) And finally, as an industry or industries, we need to take collectively all the public policy actions that allow the power of the technology to unfold.

Convergence

So, let's first go to the notion of seamless convergence of biotechnology with other sciences. The 20th century is known as the century of physics and chemistry. These were the dominant sciences that fed on each other to create an endless stream of new materials, products, processes, and equipment at ever-higher performance and at ever-lower cost. Without chemistry, no pharmaceutical industry. Without silicon, no information technology.

The 21st century is already earmarked as the century of biotechnology. The addition of biotechnology to an already impressive arsenal of sciences will over time impact every facet of our lives. This co-evolution and convergence has begun: bioethanol as energy, genetically enhanced seeds for improved food, biomaterials, biopharmaceuticals are all for real already; biosensors and biocomputers are on the lab bench. The power of this technology is much broader than just Ag, nutrition and pharma.

Convergence takes time. All of the major chemical discoveries that make up today's large uses were discovered in the 30's, 40's and early 50's**.**
It took the chemical industry 30-40 years to convert the initial scientific discoveries into reliable and large-scale use. By large-scale use, I mean low cost and high performance materials, made with safe production technologies and used with Responsible Care ®. As examples, nylon and polyethylene were

discovered in the late 30's. These initial products had nothing in common with the packaging materials or clothing fibers we use today. Only a massive amount of new science and new knowledge enabled this performance improvement over time.

Disruption

For the chemical industry, biotechnology is likely to be disruptive. This is what a study by the National Research Council of the U.S. predicts. The prediction of 10 % liquid fuels and 25 % organic chemicals production from biofeedstocks by 2020 is viewed by many as very reachable, if not conservative. Today, 1-2% of liquid fuels is made up by essentially bioethanol. For organic chemicals and polymers, 10% of today's world production is biofeedstock based. These are mostly fermentation based organic and amino acids, enzymes, bulk antibiotics, vitamins and the like. The current worldwide production of fermentation based products including bioethanol is already 10 billion pounds, worth about 4.5 billion dollars and growing at 7-8% yearly.

The oil based chemical industry we know today was rapidly built to an enormous scale, turning out low-cost products with good quality and applications profiles. The key competencies developed over the years were catalysis, chemical engineering and material science. It is easy to visualize a possible future duality in feedstock's and processes. The existing commodity grain and oil processing infrastructure produces the carbohydrates needed for bioprocessing in the form of sugars. Technology and specialty processing is put in place in order to also use plants as factories and express specific oils, biopharmaceuticals or polymers in identity preserved crops. However, bioprocessing is significantly different from conventional chemical processing, with operations conducted on mostly solid feedstocks without pressure or heat and mostly in an aqueous medium.

In order to participate in this future duality in feedstock's and processes, Dow's Industrial Biotechnology Business Vision is to transform renewable resources into existing or new value added products. Our core strengths in process engineering and low cost production provide us a competitive advantage in new product development from biotechnology.

Let's take a closer look at large scale bioprocessing. In order to be useful economically, biocatalysis, either fermentation or enzymatic conversion needs to be matched with efficient bioreactor, separation and recovery designs. As mentioned already, the dilute aqueous media operation adds a lot of cost. So the challenge is not to lose the benefits of low-cost biobased feedstock's through excessive downstream processing costs. And plant expression has similar engineering challenges in separation and recovery. The advent of genetically enhanced host systems in the late 90's that brings about new exciting prospects for the chemical industry. New enabling technologies create an enormous diversity potential for biocatalyst discovery and development. In addition, metabolic engineering enables pathway shunts and elimination of side products, thereby improving yields and reducing separation costs. These capabilities will result in a dramatic upgrade of the bioprocessing tools available

So, looking ahead, we can identify three major driving forces that will create disruptive change in the chemical industry: First, biotechnology is a powerful source of innovation for new products. New products are the lifeblood of companies, critical to business renewal and growth. And they respond to profound societal aspiration, by now even expectation. Second, biotechnology can demonstrate improved economics. Not only lower feedstock costs, but also lower investment and operating costs. Significant potential business value can be captured here. Finally, there is the promise of products with reduced environmental footprint.

Innovation/New Product Development

Let me now give a few examples, from Dow that illustrate the progress being made. New plastic product opportunities are envisioned from bio-derived oleochemicals. Convergence of Dow's low cost processing expertise with biodervied materials offer the opportunity to develop products with new attributes or lower cost plastics for existing markets. Discovery R&D is occurring now through an Oilseed Engineering Alliance to discover options for enhancing plant oils so they can be used to replace traditional petrochemical based raw materials in chemical manufacturing.

The next example is one of a large volume, lower price product. Last January, Cargill-Dow announced the construction of a 300MM pounds polylactic acid plant and 400MM pounds lactic acid unit. Polylactic acid is the first polymer produced from renewable resources that competes with high volume products such as Nylon, PET and polyethylene and this in a multitude of large applications. The production process involves dextrose fermentation to lactic acid, followed by a dehydration to lactide. Polymer production takes place in a conventional polymerization process using a chemical catalyst. The dextrose to lactic acid route has 100% theoretical yield and conserves all the carbon, thereby making it an economically favorable configuration.

This slide shows some of the key performance attributes of PLA in a variety of packaging applications.

- in candy wraps, PLA replaces cellophane
- in bottles, PET
- in paper coating, polyethylene
- in rigid containers, again PET

This demonstrates quite a broad performance spectrum and a good price/performance value proposition for PLA! We see the same versatility in fiber applications. PLA competes advantageously with nylon and polyester and can be blended with other natural fibers such as cotton. Woven cloth made from PLA fibers has a silk like feel to it. It also unique wicking and moisture management characteristics, in addition to other valuable attributes.

Life cycle inventory data such as gross energy requirements shown on this slide gives a good measure of comparative sustainability of products. About a third of PLA's energy requirement comes from sunlight. So PLA's consumption of fossil

fuel energy compares favorably with all competitive products. And this data includes all energy needs from cradle to grave, from farming input for corn to the disposal of the material.

We see a lot of evidence that biotechnology and bioprocessing are becoming useful tools in the hands of chemical engineers. I showed you a few examples just now; and there is a lot more exploration and product development effort underway in oil, chemical and biotech platform companies. There are, however, some missing links on the way to a broader use base. This chart from the U.S. Council for Chemical Research describes the overall knowledge and experience base for the two sets of feedstock's and processes. The chemical processes using fossil fuels are mature, with decades of experience. Bioprocessing of renewable resource feedstock's is emerging, but still has a narrow working base.

To be truly successful, we will have to bulk up the lower right hand quadrant with substantially more knowledge. Just a few biotechnology challenges to be solved, by way of example:

- technology to access potentially fermentable sugars in lignocellulosic biomass
- single microbial systems to efficiently convert 5 and 6 carbon sugars
- biocatalysts which can operate in solvent media.

Public Policy

Our experience in the Chemical Industry has taught us that communication and outreach are the basis for transition and change management. It is vital to discuss our viewpoints and knowledge with all stakeholders. Trust and credibility is only built if safety is foremost on our mind and scientific uncertainty questions receive credible answers. Ours must be the highest standards of ethics at all times, documented by clear guiding principles and transparent industry behavior. And solidarity and performance by all industry peers or value chain members is what makes or breaks this effort. So, in analogy to the Chemical Industry, a set of Responsible Care principles will be an absolute must for future success of this technology.

In summary, I have talked this afternoon about convergence, disruption, innovation, missing links and public policy. These dimensions are relevant not only to the chemical industry, but in the end to all industries impacted by biotechnology. We need to manage the related change with vigor and creativity; only then will we speed up the process of acceptance of this new technology and deliver a truly revolutionary impact on society. Thank you.