Advanced Biofuels and Biorefinary Platforms
Sponsored by DuPont

Monday, June 17, 2013 | 8:30am – 10:00am

Developing Biorefineries and the Bioproducts Sector—Roles for Government and for Industry

Moderator: Andrea Johnston, Strategic Policy Branch Angriculture and Agri-Food Canada

Andrea Johnston, Strategic Policy Branch Angriculture and Agri-Food Canada

Richard Bain, National Renewable Energy Laboratory National Bioenergy Center

Christophe Luguel, Pole Industries & Agro-Resources France

Paulo Cesar De Campos, Coordenacao de Sustentabilidade Petrobras Biocombustivel

Abstract

Globally, industrial technologies are shifting toward the development of new products that are greenhouse gas-neutral, cleaner burning, and more environmentally sustainable. This is being driven by a variety of factors including tremendous advances in science and technology, climate change policies, consumer demand for green products, the rising price of oil, and the discovery of new functionalities of petroleum replacements. In order for the growing interest in developing biorefineries to be translated into a vibrant bioproducts sector, key challenges still need to be overcome and often these challenges require governments and the private sector to work in collaboration. Governments throughout the world have shown an interest in helping industry overcome these obstacles. From the perspective of government, investments in biorefineries and the bioproducts sector are seen to be beneficial as these endeavours can help to achieve important public policy goals such as environmental sustainability, economic growth, energy diversity and security, the development of new economic opportunities for the agricultural and forestry sectors, and rural revitalization. Industry too is working hard to establish the bioproducts sector as many companies are seeking advantages by competing on product attributes and working to green their supply chains through the development and use of bioproducts. Governments can play an important enabling role in creating the economic, policy, and regulatory environment for innovation to flourish as well as assisting in the development of needed infrastructure. With regards to biorefineries and bioproducts, many governments have helped to advance these areas through public good research, procurement and by partnering with companies to help share the risk involved with both research and the path to commercialization. The panel will discuss the roles

played by governments and/or industry in their respective jurisdictions and the outcomes that been realized as a result of the actions each has taken by each. They will also discuss the key stakeholders (e.g. bioproducts sector, universities, agriculture sector, forestry sector etc.) and the roles they play, the specific characteristics and needs of their jurisdiction, the lessons that other countries can draw upon, and what roles governments and industry can play going forward. Following the presentations, the moderator will pose several thematic questions to the entire panel in order to engender a discussion amongst the panelists. Audience members will also be asked to contribute to this discussion by submitting questions that could be posed to the panel as a whole. Andrea Johnston will give a presentation on how Canada's federal, provincial, and territorial governments have worked with industry to develop a roadmap to advance agriculture-based industrial bioproducts. Dr. Bain's presentation will cover the history of US biomass program funding and present the US Government's current areas of focus. Christophe Luguel will discuss the Joint European Biorefinery Vision for 2030. Dr. Barbosa will provide his perspective on how Brazil has advanced biorefineries and bioproducts.

Monday, June 17, 2013 | 10:30am -12:00pm

Cellulosic Ethanol: Scale-up and Commercialization

Moderator*:* Jason Blake, Novozymes

Cellulosic Ethanol: Scale-up and Commercialization
Dr. Andre Koltermann, Clariant

PACE : Praj Advanced Cellulosic Ethanol Project
Ghansham Deshpande, Praj Industries Limited

DSM Yeast and Enzyme Technologies: From Lab Scale to Global Commercial Roll Out of Ligno-Cellulosic Ethanol
Oliver May, DSM

Novozymes and Beta Renewables Deploy World Class Cellulosic Ethanol Technology to Market
Michele Rubino, Beta Renewables

Abstracts

Dr. Andre Koltermann
Cellulosic ethanol has long been in the center of attention as a second generation biofuel. It constitutes an almost carbon neutral new energy source using an already existing renewable feedstock that doesn't compete with food or feed production and land use. Recent years have seen great success in the development and deployment of cellulosic ethanol technologies. Today, several demonstration projects are online and first production plants are on their way. Clariant's sunliquid® technology offers an efficient and economic process for the production of cellulosic ethanol. It overcomes the main challenges of competitive conversion of

lignocellulosic feedstock into cellulosic sugars for fermentation to cellulosic ethanol. In July 2012 a demonstration plant with an annual output of 1000 tons of ethanol started operation. This is the last step on the way to commercializing a technology platform for second generation biofuels and biobased chemicals. The plant represents the complete production chain, including pretreatment, process-integrated production of feedstock and process specific enzymes, hydrolysis, simultaneous C5 and C6 fermentation and energy saving ethanol separation. Thus, a high process yield of 20-25% can be achieved and cellulosic ethanol production becomes competitive to first generation ethanol. The process itself is energy neutral, yielding cellulosic ethanol with about 95% of CO2 emission reductions. However, the process is flexible for use of different feedstock and different production plant concepts. The worldwide potential for cellulosic ethanol is huge, in the transport sector as well as the chemical industry. In the US, the Billion Ton Study initiated by the Department of Energy estimates the amount of corn stover and cereal straw that would be availably sustainably at 210 to 320 million tons. In Brasil, 2011/2012 about 600 millionen tons of sugarcane will be harvested yielding almost 80 million tons of sugarcane bagasse (dry matter). Under optimal conditions, about 40% are used for energy generation at the plant, 60% would be available to produce cellulosic ethanol. This would yield another 11 million tons of ethanol increasing Brasil's current ethanol production by about 50%. The 27 member states of the EU produce about 300 million metric tons of straw ever year. The surplus straw alone (about 200 million tons) would be sufficient to cover at least 20-30% of European gasoline demand. Thus, cellulosic ethanol can make a huge contribution towards more sustainability in transport, energy independence and create green jobs and income for the agricultural sector.

<u>Ghansham Deshpande</u>

Production of renewable fuels, specifically bio-ethanol from lignocellulosic biomass, holds remarkable potential to meet the current global energy demand as well as holds promise for an improved energy security, job creation, strengthened rural economies, improved environmental quality through nearly zero net greenhouse gas emissions, and sustainable environment. Present technologies to produce bioethanol largely depend on sugar or starch based feedstocks like sugarcane, sugar beet, corn, cassava, wheat etc. However, in the past few years, manufacture of ethanol from these raw materials caused a 'food vs fuel' debate. The best alternative to avoid this is the production of cellulosic ethanol from renewable lignocellulosic biomass also known as second generation feedstocks like corn cobs and corn stover, sugarcane bagasse, wheat straw, agri-trash etc. Cellulosic ethanol has the potential to lead the bio-industrial revolution necessary for the transition from a fossil fuel-based economy to a sustainable carbohydrate economy, because these sources have widespread abundance and available at relatively low cost. Praj Matrix has developed a unique technology for the production of cellulosic ethanol which is based on a proprietary pretreatment platform and proprietary microorganisms for the conversion of both hexose and pentose sugars at high yield. The technology platform offers lowest capital and operating cost and has capability to pre-treat a variety of lignocellulosic biomass to produce hemicellulosic and cellulosic derivatives in a highly efficient and cost-effective manner. The technology has been validated in a 2 MTPD pilot plant which has been operating for over three years. The pilot plant operations have demonstrated the feasibility of producing ethanol from some of the agricultural residues like –sugarcane bagasse, cane trash, corn stover and corn cobs. The pilot plant trials have validated the work done at the laboratory scale. A scale up of 50 times in terms of order of magnitude was involved from the laboratory studies to the pilot plant. A semi-commercial demonstration of the technology on multiple feedstocks is planned in Pune, India with capital and operating costs close to a grain – based ethanol plant. The plant is expected to be commissioned by early 2014. The technology demonstration will also provide end to end solution with water and energy integration capabilities acquired over many years of experience and expertise in first generation plants.

Oliver May
Royal DSM N.V. is a global science-based company active in health, nutrition and materials. By connecting its unique competences in Life Sciences and Materials Sciences DSM is driving economic prosperity, environmental progress and social advances to create sustainable value for all stakeholders. Today’s market needs are driven by a number of major global trends and challenges. At DSM we’re using our innovative strengths to address some of the most important of these trends and challenges, such as climate change, energy independence. Advanced biofuels such as cellulosic ethanol offer excellent solutions to these challenges of today and even more for future generations. During the last 5-10 years a tremendous progress was made to continuously drive down manufacturing costs which posed major hurdles for commercialization. It has been recognized that cost optimization needs an integral process view (feedstock, pretreatment, enzymatic hydrolysis, yeast propagation and ethanol fermentation using high performing yeast) rather than optimization of single technologies. This presentation will show how integral cost modeling is used to drive yeast and enzyme development programs. Latest results to improve thermo-tolerant enzyme mixes, their production as well as advanced yeasts with improved robustness and C5 sugar converting properties will be discussed as well as their implementation at pilot and commercial scale

Michele Rubino
This presentation will briefly discuss updates on the deployment of the best in class, combined technology solutions from Beta Renewables and Novozymes. Together these winning technologies bring a very compelling value proposition to producers looking for guarantees and certainty.

Monday, June 17, 2013 | 2:30pm-4:00pm

How to Build a Large-scale Bioeconomy Megacluster Region

Moderator: Manfred Kircher, CLIB2021, Cluster industrial Biotechnology

Ludo Diels, Flemish Institute for Technological Research (VITO NV)

Luuk van der Wielen, BE-Basic, TU Delft Delft, The Netherlands

Manfred Kircher, CLIB2021, Cluster Industrial Biotechnology

Regional Economic Development
Debi Durham, Iowa Economic Development Authority – United States

Abstracts

Turning the vision of bioeconomy into reality is a real complex challenge. Often technical and scientific issues are addressed at first and without any question these are key factors when it comes to processing new feedstock and developing cost-efficient processes. However, another often underestimated hurdle is building the necessary infrastructure incl. i) logistics for feedstock, intermediates and products, ii) specific production plants and iii) supporting facilities for technical and regulatory issues as well as training. Developing such an industrial infrastructure from scratch is extremely costly and asks for advance provision of adequate measures to reach a critical regional industrial concentration. Integrating bioeconomical processes and facilities into an existing industrial infrastructure provides an alternative. It allows i) the implementation of the bioeconomy step-by-step, ii) starts from an existing – sometimes even depreciated – infrastructure thus saving and cutting investments and iii) last not least grows into large industrial structures capturing the economy-of-scale advantage. Especially the latter point is often neglected as ordinary biorefineries suffer from small-volume capacities limiting their economic potential. Mostly the reasons for this competitive disadvantage are boundaries in infrastructure. An example of an established industrial region to be transformed into the leading bioeconomy area is in Europe the Antwerp-Rotterdam-Rhine-Ruhr Area (ARRR). This mega-cluster covering 3 nations (Netherlands, Belgium (Flanders) and Germany (NRW)) provides powerful basic requirements like logistics (sea- and river harbors, rivers, pipelines, railways, highways), top science institutions, strong chemical and fuel industries, critical financial means, skilled workforce, an attractive market and a long-standing tradition in innovation – meaning pushing as well as accepting technical and economical progress by governments, industries, infrastructure and society. This panel will present and discuss the starting position of ARRR, how governments, industry and academia respond to the bioeconomical challenges and how this multinational megacluster turns its potential into competitive advantage.

<ins>Debi Durham</ins>
Iowa is the nation's premier leader in the renewable fuels industry and is focused on the use of biomass as feedstocks for the production of a broad range of industrial bio-based products including fuels, chemicals, polymers and materials. Iowa also leads the nation in the availability of biomass and has the most robust industrial biotechnology infrastructure available in the United States. In recent years, public-private partnerships between Iowa's government, private industry, and world-class research institutions have created new directions for the industry and helped to support the state's bioscience companies in being competitive on a global scale.

The state has made a significant contribution in growing the industry, investing $85 million in direct financial assistance to more than 200 biosciences projects in the state over the past nine years. Those projects have created or retained nearly 11,000 jobs in Iowa and leveraged $11.9 billion in total capital investment for the state. Employment in the sector surged 26 percent between 2001 and 2008, according to a March 2011 report by the Battelle Technology Partnership Practice.

Today, roughly 525 entities are working to commercialize Iowa's bioscience innovations. From start-up companies to globally respected industry leaders in research and development, Iowa's bioscience enterprises benefit from the state's abundant access to raw materials, strong transportation infrastructure, and its skilled, productive labor pool. Companies with operations in Iowa that are blazing the biosciences trail include Alltech, Cargill, Diamond V Mills, POET-DSM and DuPont.

Find out how Iowa's strategic advantages and business climate have contributed to the state's success in the industrial biotechnology sector.

Tuesday, June 18, 2013 | 8:30am-10:00am

Developments in Drop-In Biofuels

Moderator: Eric Mathur

Ensyn Technologies Inc. - Advanced Biofuels from Cellulosic Biomass
Robert Graham, Ensyn Technologies

Industrial Algae Revolution: Growing the World's Fuels
Jeff Webster, Sapphire Energy Inc.

Transformational Strategies: Renewable Normal Butanol Addition into Biorefineries
Joel Stone, Green Biologics Inc.

Is There a Renewable Aviation Fuel Feedstock?
Eric Mathur, SG Biofuels

Abstracts

Robert Graham
Ensyn is developing multiple projects in North America and internationally for the production of its RTP advanced biofuels. Ensyn's renewable liquid fuels business is being developed in conjunction with its key strategic relationships including UOP, a Honeywell company, Chevron Technology Ventures, Fibria Celulose S.A., and Felda Global Ventures. Ensyn's RTP technology converts non-food cellulosic biomass to Renewable Fuel Oil (RFO), a liquid, petroleum-replacement product with several applications including combustion heating, power generation in a diesel engine and conversion to transportation fuels. Ensyn's RFO can be converted to drop-in transportation fuels using existing refinery infrastructure (co-processing) or in

stand-alone upgraders. With over two decades of commercial production experience and over 30 million gallons of RFO produced to date, Ensyn's technology is proven and cost competitive with petroleum substitutes without regulatory incentives. Ensyn's 15 minute presentation will include an overview of our advanced biofuels business, including a summary of our RTP technology, commercial applications for our RFO and an overview of our recently signed Brazilian Joint Venture with Fibria Celulose S.A., the largest market pulp company in the world.

Jeff Webster
Algal fuel is at the intersection between biotechnology, agriculture, and energy production. Sapphire Energy's ambition is to improve two of the world's largest markets, energy and agriculture, through biotechnology. Sapphire Energy produces Green Crude, a drop-in petroleum replacement crude oil which can be refined in existing refineries into the fuels we use today—gasoline, diesel and jet-fuel. As we look to alternative sources for petroleum, "Green Crude" is the perfect solution with its ability to scale to demand. The agricultural revolution in the United States established the building blocks to feed the world. Today, the United States grows more than 90 million acres of corn and more than 50 million acres of wheat per year. However, the world is now facing a huge energy problem in growing and delivering that food, and could be severely impacted without a cheap supply of crude oil. According to a report by the International Energy Agency, global oil demand is predicted to grow by 7 mbd through 2020, and exceed 99 mbd by 2035. Simply put, by 2020, we will need approximately 40% more energy than we use today. Industry experts agree that technology readiness must be in place by 2020 to move the nation and world to alternative crude oil sources, or we will face oil shortages. It took us hundreds of years to move from wood to coal, and a hundred more to shift from whale oil to crude oil. We don't have another hundred years. Today, we have the opportunity to increase the world's supply of energy with a new industrial revolution: algae-to-energy farming. Sapphire's process does not compete with traditional agriculture for resources. Algae cultivation requires sunlight, brackish water, and anthropogenic CO_2, and can be done with non-potable water and on non-arable land, using only a fraction of the land that other biofuel feedstocks require. If given the right support, Green Crude has the potential to scale to meet the growing demand for liquid transportation fuels, and revitalize the rural farm industry, empowering the world to grow their own fuels. Sapphire's process harnesses the energy of the sun and naturally superior photosynthetic properties of algae to produce crude oil on a much faster time-line than traditional fossil crude. Green Crude Farms are akin to above-ground oil fields or rice paddy fields. Our process is sustainable and renewable, recycling as many nutrients and as much water as we can through cultivation and harvest processes. Ideally, our system will get as close to, or become, a closed loop system with very little need for inputs once cultivation begins. Sapphire Energy has an R&D facility in Las Cruces, NM, and a Green Crude Farm, the world's first commercial demonstration scale, algae-to-energy facility, in Columbus, NM. The Farm is now up and running with more than 70 acres production ponds, as well as all the mechanical and processing equipment needed to harvest and extract algae to produce Green Crude oil. The purpose of the Green Crude Farm is to demonstrate how algal oil can be refined into Jet-fuel, diesel and gasoline on a continuous commercial scale. The

Green Crude Farm is a huge first step in delivering a solid alternative fuel solution that this country and the world greatly needs with the technology and agronomics of the Farm serving as the beginning of a new agricultural revolution for algae biomass cultivation.

Joel Stone

Today's ethanol refineries are faced with a single feedstock and single product, ethanol; with a single co-product, DDGS. We are entering an era of transformation of ethanol assets into bio refining complexes of the future. Green Biologics Inc. offers a "bolt on" option for ethanol facilities where we can deploy a transformation that can divert a portion of feedstock to production of chemical grade normal butanol and acetone. Both normal butanol and acetone are basic building block chemicals in both the paints and coatings and plastics industries with a market value over $5bn. The economics for biorefining diversification are compelling and will be presented together with options for both "bolt on" and retrofit. The "bolt on" transformation can be completed with minimal downtime during which tie-ins to the new process train are completed. Equally important will be a review of the business economics of producing bio based and renewable chemicals that offer an improved risk management profile and offering growth to ethanol plant revenues while also supporting reduction in petroleum consumption in North America. Further developments include the deployment of a feedstock pretreatment and hydrolysis facility to access a wide range of cellulosic feedstocks. The use of cellulosic feedstocks is enabled by the Green Biologics fermentation technology using solventogenic clostridia that efficiently convert both hexose and pentose sugars to renewable normal butanol. This flexibility will enable the chemical biorefinery to operate on either corn or cellulose depending on feedstock cost. The resulting biorefining operation will diversify raw material and chemical product risk by ability to produce fuel grade ethanol alongside renewable normal butanol and acetone from grain based or cellulose derived feedstocks.

Eric Mathur

Drop-in replacements for petroleum liquid fuels represent a major component of the growing energy demand. Although cellulosic ethanol will mitigate the depletion of oil reserves used for gasoline and algal biofuels hold long term promise as jet fuel substitutes, there are no obvious present day renewable feedstocks available. Candidates include canola, oil palm, rapeseed and soybean; yet redirecting agricultural resources toward energy feedstocks negatively impacts food security and is not sustainable. A promising alternative is the non-edible oilseed shrub, Jatropha curcas. Jatropha is native to Central America and was distributed by Portuguese sailors to colonies three centuries ago in the Cape Verde Islands. The primitive crop was recognized as heating oil and as a result, 35,000 tons of Jatropha seed was exported from Cape Verde to regions throughout Africa, Asia and Latin America. The spread of a few Jatropha cultivars from the center of origin to the pan tropics created a genetic bottleneck in the diversity of Jatropha found outside Central America. Recent attempts at domestication of Jatropha failed because the plantations used undomesticated landraces derived from Cape Verde germplasm which limited genetic improvement through breeding and selection. The inability to commercialize Jatropha as an energy feedstock was not a reflection on

Jatropha, but rather of the business getting in front of the science of domestication. Here, we present evidence that Jatropha curcas germplasm is not genetically depauperate; but rather encompasses a substantial pool of genetic variation sufficient to propel breeding efforts designed to achieve economic yields. It is well known that the highest degree of genetic diversity within a species is typically found near the center of origin. High genetic diversity at the origin of a species is a consequence of population density and maximized time for accumulation of selected and unselected mutations. Jatropha planting materials were collected throughout Central America in order to create a germplasm repository which now comprises over 12,000 genotypes derived from ~600 accession families. The plant collection exhibits high levels of phenotypic diversity including variation in flowering time, oilseed content, fruit yield, plant architecture, susceptibility to fungal pathogens, pest resistance, drought, heat, flood and cold tolerance. Our results now confirm that genotypic diversity underlies the observed phenotypic variation. Small sequence repeats (SSR) and genome-wide SNP markers were used to analyze diversity of the germplasm collection. The results conclusively demonstrate that the genomic variation residing in the Central American germplasm collection positively correlates with the phenotypic diversity. Moreover, the analysis reveals that virtually all Jatropha land races cluster tightly, confirming genome scale homologies and derivation from a common ancestor. In contrast, the germplasm collected near the center of origin of the species forms eight divergent clades, punctuated with a wide spectrum of genotypic variance within each clade. Thus, our finding suggest that Jatropha curcas possesses the genetic potential necessary for crop improvement. Considering the short generation time of this perennial and the ability to propagate both by sexual and vegetative methods, there are no apparent genetic obstacles preventing Jatropha from becoming the preferred oilseed for renewable jet fuel.

Tuesday, June 18, 2013 | 2:30pm – 4:00pm

The First Generation of Biorefineries in Canada - How Canada's Leading Biofuels Producers are Using Their Platform to Develop Valuable Co-products and the First Generation of Biorefineries in Canada.

Moderator: Scott Thurlow, Canadian Renewable Fuels Association

Malcolm West, Greenfield Ethanol

Jim Grey, IGPC Ethanol Inc

Scott Lewis, BIOX Corporation

Abstract

Feed, Fuels and Chemicals: The First Generation of Bio-Based Refineries in Canada – How Canada's leading biofuels producers are using their platform to develop valuable co-products and the first generation of biorefineries in Canada.

Biorefineries encompass the production of biofuels along with other value added production streams – high value Distillers grains (DDGs) for animal feed, glycerin, corn oil, chemicals, power and commercial alcohols. By producing multiple products, a biorefinery can take advantage of the differences in feedstock components and maximize the value derived. These production streams also allow for existing facilities to reduce their overall footprint by recycling resources while increasing profitability through additional revenue streams for the facility. In order to create high value streams for their facilities, ethanol and biodiesel producers are developing new innovation and implementation processes. Creating new value added streams in the production chain is a key aspect of successfully developing a sustainable bio-based economy. This panel is comprised of Canadian producers of biofuels and represents approximately 750 Mmly/litres of ethanol and 120 Mmly/litres of biodiesel production capacity in Canada. Each producer will discuss the models and technologies being considering for their respective facilities as well as the potential and challenges in achieving increased output of feed, fuel and chemicals.

Wednesday, June 19th, 2013 | 10:30am – 12:00pm

Cellulosic Ethanol: Scale-Upand Commercialization – Part 2

Vincent Chornet, Enerkem

Bill Brady, Mascoma

Stuart Thomas, DuPont

Abstract

DuPont® Cellulosic Ethanol (DCE) as part of DuPont Industrial Biosciences, has the combined power of Genencor®'s cell factory biotechnology and DuPont®'s capabilities in advanced materials and engineering while leveraging Pioneer®'s knowledge of production agriculture to create a world-class cellulosic biorefinery offering for the global marketplace. DuPont® offers renewable fuel and chemical producers an optimized, integrated, and demonstrated farm-to-fuel Cellulosic Ethanol technology solution which is 1) cost effective, 2) sustainable, 3) investment grade, 4) enabled by DuPont® feedstock supply chain know-how, 5) and backed by DuPont® scientists and engineers to provide operations, technical support, and ongoing technology development.
As a result, the age of commercial Cellulosic Ethanol technology is here. We will discuss the market and environmental drivers and potential for Cellulosic Ethanol in the global marketplace and review DuPont®'s Integrated Cellulosic Ethanol technology offering. We will include a discussion of life cycle analysis, technology characteristics, and a snapshot of the world's largest Cellulosic Ethanol plant currently under construction in Nevada, Iowa.

- What makes DuPont®'s Integrated Cellulosic Ethanol technology different from others in the industry?

- How does an operator procure a reliable, quality, low cost feedstock to make sure this investment operates 24/7 year round?
- Can a cost effective Cellulosic Ethanol plant be built at reasonable capital expense?
- What feedstocks are best for Cellulosic Ethanol?
- Are they economical and how do I procure these feedstocks sustainably?

DuPont® Cellulosic Ethanol will answer all of these questions.

DuPont® Cellulosic Ethanol offers integrated technology licenses to global energy producers, agricultural companies, energy investors, plastics and chemical producers, and others who want to be market leaders and partner with a premier global science and technology company. Together, we will help solve the world's need for renewable, sustainable, and affordable transportation energy.

Feedstock Crops and Biomass Supply

Monday, June 17, 2013 | 8:30am-10:00am

Biomass Supply from Corn Residues: Estimates and Critical Review of Procedures

Moderator: Bill Levy, Pacific AG/Powerstock

Biomass Supply from Corn Residues: Estimates and Critical Review of Procedures
Paul Gallagher, USDA

Sorghum's Increasing Potential for Renewable Markets
Mario Carrillo, Chromatin, Inc.

High Biomass Sorghum as a Feedstock for Cellulosic Bio-refineries
MJ Maloof, NexSteppe

Addressing Supply Chain Risk Factors to Meet the Demand for Biorefineries Using Ag Biomass Feedstock
Bill Levy, Pacific AG/Powerstock

Abstracts

Paul Gallagher
Authors: Paul W. Gallagher Office of Energy Policy&New Uses, USDA and Iowa State University Harry Baumes Director Office of Energy Policy&New Uses (Director),

Some early estimates suggested that accessible and sustainable corn residue supplies are adequate for a new biomass processing industry (Gallagher and Johnson; Gallagher, et al 2003a;Gallagher, et al 2003b). Revision is justified now because the agronomic and economic environment has changed. There is also interest in the location of low cost supplies, because biomass processing facilities are under construction. A critical review for suitable cost estimation assumptions and sustainability concepts should also be incorporated in the revised estimates, in view of recent discussion. The corn stover cost and supply estimates presented here fit today's yield and input situation. The revised estimates confirm that corn stover supplies are still adequate for new processing activity; several offsetting changes in economic environment and technology combine for a total supply estimate that is slightly larger and cost estimates that are highly competitive in today's energy markets. This paper is organized as follows. First, we summarize the supply model. Second, we present new data and spatial variation in critical parameters that impinge on estimates of usable supply: current estimates of the harvest index, local feed demand, and a conservation allowance are discussed in turn. We compare our assumptions with the literature, justifying, incorporating, and discarding as appropriate. Our critical review of procedures includes cost estimation, sustainability, and harvest season constrants. Conclusions: The revised estimates confirm that corn stover supplies could be a low cost feedstock for a low cost and extensive bioenergy industry. Supplies of 100 million metric tons of stover would be available to an established industry at a delivered plant price between $37.5/ton and $40.5/ton. At moderately higher prices, the feedstock for a 10.5 MGY ethanol industry would be available (Figure 6). Ample supplies of the lowest

cost and sustainable supplies are likely found in the middle of the corn belt: Illinois, Indiana, Eastern Ohio, and Iowa. Also, sections of other states have some very low cost supplies: eastern Nebraska, southern Minnesota, southern Wisconsin, and southern Michigan. Lastly, considerable stover supplies would be available at a somewhat higher but still very competitive price in some new corn belt areas: eastern North Dakota, central Wisconsin/Michigan, and perhaps western New York. Supply estimates for specific counties are given in the paper.

Mario Carrillo
Sorghum [Sorghum bicolor (L.) Moench] is ideally suited as a renewable feedstock given its versatility as a single source of starch, sugar and lignocellulose. Sorghum is a fast-growing, C4 photosynthesis crop that has established low-cost, mechanized agronomics, harvesting and logistics. Compared with corn [Zea Mays L.] production, sorghum consumes 50% or less water, 20 to 60% less pesticides and much less energy from reduced irrigation and chemical inputs. Sorghum production is also expected to minimize indirect land use change impacts by utilizing more marginal lands. These attributes make sorghum uniquely positioned as an adaptable, economically viable biomass source that is fit-for-purpose for both traditional and advanced liquid biofuels products and technologies as well as for emerging markets such as green power and renewable chemical production. Sorghum's unmatched versatility as the only energy crop that can provide starch, sugar and lignocellulose, is enabling Chromatin to provide sustainable feedstock production to customers across bioindustrial markets.

MJ Maloof
NexSteppe is singularly focused on developing and commercializing dedicated crops and the associated supply chain solutions necessary to enable the biofuels, biopower and biobased product industries. In contrast to wastes and residues, dedicated energy crops are more reliable, scalable, uniform, and can be tailored to meet the needs of these industries. One of the Company's first commercial crop targets is high biomass sorghum. High biomass sweet sorghum is a seed propagated annual that is naturally drought and heat-tolerant and has the ability to grow in a wide range of environments. It has a relatively short growing season and is suitable for use in multiple cropping systems. Its range of maturities and ease of establishment make it well suited to providing both just-in-time biomass for immediate conversion as well as storable biomass for off-season use. Its high yield and genetic diversity make it an outstanding candidate for broad application as a feedstock for both biopower and cellulosic fuels and biobased products. Much of the early commercial capacity for cellulosic fuels is focused is on agricultural residues or forestry derived materials, which present challenges in terms of reliability, heterogeneity and negative compositional attributes that can affect conversion yields. Certain dedicated energy crops can address the first two of these concerns, but high biomass sorghum, because of its genetic diversity and rapid product development cycle, is ideally suited to address all and become a tailor-made cellulosic feedstock solution. NexSteppe has built an industry leading library of germplasm sourced from public and private collections spanning the globe, and had assembled the most experienced team of commercial sorghum breeders and agronomists of any company in the dedicated energy crop space. The Company

currently operates its commercial breeding nursery in Hereford Texas with a winter nursery in Puerto Rico and operations in Brazil. In addition to conventional breeding approaches and cutting edge analytics, NexSteppe is using advanced marker assisted breeding technology to accelerate the productivity and desirability of sorghum for use as a dedicated energy crop through its collaboration with DuPont's Pioneer Hi-Bred business. The combination of NexSteppe's extensive genetic source material, with the team's unparalleled expertise, and the most advanced technology Pioneer has to offer, makes NexSteppe well positioned to demonstrate conclusively that using current downstream conversion technology and advanced approaches to breeding and agronomic management of high biomass sorghum; it's economically viable to build scalable, sustainable, non-food based bio-refineries in the near-term.

Bill Levy

The U.S. DOE 2011 Billion-Ton Update determined that the vast majority of the sustainably available and commercially feasible potential biomass feedstock for cellulosic biofuels will come from the agricultural sector. In order to fulfill this potential, agricultural biomass supply chains must be developed that address the risk factors for feedstock supply inherent in project finance for commercial scale biorefineries. The panel will bring its extensive project and applied research-based experience to provide strategies, processes, and insights that will directly address the critical risk factors for providing a financially viable ag biomass feedstock supply chain. Methodology: The panel combines agricultural production experts who understand growers' perspectives and preferences and harvest and logistics complexities necessary for the development of sustainable, commercial-scale biomass feedstock supply chains. Their approaches and solutions to the industry's risk factors will be presented. Why should this abstract be selected for the 2013 BIO World Congress Program? This panel addresses the most significant current risk factor for development of biobased products and renewable chemical facilities. List the name/email point of contact should you want media attention: Harrison Pettit (hpettit@pacificpowerstock.com) I. Presenter/Moderator: Harrison Pettit Title: VP Business Development? Organization: PowerStock Biography: mailto:http://pacificpowerstock.com/senior-management-team.html II. Presenter: Dr. Matt Darr ? Title: Assistant Professor, Agricultural and Biosystems Engineering Organization: Iowa State University? Fit with Panel: Dr. Darr has led many of ISU's most significant applied ag engineering research work with the biofuels industry. Biography: mailto:http://www-archive.abe.iastate.edu/who-we-are/directory/matthew-darr.html mailto:http://www.public.iastate.edu/~darr/ Contact: Iowa State University? 202 Davidson Hall? Ames, IA 50011? Phone: 515-294-8545 Email: darr@iastate.edu Presenter Status: Approved III. Presenter: Robert V. Avant, Jr., P.E. Title: Director, Bioenergy Program Organization: Texas A&M AgriLife Research Fit with Panel: Texas A&M's AgriLife Research is engaged in over 40 bioenergy projects related to feedstock development and logistics; Mr. Avant is an expert in agricultural production systems. Biography: to be provided Contact: 100 C Centeq Building A 1500 Research Parkway, 2583 TAMU College Station TX 77843-258 Phone: 979-845-2908 Email: bavant@tamu.edu Presenter Status: Approved IV. Presenter: Mr. Bill Levy? Title: CEO Organization: PowerStock Fit with Panel: Bill brings 15 years leading and operating commercial scale ag biomass feedstock supply chains for both animal feed and forage and bioenergy markets. Biography: : mailto:http://pacificpowerstock.com/senior-management-team.html Presenter Status: Approved V. Presenter: Dr. Subbu Kumarappan? Title: Assistant Professor Organization: Ohio State University - Ag Tech Institute? Fit with Panel: Dr. Kumarappan has worked extensively with biomass contracting issues and in issues related to planning biomass feedstock harvest sheds. Biography: To be provided Contact: The Ohio State University ATI 1328 Dover Road Wooster, OH 44691 Phone: 330-287-1261 Email: kumarappan.1@osu.edu Presenter Status: Approved

Monday, June 17, 2013 | 10:30am-12:00pm

Biomass Supply Chain: Perspectives from Four Continents

Moderator: Murray Mclaughlin, Bioindustrial Innovation Canada

Catherine Cobden, Forest Products Association Canada

Zainal Azman Abu Kasim, Biotechcorp

Erik van Hellemond, Suiker Unie

Abstract

As the bio-based industry moves away from food crops to produce their bio-based chemicals, biomaterials and biofuels, there will be challenges in meeting the demand placed on biomass. Challenges from collection, harvesting and storing to processing – not to mention price and quality. Issues and challenges vary around the world, and need to be addressed in a proactive systematic way. This session will look at these challenges globally and discuss what countries are doing to deliver quality feedstock and maintain profitability through the value chain.

Monday, June 17, 2013 | 2:30pm-4:00pm

Creating an Acceptable Supply of Biomass Feedstock to Satisfy Financing Requirements

Moderator: Chris Roach, Ceres, Inc.

Chris Roach, Ceres, Inc.

Sam Jackson, Genera Energy, Inc.

Paolo Carollo, Chemtex International, Inc.

Bob Wooley, Gevo, Inc.

Abstract
As the biofuel and bioproducts industries continue to emerge and mature, focus is shifting towards the deployment and financing of commercial scale technologies. Considering the medium to high technology risk and large capital investment common with projects in these industries, cash flow generation risk exposure to feedstock supply must be minimized to achieve an acceptable risk premium for debt financing. Developers are compelled to create feedstock supply plans that can survive the scrutiny of financial due diligence and are based in large part on contractual commitments from credit worthy counterparties. These financeable feedstock supply plans must address process risks, third party risks, and market risks. Process risks of a feedstock supply plan include biomass performance in the field, the cost and reliability of the agronomic system to establish, manage, and deliver the material, and the quality and consistency of the material. The design of the feedstock supply plan should be based on statistically verifiable performance of feedstock types under project relevant conditions (land, climate, inputs, etc.), along with agronomic processes and equipment. Inclusion of feedstock diversification by type, source, and seasonal availability will help mitigate short and long term supply interruptions. A quantitative understanding of how feedstock quality impacts conversion characteristics should also be a project development consideration. Third party risks that can impact feedstock cost, availability, or quality, need to be contractually mitigated. To the extent possible, commitments to resources (land) and performance (establishment, harvest, delivery, etc.) that match the length of the debt term should be secured. Obligations to quantity, quality, and direct costs should also be pursued. Third parties that enter into these commitments should be selected based on past experience, adequate funding to perform, and the financial wherewithal to support guarantees. As with feedstock, third party diversification should also be included to further mitigate third party derived risks and enhance the likelihood of improving feedstock supply cost and efficiency through competition. Market risks to feedstock supply can affect both availability and cost. Dedicated energy crops should be preferred to agricultural residues as it is harder to guarantee the availability of agricultural residues, by definition a byproduct of other market activity. Cost uncertainty can be minimized through contracts with fixed or capped direct costs and hedge positions for inputs like fuel and fertilizer. Financeable feedstock solutions can be developed concurrently to an overall development effort given an in-depth understanding of the requirements, resources, and activity required. Early communication with financial partners and investors can be invaluable to anticipating due diligence requirements for feedstock plans and keeping an overall development effort on schedule. Successful financing of biomass based projects will include the same level of rigor in the feedstock plan as is required in the bio-refinery plan.

Tuesday, June 18, 2013 | 8:30am–10:00am

Critical Issues for the Next Ten Years: Building a Sustainable Supply Chain for the Biobased Economy

Moderator: Jack Huttner, Huttner Strategies, LLC

Jody Endres, University of Illinois

Arlan Peters, Novozymes North America, Inc

Marty Muenzmaier, Cargill

Abstract

As the industrial biotechnology industry moves from R&D to deployment, it needs to turn its attention toward the market for its products: global brand owners, retailers and consumers. One of the industry's principle value propositions is its contribution to a more sustainable industrial production system. Over the last decade, the industry has seen this proposition challenged by new concerns around land use change, biogenic carbon and food security. Over the next decade, the industry must engage its many stakeholders to understand their concerns, agree on metrics to track, develop best practices and report regularly on performance. It must work closely with its upstream and downstream partners to align and coordinate efforts to assure the biobased economy meets the high expectations it has set.

Tuesday, June 18, 2013 | 2:30pm–4:00pm

Carbon Capture and Biological Conversions: The Case for Co-Location

Moderator: Simon Gaboury, Rio Tinto Alcan

TBD, Bioprocess Algae

Martin Voergh, St-Mary's Cement

Simon Barnabe, University of Quebec at Trois-Rivières

Nathalie Dubois-Calero, Alga-Labs

WRI'S CAT™ PROCESS: A Biofuel-Based Carbon Emissions Capture/Re-Use Technology
Alan Bland, Western Research Institute

Abstracts

Many industries are looking for sustainable alternatives to fossil consumption. Biomass is certainly an attractive alternative. However, among all the challenges and issues for biomass used to produce fuel and energy, securing the supply of biomass remain a critical factor for success and profitability. An industry producing its own biomass can overcome this problem. We do not expect them to produce agricultural or forest biomasses. However, many industries have CO2 stream, waste

nutrients and waste energy that can be used to produce lipid-rich algae biomass for obtaining biofuel, bioenergy and coproducts. These products are marketable, but they may be also valuable for in-house uses to reduce fossil consumption in industrial plants. Such a co-locating approach for algae based fuel, energy and coproducts production could be profitable for both the algae producer and the co-located plant. This panel will discuss case studies in Canada and USA. Fourth conferences are proposed : 1) "Co-locating with a first generation ethanol plant : case of Greenplains at Iowa" by one member (name to confirm) of Bioprocess Algae; 2) "Co-locating with a cement plant: case of St-Marys Cement in Ontario" by Martin Vroegh from St. Marys Cement Inc. (to confirm); 3) "Co-locating with a smelter: case study in Quebec" by Dr. Simon Barnabé, professor at University of Quebec at Trois-Rivières (confirmed); 4) "Co-locating with the oil industry: case study in Mexico" by Nathalie Dubois-Caléro, VP R-D at Alga-Labs.

Alan Bland

CO_2 emissions in the U.S. are expected to continually increase in the upcoming decades. Without accelerated technology development to address CO_2 reduction with continued fuel use, atmospheric CO_2 levels are expected to rise and economic progress in the U.S. and globally can be severely impacted. WRI has developed and is scaling-up a biological process for the capture and utilization of CO_2 emissions from utilities, as well as from large and small industrial facilities. WRI's patent-pending Chemoautotrophic (CAT™) process enables capture and conversion of CO_2 into liquid biofuels, thereby enabling a reduction in use of petroleum oil and fuels. This novel process is based on the ability of chemoautotrophic bacteria to capture CO_2 and fix the carbon into organic molecules for further processing to value-added bio-products, while significantly reducing costs compared to other bioprocesses. Unlike many biologically-based systems (e.g., algae), WRI's CAT™ process does not require light and does not necessitate location in a warm climate for operation. WRI's CAT™ process bacteria show a rapid growth rate, indicating efficient conversion of CO_2 into biomass. The CAT™ technology can be directly integrated to an existing stationary CO_2 source and is able to operate 24 hours a day, year-round, and at any latitude. This technology can be deployed with large reaction vessels, which requires less than 2% of the land area required for open pond algae processes. Additionally, this process uses significantly less water (<1%) than that required for algae or renewable crops. In fact, chemical reactions in the CAT™ process generate water that offset losses during processing. When this generated water is combined with water recovered from flue gas, it offsets approximately half of the water consumption during biodiesel production. As a result, the CAT™ process is compatible for use with both large and small industrial CO_2 sources. Economical operation of the CAT™ process is achieved through unique biochemical systems utilized in the process, systems for biomass and water recycle, and a system for biomass residue conversion to nutrients. Preliminary limited life cycle analysis of the CAT™ process estimates that CO_2 emissions from industrial sources can be reduced by greater than 80%, and economic analysis of the process predicts that the CAT™ process-produced biodiesel will be economically competitive with petroleum-based diesel. Carbon captured by the CAT™ process bacteria may be re-used by converting the lipids extracted from the accumulated biomass into biofuels, green plastics, or similar materials using existing technologies. As such, this process replaces the fossil fuels and products from the refining of petroleum-crudes.

Wednesday, June 19, 2013 | 10:30am–12:00pm

Renewable Feedstock Crops – Can they Provide an Economic Alternative to Petroleum?

Moderator: Jack Grushcow, Linnaeus Plant Sciences Inc

Hamdy Kahlil, Woodbridge Foam

Craig Crawford, Ontario BioAuto Council

Jeff Uhrig, Elevance Renewable Sciences

Jack Grushcow, Linnaeus Plant Sciences Inc

Abstract

A recent European study has cast doubt on the ability of crop derived feedstocks to provide renewable solutions at economically practical prices. Craig Crawford will provide a background and summary of this study and will discuss the work of the Ontario BioAuto Council to find cost effective renewable solutions for its membership. Handy Khalil will discuss efforts of Woodbridge Foam to provide Urethane Foams manufactured from bio-based polyols derived from vegetable oils. He will review methods as well as customer requirements from a cost and performance basis. Jeff Uhrig will outline Elevance's proprietary chemistry platform and discuss specific value added products that are based on commonly available vegetable oils. These products include lubricants, cosmetics and polymer feedstocks that deliver additional sales side margins. Jack Grushcow will summarize recent advances in plant breeding in the non-food oilseed crop Camelina including current yield and production economics. New oilseed profiles developed in conjunction with DuPont Pioneer will be reviewed and specific high value products derived from these advanced oil profiles will be discussed.

Renewable Chemical Platforms and Biobased Material

Sponsored by: The Dow Chemical Company

Monday, June 17, 2013 | 8:30am-10:00am

Renewable Succinic Acid: The Road to Commercialization

Moderator: Sue Hager, Myriant Corporation

Alif Saleh, Myriant Corporation

Will van-den-Tweel, Reverdia

Philipp Walter, Succinity

Integrated Process for Production of Succinic Acid from Biomass
Allen Julian Julian, MBI

Abstracts

Succinic acid is a linear 4-carbon saturated dicarboxylic acid that is used in the manufacture of a wide range of products including polymers, coatings, adhesives, plasticizers, and polyester polyols. Today, succinic acid is produced via traditional petrochemical routes however, a handful of global companies are racing to commercialize succinic acid made from renewable resources. Bio-succinic acid is chemically identical to succinic acid produced by petrochemical routes, with a purity level equal or superior to the highest quality petroleum-based succinic acid. In this panel discussion, leading companies will present their approach and outlook on the bio-succinic acid market, which today, is estimated to be several billion dollars worldwide. Panelists will also discuss the various business models, partnership strategies and approaches to financing bio-succinic acid production plants.

Allen Julian
This presentation will highlight MBI's unique and integrated process for producing biobased succinic acid from biomass sugars. Succinic acid is a versatile building block chemical, and there is significant commercial interest in producing this material from non-food biomass feedstocks. MBI's organism and process are capable of simultaneously converting mixed 5-carbon and 6-carbon sugars to succinic acid with unprecendented efficiency. Highlights of process performance, including AFEX biomass pretreatment conditions, saccharification, fermentation, and downstream processing will be discussed. A techno-economic assessment will be presented, with comparisons to competitive technologies for bio-based succinic acid.

Monday, June 17, 2013 | 10:30am-12:00pm

FDCA, The Rise of a New Biobased Building Block

Moderator: Jim Barber, former CEO of Metabolix

Tom van Aken, Avantium

Yi Huang, Novozymes

Mike Schultheis, The Coca Cola Company

Whole-Cell Biocatalytic Production of 2,5 Furan Dicarboxylic Acid (FDCA)
Marc Lankveld, BIRD Engineering

<u>Abstracts</u>

The session will detail the rise of the biobased building block Furan-dicarboxylic-acid (FDCA). The presentations will cover the progress that has been made regarding the different technologies to produce FDCA, the scale-up of FDCA production and various applications for this promising building block. FDCA is regarded as a high-potential biobased building block because it is one of the few building blocks with an aromatic chemical structure, allowing it to compete with aromatic monomers made from petroleum. The US Department of Energy listed FDCA in its top 12 of highest potential biobased building blocks. In the literature FDCA is nicknamed "Sleeping Giant" because of its tremendous market potential in chemicals, polymers and fuels. Until a few years ago, there was no economically viable way to produce FDCA, but recently significant progress has been made to unlock FDCA's market potential by novel production routes that are being unlocked by companies such as Avantium and Novozymes. The interest in FDCA has further increased due to the outstanding performance of PEF, a novel, biobased polymer that is made of FDCA and monoethylene glycol (MEG). While PEF has many similarities to PET, its barrier properties for oxygen and carbon dioxide are remarkably superior, leading major brand owners such as The Coca-Cola Company and Danone to initiate the development of 100% biobased PEF bottles. Some of the main challenges for the commercialization of FDCA include:

• The cost-effective production of FDCA to allow for competition with petroleum based products such as terephthalic acid in high-volume markets

• Creating partnerships to build the new supply chain starting from agricultural feedstock and their conversion into monomers, all the way to the production of polymers and their application in chemical and fuels end markets.

• Determining the performance advantages of these new materials and matching applications to bring value-added FDCA-based products to the market. Avantium is using a chemical-catalyzed production process, called YXY, for the production of FDCA.

The company has successfully proven this process on laboratory and pilot plant scale, and is now preparing for the design and operation of the first commercial scale FDCA plant. The company will provide an update on its pilot plant operations, its plans for the scale-up to commercial manufacturing and initial data that have been collected for the Life-Cycle-Analysis of FDCA and PEF. The company will also present about its joint development partnerships of PEF and other polymers that incorporate FDCA. Novozymes' recent development in HMF/FDCA: A top value-added biobased chemical building block 2,5-Furandicarboxylic acid (FDCA) is one of twelve top value-added biomass-based chemicals identified in an influential 2004 report by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy. Now Novozymes has successfully developed technology for converting C6 sugars into HMF (5-hydroxymethyl furfural) the precursor of FDCA by using a combination technology of enzymatic and chemical transformation. In this presentation, we will describe Novozymes' development of HMF/FDCA technology and also their potential applications. The Coca-Cola Company abstract to be completed the coming days.

Marc Lankveld

Whole-cell biocatalytic production of 2,5-furan dicarboxylic acid (FDCA) Tom Elink Schuurman1,2, M.J.A. Lankveld1,2 1BIRD Engineering, Rotterdam, The Netherlands; 2BE-Basic, Delft, The Netherlands Marc.Lankveld@birdengineering.nl FDCA (2,5-furandicarboxylic acid) is a highly promising biobased replacement for phtalates in resins and polymers [1]. A lab-scale process for the biocatalytic production of FDCA from 5-hydroxymethylfurfural (HMF) has been developed based on a specific oxidase from the furan degrading bacterium Cupriavidus basilensis HMF14 [2, 3]. Further improvement of the whole-cell biocatalyst as well as the fermentation procedure has resulted in considerably faster FDCA production, with less accumulation of by-products. Further details on strain improvement and fermentation development will be presented in the paper. At present, the lab-scale FDCA production is being developed to an integrated process at pilot scale, and eventually a full-scale process is aimed for. As the availability of cheap HMF is key for economically feasible FDCA production, and competition with food production is to be prevented, the envisaged route to HMF production is via catalytic dehydration of lignocellulose-derived hexoses. The resulting raw HMF stream is expected to resemble a very toxic lignocellulose hydrolysate, which poses specific challenges to both the host strain and the downstream processing. As a host strain, Pseudomonas putida S12 has been selected which is tolerant to a wide variety of chemical stress factors. Suitable techniques for economic recovery of (ultra-)pure FDCA from raw-HMF fermentation broths are under investigation. The FDCA product from intensified lab- and pilot scale processes will be evaluated in application tests and used for polymer and resin product development, as part of a consorted effort to promote FDCA as a new and green polymer building block. 1. Werpy T, Petersen G. (2004) U.S. Department of Energy; NREL/TP-510-35523 2. Koopman, FW, Wierckx NJP, De Winde JH, Ruijssenaars HJ (2010) Biores Technol 101: 6291-6196 3. Koopman, FW, Wierckx NJP, De Winde JH, Ruijssenaars HJ (2010) Proc Nat Acad Sci USA 107: 4919-4924 Part of the work presented is executed within the BE-Basic program and is funded (in part) by the Dutch Ministry of Economic Affairs

Monday, June 17, 2013 | 2:30pm–4:00pm

Witness the Change; Creating a Bio-Based Reality

Moderator: Will van den Tweel, Reverdia

Catia Bastioli, Novamont

Catherine Tredway, White Cloud

Steve Hurff, DuPont Tate & Lyle

Jo Kockelkoren, Reverdia

Abstract

Creating a BIO based reality requires change throughout the complete value chain, from the beginning, the bio based feedstock, to the very end where a new product becomes available on the shelves for both consumers and professionals to buy. This panel session will present and discuss the change, showing the latest examples of new chemicals, materials and end product developments becoming available to the market. We have all seen the many announcements for new production capacity for biochemicals and for biomaterials. These are of course all important and all very necessary to make new bio products available to the world, but what about the market? Who is going to use these new products? Novamont Novamont has recently developed new polymeric complexing agents derived from vegetable oils and a low environmental impact process to produce chemical intermediates, building blocks for the complexing agents of starch. Such technologies will extend the interests of Novamont beyond bioplastics to the field of renewable chemical intermediates and is opening the possibility to create a fully integrated Biorefinery. White Cloud Innovations White Cloud Innovations uses resin based technologies in combination with natural fibres to design new generation construction materials. One of their impressive innovations is plywood using among others PBS and switch grass, an innovation with impact on the construction industry both in terms of material performance as well as environmental performance. DuPont Tate & Lyle Bio Products DuPont Tate & Lyle Bio Products will present their innovative biotechnology raw material, Bio-PDO™ (renewably sourced 1,3 propanediol). Bio-PDO™ is a building block ingredient being commercially used in products to provide: superior functionality and quality, reduced environmental footprint and a sustainable business environment. As a result of this leading-edge industrial biotechnology, DuPont Tate & Lyle Bio Products is helping manufacturers create products that offer better performance, quality and sustainability across a wide range of end uses. Reverdia will present the availability of Biosuccinium™, sustainable succinic acid, for which the world's first large scale plant has started operations end 2012. Commercial volumes are available, which is essential for downstream players. Additional information will be shared on application development work supporting Reverdia's ambition to be a knowledgeable supporter for its end users. This panel session will present the change throughout the value chain, from Biosuccinium™ sustainable succinic acid and Susterra® 1,3 propanediol via innovative biodegradable polymers to plywood for the construction industry, a BIO based reality from beginning to end.

Tuesday, June 18, 2013 | 8:30am–10:00am

Direct Conversion of Methane to Higher Value Products Using Biological Systems

Moderator: Doug Cameron

Gregory Stephanopoulos, MIT

Mark Herrema, Newlight Technologies

Josh Silvermann, Calysta Energy

Sean Simpson, Lanzatech

Abstract

The accessibility of shale gas reserves due to the deployment of unconventional procurement technologies, such as fracking, has dramatically increased the availability of natural gas in North America and will likely lead to greater production volumes across the globe. With the marked influx of natural gas in the marketplace over the past decade, the price of methane has fallen far below that of petroleum on a carbon equivalent basis. This panel examines the potential of methane as a feedstock for the bio-based industrial manufacturing of organic chemicals and carbonaceous materials. Despite methane's pricing favorability, the stability of its C-H bonds creates significant kinetic and thermodynamic limitations for conversion. With the rapid innovation in biochemical engineering and increased understanding of methanotrophs, direct methane conversion in biological systems has the potential to remove many of the challenges and economic shortcomings of indirect conversion technologies, while simultaneously opening up new product landscapes. The members of this panel discuss applying genetic systems and tools to methane utilizing organisms, the need for innovation in reactor designs to combat mass and heat transfer limitations, and the suite of target products most suitably derived from methane.

Tuesday, June 18, 2013 | 2:30pm–4:00pm

Biopolyamide Platform

Moderator: Ray Miller, Verdezyne, Inc

Production of Pentane Diamine from Plant Sugars for Use as a New Biobased Diamine in Polyamides
Paul Caswell, Cathay Industrial Biotech Ltd.

What is in Store for Bio-Based Polyamides?
Benjamin Brehmer, Evonik

The Production of Green Nylons
Ray Miller, Verdezyne, Inc.

Development of Enzymes for Industrial Uses, Achieving Green Chemistry in Amides and Inosinic Acid Syntheses
Yasuhisa Asano, Erato

Abstracts

Paul Caswell
Cathay Industrial Biotech has supplied the polyamide (nylon) market with specialty long chain diacids since 2003. Polyamides, commonly known as nylons, are used as synthetic fibers and engineering plastics/resins. Polyamide 6,6 is a polymer of the six carbon hexamethylenediamine (HMDA), and the six carbon dicarboxylic acid, adipic acid. Polyamide 6 is a closely relate polymer from caprolactam which has an acid and amine on either end of a 6 carbon chain. Polyamide 6 and Polyamide 66 are the largest nylons with a $20 billion worldwide market. They have more than a 95% share in the nylon family and have been used since 1940 in many industries. In smaller applications where chemical and water resistance is required polyamide producers replace the adipic acid with a longer chains, such as dodecanedioic acid (DC12) produced by Cathay from oil-based paraffin. In the last 3 years Cathay has produced several hundred tons of "green" DC12 from renewable feedstock using a new, improved process and is actively working to commercialize this next generation technology. For the diamine half of the polyamide there has been no viable "green" product available until now. Cathay Industrial Biotech has recently launched biobased pentane diamine (DN5), a five carbon diamine produced using Cathay's patented process from plant sugars. DN5 can provide a biobased alternative to HMDA, the most prevalent diamine used for nylon today. Cathay's green DN5 offer a "green" alternative to produce new polyamides with improved properties at competitive prices. This presentation will provide a summary of the technical and application advantages that Cathay's long chain diacid provide to polyamides. The properties of the new polyamides, including PA5,6; PA5,10; PA5,12; and PA5,X, using Cathay's other long chain diacids, will be summarized. Synthetic fibers and engineering plastics are the major applications for polyamides and a large market opportunity for Cathay. Nylon production in 2001 was 5.69 million MTs (metric tons), and in 2011 it was 6.81 million MTs, a 1.12 million MTs growth. This corresponds to a market of about USD 20 billion. Based on PCI's forecast, by 2020 the demand for nylon in general will be 8.81 million MT, a 2 million MT additional growth compared with 2011. Cathay Industrial Biotech currently provides a "drop-in" alternative to butadiene-based dodecanedioic acid (DDDA), produced by the fermentation of paraffin. Cathay supplies over half of the world market for dicarboxylic acids between 11 through 18 carbons long. Building on its long chain diacid strength Cathay offers with the new diamine offers a range of bio-based monomers and potentially polyamides to meet market demand.

Benjamin Brehmer
In recent years, Evonik has developed and is pushing a line of bio-based polymers under the trade name VESTAMID® Terra. Currently three products are available within this group of polyamides that are partially or entirely based on renewable feedstocks: VESTAMID® Terra DS, HS and DD. The castor bean plant (Ricinus

communis), with its oil-based monomer derivates, form the carbon backbone of these products. For example, Terra "DS" (a PA10,10 grade) is polymerized by 1,10-decamethylene diamine "D" and sebacic acid "S", which are both directly sourced from the castor bean. To guarantee not only the bio-based sourcing aspect, but also sustainable practices, a detailed life cycle assessment (LCA) has been conducted. Compared to similar polyamides (such as nylon 12 and 6,6) these products can greatly reduce greenhouse gas emissions by 42% up to 56%. It is also expected that these values will drastically increased as these bio-based products evolve from a novel to a mature business. In this respect, and in correlation with the market developments, customers are placing heightened importance on ecological certifications and bio-labelling. Yet, despite this trend, the main market pull of the VESTAMID® Terra line remains their superior properties. Technically speaking, this group of polyamides occupy the gap between the highperformance polyamides (such as 6,12 and 12) and the standard polyamides (such as PA 6 and PA 6,6). They are renowned for low water uptake, high temperature deflection, high dimensional stability, extreme chemical resistance, and other such properties which facilitate their use in demanding application areas. This makes them unique in the field of bio-polymers, as most others are focused on low-end applications, which include but are not limited to features like biodegradability. Thus in the traditional sense of the word "sustainable", Evonik's VESTAMID® Terra line are products that last while providing high performance with the added benefit of a reduced ecological impact.

Ray Miller

Consumer demand for sustainable nylon products continues to gain momentum in the marketplace. Some current "bio-based" alternatives fail to deliver truly sustainable solutions. To meet this challenge, Verdezyne is developing bio-processes for cost-advantaged production of renewable intermediates, including adipic acid and dodecanedioic acid (DDDA). Adipic acid is primarily used to manufacture nylon 6,6 and thermoplastic polyurethanes. DDDA is used in part to manufacture nylon 6,12 for engineered plastics requiring special properties such as chemical and abrasion resistance. Verdezyne's proprietary fermentation technologies offer both feedstock flexibility and other advantages. The development and commercial introduction of these bio-based processes provides the world with cost-effective, renewably-sourced and greener alternatives to the current environmentally unsustainable petrochemical processes to make these ingredients.

Yasuhisa Asano

1. Discovery and application of enzymes from "aldoxime-nitrile pathway" in microorganisms.

Microbial nitrile hydratase (NHase) has become one of the most important industrial enzymes, overwhelmingly used for syntheses of acrylamide and other amides over Cu catalysts (1).

Recently, we have been successful in the enzymatic synthesis of nitriles from aldoximes by using a new microbial enzyme aldoxime dehydratase, which functions in the "Aldoxime-Nitrile" pathway, as a nitrile-synthesizing enzyme located upstream of NHase. Aldoxime dehydratase from E-pyridine aldoxime assimilating bacterium, Rhodococcus sp. strain YH3-3, catalyzed a dehydration reaction of

various aldoximes to form the corresponding nitriles. The enzyme is promising because cyanide is not used in the nitrile synthesis. The structure of aldoxime dehydratase of Bacillus sp. strain OxB-1 has been solved (2).
Non-stereoselective NHase is used for dynamic kinetic resolution (DKR) of amino nitriles (3). We found that a-amino-e-caprolactam (ACL) racemase catalyzes the racemization of a-amino acid amides as new substrates and is effective for DKR of a-amino acid amides (4) or a-aminonitrile. ACL racemase has narrower substrate specificity, and hardly racemizes a-amino acid amide with bulky side chains. So, we developed an efficient synthetic method for phenylalanine derivatives by DKR using NHase, mutant ACL racemase and stereoselective amino acid amidase. A mutant ACL racemase racemizing phenylalaninamide with high efficiency has been obtained by a rational designing based on X-ray crystallography (5). E. coli transformants co-expressing ACL racemase and R or S-amino acid amidase were constructed and used as biocatalysts for DKR of aromatic a-amino acid amide to form (R) or (S)-a-amino acid. (R) or (S)-Phenylalanine was synthesized with excellent enantiomeric purity in high yield from (RS)-phenylalanineamide or (RS)-phenylalaninonitrile by DKR. This new DKR method is very useful in the production of optically pure amino acid derivatives.

2. A new enzymatic method of selective phosphorylation of nucleosides (6)
Nucleotides are often used as food additives and as pharma intermediates. We have investigated a new nucleoside phosphorylation reaction using pyrophosphate (PPi) as the phosphate source. Morganella morganii that produced the highest level of 5'-IMP with high regiospecificity, was selected as 5'-nucleotide producer. In order to achieve more efficient nucleotide production, the gene coding phosphotransferase activity was isolated from M. morganii and then, sequential in vitro random mutagenesis on the gene was performed by error-prone PCR. One mutated acid phosphatase that increased in phospho-transferase reaction yield was obtained. A novel process for producing 5'-nucleotides has therefore been achieved.

1. Y. Asano and P. Kaul, Selective nitrile hydrolysis using nitrile hydratase and nitrilase, In Comprehensive Chirality, 7, pp 122-142 (2012).
2. H. Sawai, et al., J. Biol. Chem., 284 (46), 32089-32096 (2009).
3. K. Yasukawa and Y. Asano, Adv. Syn. & Catal., 354 (17), 3327-3332 (2012).
4. Y. Asano and S. Yamaguchi, J. Am. Chem. Soc., 127 (21), 7696-7697 (2005).
5. S. Okazaki, et al., Biochemistry, 48 (5), 941-950 (2009).
6. E. Suzuki, K. Ishikawa, Y. Mihara, N. Shimba, and Y. Asano, Bull. Chem. Soc. Jpn., 80 (2), 276-286 (2007).

Wednesday, June 19, 2013 | 10:30am–12:00pm

Olefinic Synthetic Pathways and Biobased Products

Moderator: Damien Perriman, Genomatica

Butadiene: Bringing On-Purpose Bio-Production Towards Commercialization
Hiroshi Mouri , Bridgestone Americas Center for Research and Technology

Gaseous and Direct Fermentation to Light Olefins to Significantly Lower Production Cost of Renewable Isobutene, Butadiene, Propylene and Isoprene
Marc Delcourt, Global Bioenergies S.A.

Deinococci an "Old New" Platform Well-Suited for Terpenoids and Isoprenoids Production
Emmanuel Petiot, Deinove

Securing the Future of Natural Rubber – An American Tire and Bio-Energy Platform from Guayule
Jeff Martin, Yulex Corporation

Olefinic Synthetic Pathways and Biobased Products
Damien Perriman, Genomatica

Abstracts

Hiroshi Mouri
This panel starts by addressing the 'why' of on-purpose butadiene, from both a producer and a user point of view. This is followed by a discussion of the need for varied approaches, based on differing feedstock availability by region and differing economics.

Marc Delcourt
Light olefins such as propylene, isobutene and butadiene are the key building blocks for the petrochemical industry, representing each a multi-billion dollar market. Light olefins are not naturally produced by microorganisms. The commonly followed routes (commercial or under development) to produce those molecules from renewable resources consist in firstly producing a precursor such as ethanol, butanediol or isobutanol through fermentation. Secondly those precursors would then be chemically transformed into the light olefin of interest, sometimes involving a several step approach such as ethanol to ethylene which would subsequently undergo a metathesis process to propylene. Apart from the significant Capex and Opex requirements of such additional chemical reactions, the precursor molecules are all soluble in the fermentation broth, where they would enrich during production and become toxic for the production organism at low concentrations. This situation requires costly separation techniques such as distillation or liquid from liquid extraction. Global Bioenergies had been founded in 2008 based on the belief that its technology would allow the direct fermentation of light olefins, eliminating the above described problems and thereby allowing to access a total market of well above USD 100 billion. Indeed, whereas the above-described precursors are liquid at room temperature, light olefins are gaseous and therefore spontaneously evaporate from the fermentation broth, not representing any toxicity problems for the production microorganism. Since inception, Global Bioenergies has obtained proof of concept for such direct bio-production of isobutene, and, very recently (October 2012) for propylene. While those two molecules are now respectively in the industrialization and development phase, other molecules such as isoprene and butadiene are progressing in the research pipeline and may well get to proof of

concept before June 2013, in which case they would be included in the presentation. Global Bioenergies has used synthetic biology to design new metabolic pathways, non-existing in nature, to transform natural metabolic intermediates into light olefins. Whereas this design had been carried out purely in silico, the next step required to physically identify the imagined enzymes in the company's laboratories. Once those enzymes in hand, their activity needs to be enhanced and the production strain has to be "rewired" for certain metabolic pathways in order to optimize the molecule and energy flow. Finally fermentation parameters need to be adjusted and up-scaling of the process to be performed. The proposed presentation would - Describe the state of the art of light olefin bio-production - Explain the gaseous direct fermentation technology - Provide cost estimations - Indicate a development schedule.

Emmanuel Petiot
Deinove is a French green technology company specialized in development and commercial exploitation of innovative, environmentally friendly, high-performance processes for production of biofuels and other compounds of industrial or pharmaceutical value. The processes developed by Deinove use bacteria with exceptional natural properties - the Deinococci. Deinove is the only company in the world with an activity based on systematic exploration of the Deinococci - a bacterial genus with exceptional biodiversity but which has rarely been studied and never exploited commercially. By combining the selection of wild-type strains (with natural properties that are already of industrial value) with bacterial engineering, Deinove is building a unique portfolio of intellectual property and innovative bio manufacturing processes. One of Deinove's top priority is green chemistry, with the bio-based production of building block chemicals as substitutes for petrochemical processes and especially compounds from the isoprenoids and terpenoids family. Due to its extraordinary genetic stability, its resistance toward chemical toxicity, and its ability to use low cost sugar, Deinove thinks that its Deinococci platform is very well suited for isoprenoids compounds production and will discuss its latest achievements in this field.

Jeff Martin
Securing the Future of Natural Rubber – An American tire and bio-energy platform from Guayule Submitted by: Jeff Martin, CEO, Yulex Corporation November 18, 2012 Yulex Corporation, Cooper Tire and the USDA-ARS were awarded a $6.9 million Biomass Research and Development Initiative (BRDI) grant from the USDA/DOE to demonstrate that the new industrial crop guayule has the potential to produce an economically/technically viable tire and utilize residual biomass for bio-energy production. My proposed presentation will overview the project goals and provided an update on progress to date. Natural rubber (NR) is a significant US import and is essential to a broad range of civilian and strategic military domestic industries with tires (automotive, agricultural and aviation) driving much of the demand. Presently, all manufacturers of rubber goods are dependent on either imported NR from Hevea brasiliensis (the Brazilian rubber tree) or petroleum-based synthetic polymers as feedstocks. Creation of a domestic rubber industry would both reduce the export of capital from our economy and create a significant number of new jobs. Tires are complex, highly engineered products and require natural

rubber to perform safely and effectively. About 70% of passenger tire raw materials are petroleum-based; severe shortages of butadiene monomer, a key ingredient for synthetic rubber (SR), occurred worldwide in 2008 and again in 2011. NR represents one possible solution to reducing petroleum dependency. However, the US tire industry relies on 100% imported NR and the supply of NR is under intense pressure from developing economies in India and China. Guayule, Parthenium argentatum, is a perennial hardwood shrub native to North America that currently produces significant quantities of NR and biomass with moderate agronomic inputs. Through their own investment and continued cooperation with USDA-ARS, Yulex has built a platform for production of domestic NR latex and bioenergy from guayule. Through this combined work, guayule can grow in a diversity of soils, requires low agronomic inputs, and demonstrates significant biomass yield advantages over other potential biomass crops for this region. Yulex has completed building its first commercial scale guayule natural rubber processing facility in early 2012 with an annual capacity of 500/MT and has begun commercial shipments of Yulex Natural Rubber. In subsequent years production output will increase annually. Ongoing commercial development requires continuing advances in guayule crop science, extraction processes, and crop residue utilization. Accordingly, we have assembled a multi-state; multi-institutional consortium of expertise to produce a bio-based concept tire through a US tire company, featuring replacement of 100% of the imported Hevea NR and synthetic rubber with US farm-produced and US processed guayule rubber. This milestone will lead to broad acceptance of guayule rubber for tire applications and thereby greatly expand the guayule NR market. These technology advances will facilitate further investment and lead to broad commercialization in the US. A parallel, comprehensive system-level sustainability analysis will promote such investments throughout the supply chain.

Specialty Chemicals, Pharmaceutical Intermediates & Food Ingredients

Sponsored by Biocatalysts

Monday, June 17th, 2013 | 8:30am-10:00am

A Biorefinery for High Value Products

Moderator: Johan De Coninck, IAR CLUSTER

Johan De Coninck, IAR CLUSTER

Mathieu Tournat, Soufflet Group

Frederique Lafosse, SOLIANCE

Jean Luc Dubois, ARKEMA

Abstracts

Johan DE CONINCK, CLUSTER IAR

In order to be competitive with crude-oil or in the future with shale gas based products, an integrated biorefinery development strategy has been developed by IAR and its member to optimize the added value from biomass. IAR's members have decided to create an ecosystem for innovation, by building 3 platforms to anticipate the evolution of future biorefineries. The approach takes into consideration the valorisation of the whole biomass, it is based on a zero-waste concept and it rises to an industrial metabolism aimed at relevant market-competitive and environmental-friendly synthesis of food products, bio-based chemicals and/or materials, together with the production of specialty and high valued products.

The first platform is BRI (Biorefinery Research and innovation) specialised in scaling up fermentation and its downstream processing. BRI includes a technical center, a demonstration plant an academic research center and a foundation.
The second platform, PIVERT is under construction and will focus on the oilseed biomass valorisation. Its particularity will be a very flexible pilot centre where thermochemical, fermentation and chemical treatment will be available to design tomorrow's processes of valorisation of the entire oilseed biomass.
The third platform, Improve comes to complete the tool by focusing its works and technology in the valorisation of proteins. Food, feed but as well other sectors such as polymer, surfactant and other active ingredients are in the firing line of the platform.

Mathieu TOURNAT, GROUPE SOUFFLET

Assessing feedstocks variability in biorefineries: use of biocatalysts produced by solid state fermentation, an innovating strategy

Biorefineries all over the world use various feedstocks, each of them presents different characteristics depending on climate, location, etc... "Biomass" is indeed a global denomination for a large variety of feedstocks with different carbohydrates content, protein content, fiber content, viscosities, etc... This compositional variability affects biorefineries economics, thus it is a major cause of concern for the biotech industrials who often do not have a great experience in this field. Soufflet, a major agribusiness company (largest private collector of grains in France, largest miller in Europe, Top 3 maltster in the world) developed a new generation of products called biocatalysts, produced by solid state fermentation. These biocatalysts provide a nutritional boost to the micro-organisms used in biotechnological processes. They compensate the compositional variability of raw materials, and for example allow an improvement of performances in bioethanol production (yield increase, faster fermentation), animal feed (weight gain increase), etc...

Through the R&D project "Osiris", Soufflet invests 70 M€ from 2008 to 2016 on solid state fermentation technology and its applications.

Frédérique LAFOSSE, SOLIANCE

If bio-based materials are serious alternatives to mass-produced or specialty chemical intermediates that are currently offered by the petrochemical industry, we will see that they cannot be disconnected from their industrial environment, or from scientific and technical processes and techniques used to obtain them and produce them in a sound manner. We will discuss these biotechnological processes, which have many advantages over chemical synthesis and can also be used to foster new production and development methods.

For that purpose, we will focus on applying these models to the cosmetic industry while explaining the concepts of renewable resources and technical performance through concrete examples of bio-based raw materials developed and industrially produced by Soliance. From biological active to ingredients, the interest of such bio-based products for the cosmetics industry will be clear. This industry is pioneering corporate ethics and sustainable development.

Jean Luc DUBOIS, ARKEMA

Castor Oil, a non-edible vegetable oil, is rather unique since it has a high concentration of an hydroxyfatty acid (ricinoleic acid). The conversion of Castor oil in high value chemicals and polymers is used to illustrate the values that can be generated in a biorefinery concept. In a biorefinery several products are made from one or more starting material, and this may require thermal processes, bioprocesses and catalytic processes.

In Arkema’s Biorefinery, Castor oil is processed to make a high value technical monomer: aminoundecanoic acid. The process starts with a transesterification to produce the methylester of castor oil. The second step is a thermal cleavage leading to heptanaldehyde and methyl 10-undecenoate. After hydrolysis, undecenoic acid is converted through hydrobromination to 11-bromoundecanoic acid, which is further reacted with ammonia to lead to the monomer. Glycerol is produced in the first step, and methyl ester of non-ricinoleic acids are isolated and sold separately. The monomer is used to produce Polyamide-11, known as Rilsan-11. Laurolactame can compete with this monomer, and is used to produce Polyamide-12, but this polymer relies on butadiene and is not renewable.
with this monomer, and is used to produce Polyamide-12, but this polymer relies on butadiene and is not renewable.

Monday, June 17, 2013 | 10:30am-12:00pm

Expanding the Role of Enzymes in Industrial Processes

Moderator: Kenneth Barrett, Verenium

David Weiner, Verenium Corporation

Michael Rabb, Agrivida

Wade Robey, POET

Neil Parry, Unilever

Anthony Pavel, Partner, Morgan, Lewis & Bockius LLP, General Counsel ETA

Abstract

Enzymes have already enabled improvements in efficiencies and environmental sustainability across many industries and are driving the change from a chemical to a bio-based economy. With increasing population growth and global urbanization, this trend is expected to continue, creating an increasing need for more efficient enzyme-catalyzed processes. This session will explore opportunities that emerge by expanding the availability of high performance enzymes with unique properties and developing new ways to apply and control these enzymes to transform global industrial process. Verenium Corporation has been evolving industrial processes with high performance enzymes for years and will host this panel. More than three and a half billion years of natural evolution has led to a tremendous diversity of microbial life on our planet. Verenium has developed a proven suite of proprietary technologies that unlock the secrets of untapped microbial genomes enabling the Company to develop new and versatile enzymes. In this presentation, Verenium will describe some of its recent work on the discovery, evolution, and commercial implementation of high-performance enzyme products that are transforming industrial processes. Other panel members will include companies like Agrivida, who are engineering high-performance, regulated enzymes using Intein Technology. Agrivida's intein technology allows the regulation enzyme activity. In essence, enzymes can be produced in an inactive form and then activated on demand with a variety of stimuli such as heat, pH or cold. The technology allows the development of new, high performance enzymes with unique characteristics and applications. Inteins also allow the economic production of difficult to express proteins, where unregulated enzyme activity is deleterious to the host organism.

Monday, June 17, 2013 | 2:30pm-4:00pm

Renewable Specialty Chemical Products

Moderator: Atul Thakrar, Segetis

Segetis Gains Commercial Momentum with Expanded Production
Atul Thakrar, Segetis

Adventures in Monodose Detergents
John Shaw, Itaconix

Deployment of a Truly Capital-Efficient Catalytic Oxidation Platform
Mike Knauf, Rivertop Renewables

Adam Malofsky, Bioformix

Peter Nieuwenhuizen, Akzo Nobel

Atul Thakrar
Recently Segetis completed expansion of our proprietary levulinic ketal based JavelinTM technology manufacturing at a demonstration plant. The added capacity to produce these specialty chemicals from renewable feedstocks is helping to gain momentum with selected customer partners to support their market launches of formulated and compounded products. Continued transition of market success will provide a strong position to de-risk the investment decision in the ultimate dedicated commercial facility.

John Shaw

Adventures in Monodose Detergents

New renewable specialty chemicals are offering performance and cost advantages in many applications. As additives in customer formulations, however, they may struggle to gain use based solely on their own value. Potential customers can acknowledge the value, but still need greater motivation to reformulate their products for new renewable specialty chemicals.
Trends toward compact and sustainable detergents are creating reformulating opportunities for new materials in the detergent market that favor Itaconix DSP™ polymers. Looking to improve performance, reduce costs, and provide sustainability, Itaconix adapts to customer needs with a range of approaches for working with detergent brands to launch improved formulations and new product formats.

Mike Knuaf

Rivertop Renewables is scaling-up its proprietary catalytic oxidation process capable of producing a platform of sugar acids. Rivertop's first application of the technology is to convert glucose to glucaric acid (aka saccharic acid). The platform can be applied to wood sugars, glycerin, and even petrochemical alcohols for the production of corresponding acids. The technical attributes of this re-invented technology translate directly into capital and operational cost advantages: high product yields, low-cost catalyst, and regeneration and recycling of the reagent. Together, these advantages reduce capital requirements by 30-50 percent and operating costs by 35 percent while also minimizing the costs of permitting and monitoring would-be effluents. The process is further characterized as feedstock flexible, safe, and efficient in that it yields 100 percent of the dextrose carbon content. Utilizing off-the shelf equipment and adapting proven units of operation, Rivertop is scaling-up along parallel routes to commercialization: contract manufacturing will supply commercial volumes to detergent brands as they adopt our ground-breaking solution to spotting and filming on glassware. Rivertop will demonstrate an optimized process at the company's facilities in Montana prior to building a world-scale plant. This presentation will analyze both the technical and strategic aspects of Rivertop's deployment of a truly capital-efficient oxidation technology platform.

Tuesday, June 18, 2013 | 8:30am-10:00am

Value Chain Partnerships to Accelerate Commercialization of Biobased Materials

Moderator: Babette Pettersen, BioAmber

Dann Winn, Inolex

Karsten Job, Lanxess

Laurence Dufrancatel, Faurecia

Carmen Rodriguez, Arkema

Abstract

The market transition to biobased materials continues to advance, as both manufacturers' and consumers' awareness and interest in the benefits of these more sustainable solutions increases. Two McKinsey surveys in 2011 confirmed that over 80% of global company executives and 90% of consumers see 'green' as an important trend and a viable alternative to standard, petroleum-based materials with the potential to generate value. Significant interest was expressed in 'green' materials, combined with some willingness to pay for materials that meet the right sustainability criteria and present no performance disadvantages. As the commercialization of biobased chemicals advances, new performance advantages are being identified, demonstrating that biobased chemicals go beyond replacing fossil fuel-based materials with more sustainable solutions, as they offer a new

chemistry set with a broad innovation potential based on a unique combination of benefits building on performance, an improved environmental profile, and competitive economics that consumers are now looking for. However, success is not predicated on technology alone. Market penetration of new chemicals is a significant challenge. Significant barriers to sustainable application development stand in the way for companies, and therefore consumers, across all markets. These barriers include perceptions of product performance, pricing, skepticism about product claims and a lack of knowledge about what makes a product socially or environmentally-responsible. This panel will discuss how to develop partnerships across the value chain in biobased chemicals that can be used to accelerate the commercialization of biobased materials across a broad range of applications and bring new products to a willing marketplace.

Finding all the tools to make your sustainability story a reality is not always right at your finger tips. Companies are constantly looking for alternative paths that ultimately lead to diversified solution to the "green" story. Starting with a template for what sustainability means in an organization, possible contributions in key areas, and then matching core strengths to ensure an effective contribution is key to future grwoth and a successful implementation. The short talk will introduce Arkema Inc and the company's Sustainability Strategy. This discussion will lead into up to date results and some examples of sustainable solutions stemming from the implementation of this strategy.

Tuesday, June 18, 2013 | 2:30pm-4:00pm

Creating the Lignin Value Chain

Moderator: Joyce Yang, DOE EERE Biomass Program

Kendall Pye, Lignol

Gregg Beckham, National Renewable Energy Laboratory

Arthur Ragauskas, Georgia Institute of Technology

Cliff Eberle, Oak Ridge National Laboratory

Abstract

The saying goes, "You can make anything out of lignin except money". Recent research and manufacturing advancements may prove that old adage wrong. It may be possible in the near future to harness the power of bioprocessing, chemical catalysis, separation and advanced manufacturing technologies to produce lignin derived fuels, chemicals and materials, such as carbon fibers. Creating a sustainable value chain from lignin - from harvesting raw feedstocks to meeting end-user specifications - will revitalize the American chemical industry, provide additional revenue for traditional (e.g. pulp and paper) as well as new (e.g. integrated biorefineries) biobased industries, and help the U.S. national policy objectives, including but not limited to the Corporate Average Fuel Economy (CAFE) Standards (Clean Air Act, the Energy Policy and Conservation Act), the Renewable Fuel Standards (RFS; the Energy Policy and Conservation Act, Energy Independence and Security Act), and the USDA BioPreferred Program (Food, Conservation and Energy Act). Lignin makes up more than a third of the weight of biomass. From both economic and environmental sustainability perspectives, lignin is simply too valuable to consume just for electricity generation. Given the Department of Energy's push for infrastructure-compatible but oxygen-poor hydrocarbon fuels, it is especially critical to realize pathways to higher value products from the lignin portion of biomass. The timing is ripe to leverage advancements in bioprocessing and chemical catalysis to create value from lignin. New lignin deconstruction processes are being elucidated, and new lignin utilization pathways are being discovered. These pathways are enabled not only by cutting edge synthetic and systems biology, but also by concurrent advancements in the field of chemical catalysis. The timing is also ripe to capture the momentum from advanced manufacturing platforms and markets for innovative materials. New processing techniques and advanced separations technologies may soon allow for the manufacturing of higher-quality lignin intermediates, and derivative materials, in the kilogram to metric ton scales. This in turn, will enable the blending of chemical precursors for product formulation, material property testing, and allow for the integration of these components into the manufacturing supply chain for automotive, aerospace and energy sectors. While the potential is there, key

technical hurdles and challenges in making lignin derived value chain possible, robust and profitable must be addressed. Taken together, it is not difficult to imagine in a not-so-distant tomorrow, Americans will drive or fly in lightweight but collision and corrosion resistant cars made from lignin derived carbon fibers, recline on polyurethane derived from lignin monomers, fill-up on lignin-derived gasoline or jet fuel, all while they admire the lignin-derived windmills and aircrafts, the biorefineries generating the chemical precursors, surrounded by the ever renewing biomass landscape outside of their vehicles. The speakers of this panel today are each playing an integral part of making that vision a reality and will offer perspectives from research and manufacturing.

Wednesday, June 19th, 2013 - 10:30am

New and Better Personal Care Ingredients from Biosynthesis

Moderator: Kathy Lowther, Alberta Agriculture and Rural Development
Kathy Lowther, Alberta Agriculture and Rural Development
Neil Burns, P2 Science, Inc
Albert Soley, Lipotec

Kathy Lowther, Alberta Agriculture and Rural Development
Advancing the Specialty Chemical/Green Chemistry Cluster in Alberta

Alberta is well positioned to become a preferred supplier of green bio-based actives, ingredients and platform technologies for the natural cosmetics and personal care industry. The Specialty Chemical Ingredient (SCI) Initiative of Alberta's Ministry of Agriculture and Rural Development is helping to facilitate the development of innovative products from renewable biomass by advancing an emerging green chemistry cluster that includes provincial, national and international industry and researchers. SCI's goal is to establish Alberta as a preferred supplier of high value specialty ingredients to the global plant-based cosmetics and personal care industry. Industry and research collaborations are key to the development and commercialization of specialty/drop-in and novel chemicals, products and platform technologies. Ms. Kathy Lowther, lead of the SCI Initiative, will provide a brief review of opportunities and challenges in Alberta's green and specialty chemical/cosmetic ingredient industry.

Neil Burns, P2 Science, Inc
Specialty Chemicals from Biomass
Mr. Neil Burns, CEO of P2 Science, a venture backed biorefinery start-up, will present new technology that enables production of renewable cosmetics and personal care ingredients from biomass feedstocks.

Albert Soley, Lipotec
Cosmetic actives based on marine microorganisms

Despite the remarkable number of marine molecules that have been identified (over 15.000) and the fact that the percentage of actives is higher compared to terrestrial molecules, there's a much more limited number of marine molecules present in the therapeutic, cosmetic or alimentary markets. In the cases of the cosmetic or alimentary field, marine origin is present in algae extracts and fishery derived products. But a few pure molecules requiring basic research, from screening of marine macro organism extracts, fractionation, active identification, structure elucidation and chemical synthesis for production purposes are present in the market, due to the unmatch with the usual speed needed in research projects of these fields. An alternative path to reduce steps from these processes is the use of microorganisms (non-GMO) which can be used directly for production purposes, directing the focus of the research to specific families of molecules naturally produced by the microorganisms.

The approach of Lipotec for the search of marine cosmetic actives has been to select a library of microorganisms from various origins and ecosystems, covering a wide range of biodiversity and geographical origins, and paying special attention to the ExtraCellular Polymeric Substances, which comprise proteins, glycoproteins and polysaccharides, which are families of molecules known to stimulate various processes such as regeneration, extracellular matrix production, and mediate in signaling pathways present in skin.

Concretely, some of the projects that have been run have worked on the concept of extrapolating cell protection mechanisms present in harsh environments to skin. Specifically, a hydration active was developed from an intertidal area where the microorganisms suffer desiccation periods, an active increasing tissue regeneration and integrity was developed based on Antarctic microorganisms, and some further projects explore signaling on skin biochemical pathways.

Neil Goldsmith, Evolva
New and Better Personal Care Ingredients from Biosynthesis

Evolva's uses biosynthetic, fermentation and evolutionary technologies to discover and provide innovative, sustainable ingredients for health, nutrition and wellness. Key technologies include combinatorial genetics, glycosylation and a variety of gene/chemistry integration technologies.
We focus on low volume, high margin speciality products where our technologies can create disruptive products based on dramatically improved performance, significantly lower production costs and greatly simplified, supply chains.   Example products include:
• Resveratrol: the "good stuff in red wine", resveratrol has been shown to have many protective benefits against health conditions related to aging. Fermentation approaches can provide high quality, high performance forms of resveratrol at attractive prices. On market.
• Vanilla: One of the most important fragrance and flavouring products in the world. The product of vanilla by fermentation allows high quality products at attractive prices, and customisation of the organoleptic profile for specific markets. Market launch 2013/2014
• Stevia: A fast growing natural high intensity sweetener. By making the key components individually via fermentation, the taste and customisability of Stevia can be significantly improved and costs reduced, expanding the applications in which Stevia can be used
• Saffron: the world's most expensive spice. By making the key components individually the performance and customisability of Saffron can be significantly improved and the costs significantly improved. The very complex supply chain of Saffron can be greatly simplified
Evolva is HQ'd in Basel, has a headcount of c. 80 and is listed on the Swiss stock exchange. (SIX: EVE)

Synthetic Biology and Microbial Genomics

Sponsored by

Monday, June 17, 2013 | 8:30am-10:00am

Renewable Chemicals through Strain Engineering and Process Potimization

Developing Robust Clostridia Fermentation Hosts for Renewable Chemicals
Edward Green, Green Biologics Ltd.

Renewable Chemicals: The Path to Commercialization
Max Senechal, Metabolix

High Efficiency Fermentation of a Xylitol Co-Product from Hemicellulose
David Demirjian, zuChem, Inc.

2,3-Butanediol from Renewable Resources
Rishi Jain, Praj Matrix - The Innovation Center

Abstracts

Edward Green
Proposal Description: Synthetic biology involves the design and engineering of biologically based parts as well as the redesign of existing biological pathways. It has the potential to deliver new applications and improve existing industrial processes resulting in economic growth and job creation. A recent assessment by BCC research concluded that the global synthetic biology market will grow from $1.6bn in 2011 to $10.8bn by 2016. Green Biologics is a global industrial biotechnology company based in Abingdon, Oxfordshire UK with the skills and experience to deliver competitive, capital efficient production of biobutanol and other C4 chemicals for the chemicals and biofuels markets. The Company has developed proprietary fermentation technology using solventogenic clostridia for the production of n-butanol, a high value chemical used in a variety of polymers, plastics and resins in a market worth over $5bn. Green Biologics has a large collection of robust industrial strains representing many clostridia species. Conventional mutagenesis and genetic engineering have been used successfully to improve strain performance focusing on both butanol yield and titre. In addition, we have sequenced many industrial strains plus mutated strains and used comparative genomics to identify novel gene targets and pathways for manipulation. In this paper we report on progress using genetic engineering with a variety of industrial strains. We also demonstrate the application of synthetic biology for clostridia using advanced molecular biology tools and discuss two examples focused on improving substrate utilization and butanol production. Synthetic biology has the potential to make a transformational change to performance and process economics when applied to robust and proven fermentative microbes. The overarching goal is to

develop a clostridia fermentation platform that produces a wide range of C3 and C4 chemicals from sustainable cellulosic feedstocks.

Max Senechal

Metabolix is a leading industrial biotechnology company and pioneer in the development of biobased plastics and chemicals, combining its expertise in bioscience with innovative engineering excellence to address global markets. The Metabolix scientific foundation and core science is the metabolic pathways for the production of a class of microbial biopolymers – polyhydroxyalkanoates (PHAs) – from renewable resources. PHAs can be tailored through metabolic pathway engineering and have a wide range of applications in industry, including use in polymer form as biobased plastics or in monomer form as chemical intermediates. The first commercial product using the fermentation route are biopolymers marketed under the Mirel and Mvera brands.

Metabolix is also focused on developing biobased four-carbon (C4) and three-carbon (C3) chemicals. The C4 program is currently at the semiworks scale (80,000L) and Metabolix has shipped samples of biobased gamma butrylactone (GBL) to prospective customers for testing, and GBL has been successfully converted to BDO via hydrogenation. Metabolix is making steady progress with its C3 program as well – the Company is currently running fermentation at the 20L scale and recently successfully recovered acrylic acid from biomass using its proprietary FAST process. In 2013, Metabolix plans to continue fermentation scale up, engineering of microbial strains, and development and optimization of its FAST recovery technology to produce biobased C4 and C3 chemicals to match chemical industry specifications for quality and purity. In this presentation, Metabolix's vice president, biobased chemicals, Max Senechal, will outline the Company's experience developing biobased "drop-in" replacements for petroleum-based industrial chemicals, and the path to commercialization focusing on biobased acrylic.

David Demirjian

The production of value-added bio-products from renewable biomass waste streams is an important economic driver for their production. Hemicelluose is one such side-stream that is generally either sold as animal feed or burned for energy. Conversion of hemicellulose to a higher value, high volume co-product such as xylitol could also significantly increase biofuel economics. Xylitol is a specialty sweetener used worldwide in confectionary products because of its oral hygiene, physical, and sweetening properties. Unfortunately current production methods for xylitol require highly purified xylose as the substrate which is both expensive and available in limited quantities. We have developed a highly efficient fermentation using recombinant strain of E. coli for the production of xylitol. The strain produces xylitol from a variety of different hemicellulose hydrolysate feedstocks containing a mixture of C5/C6 sugars. Feedstocks include agricultural feedstocks such as from (corn, wheat, bagasse) forestry biomass (hardwood and softwood) as well as at yields over 110g/l pure xylitol with no contaminating sugars or polyols. The process is now in pilot.

Rishi Jain

2,3-butanediol is a C4 molecule which is used as an antifreeze agent. It is also used in chiral drug synthesis, manufacture of pesticides and printing inks. It's biggest potential is being realized for its conversion to 1,3-butadiene that finds application in the manufacture of synthetic rubber. Another potential application of 2,3-butanediol is its dehydration to methyl ethyl ketone(MEK) which is used as an industrial solvent Earlier 1,3-butadiene and MEK were obtained from naphtha cracking. However, the discovery of cheap shale gas in USA has made naphtha cracking for making C4 molecules unviable. This has opened up opportunities for making 2,3-BDO from renewable resources competitively. A number of species of the genera Klebsiella, Enterobacter, Serratia, Bacillus and Paenibacillus have the ability to produce 2,3-butanediol as one of the by-products of the mixed acid pathway. Although Klebsiella species have been reported to produce 2,3-butanediol in high titers, their pathogenecity prevents them from being scaled up. BSL-1 microbes from the Bacillus genera are promising candidates for industrial scale-up of fermentative production of 2,3-butanediol. This talk focuses on making the 2.3-BDO bio-process industrially viable. Techno-economic evaluation throws up a challenge of high fermentation efficiency. In order to achieve this, not only strain engineering but, fermentation process optimization is also required. Strain improvement strategies were targeted for reducing byproduct profiles. Process development included optimizing fermentation conditions such as dissolved oxygen concentrations, pH and modes of fermentation. In addition, various sources of nutrients were tested for media optimization.

Monday, June 17, 2013 | 10:30am-12:00pm

Robust Microbial Systems for Agriculture, Renwable Chemicals and Biofuels

Moderator: Grace Colon, Blue Sierra Consulting

Innovating across verticals: biotech for the agriculture, industrial, and energy sectors
Matthew Crisp, Benson Hill Biosystems
Douglas Eisner, GrassRoots Biotechnology
Margaret McCormick, Matrix Genetics and Targeted Growth

Designing fast-growing cyanobacteria for chemical and biofuel production
Alexander Beliaev, Pacific Northwest National Laboratory

Abstracts

Matthew Crip
Advances in agricultural biotechnology have been applied for decades to improve productivity and quality of food crops. Platform technologies have also been developed from research funding through private sector collaborations with major agbiotech/seed companies. Increasingly, these advances are being applied to bioindustrial and bioenergy applications, for instance in feedstock crops and microbial production systems. Benson Hill Biosystems is an agricultural biotechnology company dedicated to delivering substantial production gains to the agricultural sector by advancing traits to increase intrinsic yield. The company is using model crop systems and technology applicable for many crops, irrespective of their use as food or fuel. GrassRoots Biotechnology has developed a suite of integrated technologies to meet the growing gene regulation needs of the biotechnology industry. This technology has been successfully applied in food crops in a broad collaboration with Monsanto. Recently, the company began to apply its technology to industrial applications and is currently pursuing collaborations for manufacturing high value products in plants and microbes. Targeted Growth is a crop biotechnology company focused on developing products with enhanced yield and improved quality for the agricultural and energy industries. Recently, the company spun out Matrix Genetics, a biotechnology company focused on producing renewable fuel and specialty chemicals derived from cyanobacteria. Each of these companies is applying technology and learnings from agbiotech R&D to applications that have significant impact in the bioindustrial and bioenergy arena. The presenters will highlight their companies' key capabilities and review the rationale, risks and potential benefits of applying innovations from an established to a rapidly emerging sector.

Douglas Eisner

Advances in agricultural biotechnology have been applied for decades to improve productivity and quality of food crops. Platform technologies have also been developed from research funding through private sector collaborations with major agbiotech/seed companies. Increasingly, these advances are being applied to bioindustrial and bioenergy applications, for instance in feedstock crops and microbial production systems. Benson Hill Biosystems is an agricultural biotechnology company dedicated to delivering substantial production gains to the agricultural sector by advancing traits to increase intrinsic yield. The company is using model crop systems and technology applicable for many crops, irrespective of their use as food or fuel. GrassRoots Biotechnology has developed a suite of integrated technologies to meet the growing gene regulation needs of the biotechnology industry. This technology has been successfully applied in food crops in a broad collaboration with Monsanto. Recently, the company began to apply its technology to industrial applications and is currently pursuing collaborations for manufacturing high value products in plants and microbes. Targeted Growth is a crop biotechnology company focused on developing products with enhanced yield and improved quality for the agricultural and energy industries. Recently, the company spun out Matrix Genetics, a biotechnology company focused on producing renewable fuel and specialty chemicals derived from cyanobacteria. Each of these companies is applying technology and learnings from agbiotech R&D to applications that have significant impact in the bioindustrial and bioenergy arena. The presenters will highlight their companies' key capabilities and review the rationale, risks and potential benefits of applying innovations from an established to a rapidly emerging sector.

Margaret McCormick

Advances in agricultural biotechnology have been applied for decades to improve productivity and quality of food crops. Platform technologies have also been developed from research funding through private sector collaborations with major agbiotech/seed companies. Increasingly, these advances are being applied to bioindustrial and bioenergy applications, for instance in feedstock crops and microbial production systems. Benson Hill Biosystems is an agricultural biotechnology company dedicated to delivering substantial production gains to the agricultural sector by advancing traits to increase intrinsic yield. The company is using model crop systems and technology applicable for many crops, irrespective of their use as food or fuel. GrassRoots Biotechnology has developed a suite of integrated technologies to meet the growing gene regulation needs of the biotechnology industry. This technology has been successfully applied in food crops in a broad collaboration with Monsanto. Recently, the company began to apply its technology to industrial applications and is currently pursuing collaborations for manufacturing high value products in plants and microbes. Targeted Growth is a crop biotechnology company focused on developing products with enhanced yield and improved quality for the agricultural and energy industries. Recently, the company spun out Matrix Genetics, a biotechnology company focused on producing renewable fuel and specialty chemicals derived from cyanobacteria. Each of these companies is applying technology and learnings from agbiotech R&D to applications that have significant impact in the bioindustrial and bioenergy arena. The presenters will highlight their companies' key capabilities and review the rationale, risks and potential benefits of applying innovations from an established to a rapidly emerging sector.

Alexander Beliaev

As new design principles are implemented to improve cellular properties through assembly and introduction of new parts and biochemical modules, basic information characterizing the properties of individual components, as well as their behavior within the system, becomes the critical limiting factor. Desirable engineering outcomes are extremely difficult to achieve without predictive understanding of the genetic, regulatory, and physiological properties of the organism. It is essential to point out that Escherichia coli and Saccharomyces cerevisiae have become dominant industrial platforms, not necessarily because of their superior or specialized metabolic properties, but because of their robust genetics, ease of cultivation, and the availability of advanced genome-scale metabolic models. We contend that engineering biological systems for bioenergy requires platforms already in possession of highly complex traits (e.g., photoautotrophy, adaptations to extremes of temperature, light, salinity, pH, etc.) that cannot readily be introduced into the traditional platforms used for metabolic engineering. O_2-evolving photosynthesis is a highly complex process, which requires cells to coordinate pigment and lipid biosynthesis, photosystem and thylakoid membrane biogenesis, carboxysome assembly, CO_2 reduction, and intermediary metabolism. Moreover, the light-dependent reactions of photosynthesis inherently generate toxic reactive oxygen species (ROS). The tolerance responses of cells to light and ROS are also complex, and even among prokaryotic photoautotrophs there are enormous differences in the relative sensitivities of organisms to various stressors. Despite the tremendous progress towards understanding the structural and functional relationships for many components of the photosynthetic apparatus, current knowledge gaps in many relevant subjects do not realistically allow one to consider transforming E. coli into a functional chlorophoto-autotroph. More logical is to improve the quality of photoautotrophic model organisms for the production of biofuels and other valuable biomolecules. To take advantage of alternative engineering platforms, and to bypass the need for many person-years for the development of the requisite genetic systems, we need more robust means for optimizing existing cellular functions and models that integrate various types of -omics data, facilitate hypothesis development, and predict the most likely outcome of metabolic engineering. To that end, the DOE Biofuels Scientific Focus Area (BSFA) at Pacific Northwest National Laboratory (PNNL) conducts fundamental research on cyanobacteria with specific emphasis on pathways of carbon, nitrogen, and redox metabolism. Using model cyanobacterial systems (Synechococcus sp. PCC 7002), we are conducting systems-level analysis of modules involved in photosynthetic energy conservation and reductant generation; CO_2 fixation; photosynthate production; and biosynthesis of metabolic intermediates and monomers. Coupled with regulatory network reconstruction, this approach is providing testable predictions of reductant fluxes, reductant partitioning to carbon metabolism and other sinks, as well as anabolic and biosynthetic pathways that lead to macromolecular synthesis. This presentation discusses approaches for designing of novel pathways and cellular functions through genetic and metabolic engineering and summarizes the current progress in developing alternative bioengineering platforms.

Monday, June 17, 2013 | 2:30pm-4:00pm

Consolidated Bioprocessing of Lignocellusolic Feedstocks

Moderator: David Levin, University of Manitoba

David Levin, University of Manitoba

Richard Sparling, University of Manitoba

Gideon Wolfarrdt, Ryerson University

Jorg Riesmeier, Direvo Industrial

Development of a C5 and C6 to Ethanol Consolidated Bioprocess with An "Old New" Bug; Use of the Deinococci Platform
Emmanuel Petiot, Deinove

Abstracts

Albrecht Laeufer
Direvo´s BluCon™ strain and process portfolio provides efficient conversion for a broad range of different substrate streams into valuable biofuels and bio-based chemicals. Without the need for costly enzymes, it enables the direct conversion of both pretreated lignocellulosic feedstock and sugar-rich side-streams into ethanol and / or lactic acid in a consolidated bioprocess. Enzyme production, cellulose breakdown and product formation are combined into one vessel. Global switch from a fossil-based to a bio-based economy continues to increase demand for sustainable transportation fuels and chemical building blocks. With 1st generation processes being critically discussed for limited sustainability and food competition, significant effort has been put into the development of 2nd generation technologies. However, enzyme cost for saccharification of biomass still constitutes a major economic burden to most conventional 2nd generation processes. Direvo's approach to overcoming this pitfall is the use of cellulolytic organisms for direct conversion of biomass. Direvo has undertaken a major research program leading to identifying a portfolio of proprietary microorganisms. Based on the resulting, extremely thermophilic Caldicellulosiruptor and Thermoanaerobacter strains, fermentation processes accommodating different substrate streams are now being developed and optimized. The BluCon™ platform is extremely flexible both for feedstock and products and can be applied around the globe. Both C6- and C5-streams from a broad range of substrates including perennial grasses, agricultural residues, hardwood and softwood are readily converted. BluCon™ delivers transportation fuels like ethanol or chemical building blocks like lactic acid at lowest possible cost. The high process temperature protects the process from contamination; it reduces cooling requirements and distillation energy. Without added enzymes, already the wild-type strains achieve product titers > 12 g/L. With decades of experience in directed evolution and process design, Direvo is perfectly

positioned for the final steps of this development. Strain and process optimization include pretreatment, fermentation, metabolic strain engineering as well as directed evolution and are carried out in house and in collaboration with global partners from industry and academia.

Emmanuel Petiot
Deinove is a French green technology company specialized in development and commercial exploitation of innovative, environmentally friendly, high-performance processes for production of biofuels and other compounds of industrial or pharmaceutical value. The processes developed by Deinove use bacteria with exceptional natural properties - the Deinococci. Deinove is the only company in the world with an activity based on systematic exploration of the Deinococci - a bacterial genus with exceptional biodiversity but which has rarely been studied and never exploited commercially. By combining the selection of wild-type strains (with natural properties that are already of industrial value) with bacterial engineering, Deinove is building a unique portfolio of intellectual property and innovative bio manufacturing processes. Deinove's top-priority program is the development of breakthrough industrial biofuel production processes based on biomass digestion and fermentation by Deinococcus sp. At present, bioethanol is conventionally produced by fermenting the glucose obtained (after a variety of pre-processing steps) via enzymatic hydrolysis of biomass (sugar beet, wheat, corn, sugar cane, etc.). The fermentation itself is generally performed by brewer's yeast (Saccharomyces cerevisiae). Deinove is leveraging Deinococcus's exceptional properties and is changing the paradigm in bioethanol production. The company is developing integrated processes capable of degrading not only glucose but also lignocellulosic raw materials (whole plants, wood, green waste, etc.). The Deinove processes seek to significantly improve industrial and environmental performance levels by allowing the co-fermentation of C5 and C6 complex sugars such as hemicellulose, starch and cellulose in a fully consolidated bioprocess. During its talk, Deinove will show where it stands in terms of biomass degradation and ethanol production within its partnership with Tereos, one of the top five global sugar producers

Tuesday, June 18, 2013 | 8:30am-10:00am

Biotechnological Processes for Biobased Products from Celluloisc Biomas:

Moving toward Commercialization of Multiple Bio-Products from Cellulosic Biomass

Mark Burk, Genomatica

TBD , Graal Bio

Paul Dwyer, Gevo

Vonnie Estes, Codexis

Abstract

One approach for improving the economics and acceptability of bio-based chemicals and products is using cellulosic biomass as feedstock – whether agricultural waste or purpose-grown energy crops. To do so successfully requires the thoughtful integration of biomass conversion, product fermentation and overall production processes. This panel explores the progress in integrating the PROESA biomass conversion technology for the production of multiple, very different products.

Tuesday, June 18, 2013 | 2:30pm-4:00pm

Advances in Biomass Pretreatment Processing:

Moderator: Barry Wortzman, GreenField Ethanol

Pre-treatment - The Key to Commercialzing Cellulosic Ethanol
Barry Wortzman, GreenField Ethanol

Small Scale Continuous Biomass Pretreatment Reactor Development: A Case Study
Dale Monceaux, AdvanceBio, LLC

A "Compare-and-Contrast" of Pulping Processes That Have Been Adapted for Biomass Pretreament
Jack Saddler, UBC

Nature-Inspired Lignocellulose Pretreatment Technologies
Shulin Chen, Washington State University

Andritz is Providing Commercial Scale Pretreatment Systems for Advanced Cellulosic Biofuels Based on our Expertise in Pulp & Paper
Thomas Pschorn, Andritz Ltd

Abstracts

Barry Wortzman
Cellulosic ethanol is real. At least 8 commercial scale projects are underway for start-up in 2013. This is a very good beginning. But many more plants will have to be built to satisfy RFS2 in the U.S. which mandates 30 billion gallons of biofuels by 2022, of which 21 billion gallons must be derived from advanced biofuels. GreenField can make a significant contribution to this build-out. We are experts in pre-treatment. Our pre-treatment process recovers the most C5 and C6 sugars, in their cleanest form, for optimal down hydrolysis and fermentation. In the result, we consistently achieve the highest yields of cellulosic ethanol from a variety of low-to-high lignin feedstocks – on average 309 liters of ethanol per tonne on a dry matter basis. And, we do this without acid, and in an opex efficient manner, driven by, for example, very low doses of enzymes and yeasts. However, there is also the capital cost of the equipment cost to address. And, we have developed our own unique equipment (our Modified Extruder) to execute our pre-treatment process for a cost substantially less than other off-the-shelf equipment. To validate the efficacy of this equipment, we undertook an extensive project to incorporate our Modified Extruder into our 1 tonne per day Pilot Plant, with the capability to operate on a continuous basis. We have demonstrated that it works and are currently addressing commercial application of our pre-treatment package.

Dale Monceaux

Biomass offers the potential of being a significant source of fermentable carbohydrates for the production of fuels and chemicals. The complex nature of lignocellulose-rich biomass requires efficient application of an initial pretreatment process to solubilize the hemicellulose fraction and produce a reactive cellulose fraction amenable to enzymatic hydrolysis. Development of cost effective, advanced cellulose hydrolyzing enzymes, catalysts and fermenting organisms requires volumes of representative pretreated biomass. Here, "representative" is defined as materials with chemical and physical properties similar to those expected from likely commercial scale processes. A development program was initiated to scale down continuous, horizontal screw reactor systems that have a demonstrated track record processing woody and non-woody biomass substrates employing a range of chemical process technologies. The approach and findings (expected and unexpected) from the brainstorming, design, fabrication, commissioning and startup phases of project are described along with a review of the as-built bench-scale continuous, pretreatment reactor system.

Jack Saddler
Pulping has a long and storied history with the main goal of recovering strong, bright cellulosic fibers, ideally at high yield and inexpensively produced. An ideal pretreatment process at the front end of a "Biorefinery process" shares many of the characteristics of a pulping process. However, in this case, all of the initial lignocellulosic components should be recovered resulting in high sugar yields and a highly reactive lignin. A desirable pretreatment process should provide fast, complete cellulose hydrolysis at minimal enzyme loadings after fractionating and recovering the hemicellulose, lignin and extractive components in a usable form. Although various chemical and mechanical pulping methods are currently being assessed for their potential as a "front end" for biorefinery processes, the "jury is still out" in terms of there being a clear, ideal pretreatment. One starting premise in adapting current pulping processes is that pulps are typically worth more than the equivalent amount of sugar. Thus, although dissolving pulps can be readily hydrolyzed by relatively low loading of enzymes, these pulps are too valuable to be considered as starting feedstock's for a biorefining process. In contrast, although mechanical pulps are considerably less expensive than either Kraft or dissolving pulps, they are still quite recalcitrant to enzymatic hydrolysis, despite a significant increase in the cellulosic surface area resulting from refining of the fibers. As a result, various groups have looked at adapting or modifying traditional or novel pulping methods to both decrease the cost of the process while enhancing the recovery and utilization of all of the components present in the initial lignocellulosic feedstock and increasing the ease of enzymatic hydrolysis of the cellulose. Pretreatment processes such as steam explosion, SPORL (Sulfite Pretreatment for Overcoming Recalcitrance of Lignocellulosics), Green liquor treatment and Organosolv are all variations on pulping process and each have their strengths and challenges. In many cases these "mild" pulping processes still face obstacles related to the ability to process all biomass types, high chemical loadings, chemical recovery, etc. The presentation will "compare-and-contrast" various pretreatment processes that are modifications of known pulping processes and why our own group has tended to focus on steam and organosolv as more suited for the pretreatment of softwoods.

Shulin Chen

Overcoming biochemically recalcitrance of plant cell wall remains one of the most significant challenges in technology development for producing biofuels and biochemicals. The current saccharification technology requires a pretreatment process that removes lignin inhibition and facilitates subsequent access of cellulase to cellulose to release the sugar. Unfortunately, the existing pretreatment processes are often energy intensive and environmentally unfriendly and due to the needs for high temperature and high pressure and excessive chemicals. Transformative break-through in pretreatment technology is required to overcome this major technological barrier in lignocellulose processing. Nature, on the other hand, has evolved biological systems such as termite for deconstructing lignocellulose and extracting energy from plant materials under natural conditions. Recent findings in understanding these biological systems has provided scientific basis for developing a new generation of pretreatment and saccharification technologies. The Bioprocessing and Bioproduct Engineering Laboratory (BBEL) at Washington State University has been exploring how termites and white-rot fungus modifies lignin to initiate plant cell wall deconstruction. Without destroying lignin molecules, the termite system selectively modifies lignin structure and alleviates associate inhibition to cellulases. Based on what learned from termite system, BBEL has invented technologies that are capable of pretreating lignocelluloses with ambient pressure and close-to-ambient temperature. The presentation summarizes the results of the termite system study and introduces the new pretreatment technologies.

Thomas Pschorn

The chemical and biological processing of lignocellulosic feedstocks involves the integration of feedstock handling with pretreatment and hydrolysis (saccharification) technologies and biomass sugar conversion technologies leading to the production of cellulosic biofuels and biochemicals. Andritz is a global market leader for customized plant, systems and services for the pulp and paper, hydropower, steel and other specialized industries, including biofuels and biopower. Andritz is applying proven process technology, concepts and large scale process equipment from the pulp and paper and environmental industry with minor modifications on various types of ligno-cellulosic feedstocks for pre-treatment systems, liquid solid separation or reactor feed systems in the biofuels & biochemicals area. Andritz has delivered over a dozen of biomass pretreatment pilot and demo systems in the US, in Europe and Australia most of them for the bio-chemical pathway and is presently building systems and unit components for the 2nd commercial system. Their latest plants incorporate an advanced steam-explosion process developed by Andritz. Andritz will show process concepts, equipment solutions and share it's experiences in optimizing this processes for maximum sugar yields at minimum enzyme loads.

Tuesday, June 18, 2013 | 10:30am-12:00pm

Global Benefits for Synthtic Biology Tools

Moderator: Edward You, FBI Weapons of Mass Destruction Directorate

TBD
Edward You, FBI Weapons of Mass Destruction Directorate

Organism Engineering at Scale: Aligning technology and business model in a synthetic biology company
Jason Kelly, Ginkgo BioWorks

TBD
Mark Emalfarb, Dyadic International, Inc

Development of targeted recombinant polymers that can deliver siRNA to the cytoplasm and plasmid DNA to the cell nucleus
Ali Goodarzi, Harvard University

Abstracts

Edward You
The development of new and groundbreaking technologies that harness the power of biology and genomics are necessary and effective tools towards addressing our world's many issues. A concerted effort is needed to address the very real potential of synthetic biology commercial products and technologies being exploited, misused, or illegally appropriated. The use of outreach and engagement with the community and the development of codes of conduct are just two of the efforts being undertaken to address this over-the-horizon trend. Currently, discussions are underway between security and biotechnology industry members. The goal of these efforts is to establish mutual understanding of each sectors roles and responsibilities in safeguarding science to ensure that the global benefits of synthetic biology can be realized while mitigating any associated risks. The FBI Weapons of Mass Destruction Directorate would like the opportunity to attend the upcoming 2013 BIO World Congress on Industrial Biotechnology and participate in any forum (panel discussion, presentation, poster session) to provide information on our biosecurity efforts and highlight results that have occurred as a result of the partnership between law enforcement and the scientific community.

Jason Kelly
Over the past few years, synthetic biology has made great advances in our ability to redesign biosynthetic pathways. This work is made possible by rapid technology advances in DNA sequencing, DNA construction, and computer-aided design (CAD). Specifically, synthetic biology approaches are now being used for metabolic engineering of microorganisms for use in fermentation-based production of small molecule natural products. These advances have resulted in the successful entry of a limited number of high value molecules into the commercial space. However,

many targets remain unexplored. In order to fully capitalize on the opportunity in this field, scalable technical approaches must be aligned with successful business models. This talk will outline Ginkgo BioWorks' unique position in developing a novel platform and delivering it into the commercial space. To create a scalable technical approach, synthetic biologists have begun to apply principles of modularity, standardization and functional genetic part characterization and reuse. However, such an effort requires a well-planned strategy to manage the complexity of conducting multiple organism engineering projects. To address this need Ginkgo BioWorks has developed a "fab" for the engineering of organisms. The fab includes: a library of reusable, well-characterized genetic parts, high throughput, automated methods for assembly of modular DNA constructs [WO 2010/070295], and proprietary, custom software including CAD tools to optimize DNA design and assembly as well as computer aided manufacturing (CAM) to track and monitor every process run through the lab. Collectively these modules form the basis of a pipeline that can run 10s of microbe engineering projects in parallel and can manage the complexity of the expanding data, libraries, and organisms. This lowers the cost of an individual project overall, provides organism engineers the benefit of a shared resource, and enables the rapid delivery of new or improved technologies across the company. While a first-in-class organism engineering fab provides an unparalleled resource for constructing novel biosynthetic pathways in an industrial host, the platform must be successfully paired with a business paradigm that likewise represents a repeatable and scalable model. Because of the newness of the field, business practices and partnering norms are still emerging. Ginkgo's approach to this is reflected in our belief that for us, "the organism is the product." That is, we deliver organisms for use in the production of a commercially valuable molecule to commercial partners. By adopting a channel partner-based strategy, the company is able to access the wealth of molecule-specific commercial knowledge and capabilities held in partner companies and to align that with our internal organism engineering expertise. In addition to channel partners, Ginkgo recognizes the value of bioprocess developers and manufacturers who will play a critical role in the successful commercial scale-up and production of products derived from engineered organisms. Our vision of the bio-based chemical industry is one where the unique strengths of each party are clearly defined and incentives are aligned to assemble a seamless value chain from organism to chemical product. We believe successful partnering across this chain to be the key strategy in determining not just the success of an individual product but of the industry as a whole.

<u>Mark Emalfarb</u>
Dyadic's patented and proprietary C1 technology is an industrial scale platform for developing and manufacturing proteins and other enzymes based on the Myceliopthora thermophila fungal microorganism. The C1 technology is being adopted throughout the biotechnology industry to develop and manufacture enzymes and other proteins for diverse markets. Although the C1 platform is still a young system, it effectively competes with, and often surpasses, the results of the well-established Trichoderma and Aspergillus production systems. As genomic and proteomic tools continue to advance rapidly, they are helping to uncover novel genes that encode for a growing number of new and improved enzymes for traditional industrial enzyme markets. These tools are also being utilized to support

the growing demand for sustainable products and environmentally-friendly production processes. As the demand for enzymes continues to grow rapidly, the concentration of commercially available expression systems with the major enzyme producers has caused a bottleneck in the biotechnology industry in developing and producing low cost and efficacious enzymes. Dyadic's C1 production platform is helping the industry meet this challenge by enabling the production of a wide variety of both homologous and heterologous enzymes and other proteins at high purity and low cost. Dyadic not only produces its own enzymes, but also develops and out-licenses C1 strains to third parties, allowing them to develop and produce specific enzymes on-site at their own facilities.

Ali Goodarzi
One of the major limitations to effective siRNA delivery is the lack of a siRNA-specific delivery system. Currently, the same delivery systems that are used for plasmid DNA (pDNA) delivery to the cell nucleus are used for siRNA delivery to the cytoplasm. To fill this gap, the objective of this study was to design a biopolymer that can be programmed via its amino acid sequence to deliver siRNA specifically to cytoplasm. For pDNA delivery, a nuclear localization signal (NLS) was added to the biopolymer structure to facilitate active translocation of the genetic material towards nucleus. The biopolymers were complexed with pEGFP and GFPsiRNA and used to transfect SKOV-3 (HER2+) cells. The intracellular trafficking of the nanoparticles was also monitored in real-time and live cells. The results demonstrated that the biopolymer with NLS is a suitable carrier for pDNA delivery but not siRNA delivery. Conversely, the biopolymer without NLS was suitable for siRNA delivery to the cytoplasm but not pDNA to the cell nucleus. The potential use of the designed biopolymer for combination therapy of cancer cells with gene (thymidine kinase) and siRNA (BCL2) was also examined in SKOV-3 cancer cells.?

Technical Presentations
Sponsored by

Monday, June 17, 2013 | 8:30am-10:00am

Bio Composite Materials from Natural Fibers

Moderator: Ian McLennan, EcoSynthetix Inc

Mario Pennisi, Life Sciences Queensland Ltd

Current status of Biocomposites and Bionanocomposites: From Technology Development to Commercialization
Manju Misra, University of Guelph

Development of Glucose-Epoxy Bio-Composite Material
Ian McLennan, EcoSynthetix Inc.

The Big Ticket – How Large Scale Industrial Biotechnology is Being Applied to Benefit Agricultural Biotechnology
Mario Pennisi, Life Sciences Queensland Ltd
Joe Hogue, SWM INTL

<u>Abstracts</u>

<u>Manju Misra</u>
The government's push for green products, consumers' desire and energy conservation are some of the key factors that drive research towards the development of renewable resource-based polymeric biomaterials. The use of bio- or renewable carbon unlike petro-carbon for manufacturing bioplastics and biobased materials is moving forward for a reduced carbon footprint. The goal is to use biobased materials containing the maximum possible amount of renewable biomass-based derivatives to have a sustainable future. The incorporation of bio-resources, e.g. crop-derived green plastics and plant derived natural fibres into composite materials are gaining prime importance in designing and engineering green composites. Biocomposites derived from natural fibers and traditional polymers like polypropylene, polyethylene, epoxy and polyesters have been developed for automotive parts and building structures. Renewable resource based bioplastics like polylactic acid (PLA), polyhydroxyalkanoates (PHAs), biobased polytrimethylene terephthalate (PTT), bio-polyolefin, bio-polyamide, cellulosic plastics, soy protein based bioplastics and vegetable oils derived bioresins need value-added and diverse applications to compete with the fossil fuel derived plastics. Through reactive blends, composites and nanocomposites new biobased materials are under constant development. Hybrid and intelligently engineered green composites are going to be the major drivers for sustainable developments of new industrial bioproducts. Besides agricultural natural fibers like kenaf, jute, flax,

industrial hemp, and sisal; inexpensive biomasses such as wheat straw, rice stalks, corn stovers, grasses, soy stalks and lignin have great potential for use in sustainable biobased materials. This presentation will highlight the current status, opportunities and technical challenges of bioplastics and biobased materials for uses in car parts, consumer goods and sustainable packaging. This research is financially supported by the Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA)-New Directions Research Programs; University of Guelph-OMAFRA (Bioeconomy for Industrial Uses Program); the Ontario Research Fund (ORF) Research Excellence (RE) Round-4 from the Ontario Ministry of Economic Development and Innovation (MEDI); Natural Sciences and Engineering Research Council of Canada (NSERC)-CRD grant; Grain Farmers of Ontario (GFO); and Manitoba Pulse Growers Association (MPGA).

Ian McLennan
To Reviewers: The following abstract contains proprietary business information and must be kept confidential until further notice. EcoSynthetix would appreciate that the abstract not be published until after the conference as part of the conference proceedings. Should there be any questions, please contact Melissa Faye at mfaye@ecosynthetix.com Development of Glucose-Epoxy Bio-Composite Material Abstract Epoxy formulations involve expensive petroleum based compounds that rely upon toxic curing agents. The applications for epoxy-based materials are extensive and involve coatings, adhesives and composite materials using natural and synthetic fibre reinforcements. This paper describes the development of an alternative eco-friendly bio-composite that comprises a bio-degradable polymer matrix and natural fibres, which doesn't require toxic curing agents. The polymer matrix composition contains epoxy resin and a bio-based macromer, EcoMer™, mixed with a substantial volume of natural fibres. Ingredients were combined in a hot melt blending process and were cured at typical industrial temperatures. Performance tests revealed thermal stability of the cured polymer matrix is approximately twice that of its bio-macromer component, EcoMer™. Decomposition begins at 153° Celsius for EcoMer™ whereas the cured polymer matrix demonstrated thermal stability of up to 300° Celsius. The durability of the compound was evaluated by water immersion testing over 1000 hours. Excellent adhesive strength stability in wet conditions amid minimal weight gain was observed. The resulting simplified preparation offers a cost-effective bio-composite with distinct advantages over existing commercial epoxies – including elimination of the toxic curing agent, lowered cycle time, raw material costs and minimal handling concerns. Potential applications for this material include adhesives and coatings for the architectural and transportation industries.

Mario Pennisi
Joe Hogue

The economic future of agriculture in developed countries will likely hinge on the ability to utilise biomass resources as a factory to make not only products which feed and heal but also new advanced bioproducts and biomaterials which will literally build the infrastructure of the new bioeconomy block by block. Such products range from advanced, ultra-light-weight biocomposites in automotive and aerospace applications to new high-tech designer twists on millennia-old building construction materials. To realise the goal of large-scale industrial application of these sustainable, renewable products, it is recognised that an equally large-scale research effort is required to ensure that the best technologies and solutions are available to the agricultural sector. This session offers a state-of-the-art global review of how "big-ticket science" – from the use of synchrotron facilities to examine the nano-scale topochemistry of plants to the complete sequencing of the flax genome – is being employed to assist farmers gain new value streams from their biomass resources.

Monday, June 17, 2013 | 10:30am-12:00pm

Perennial Herbaceous Energy Crops and CRP Land for Biomass Production in the USA: A Five Year Regional Feedstock Partnership Report

Moderator: Vance Owens, North Central Sun Grant Center, South Dakota State University

Vance Owens, North Central Sun Grant Center, South Dakota State University

B.S Baldwin, Mississippi State University

D.K Lee, University of Illinois at Urbana-Champaign

T.B., Voigt

Abstract

The Regional Feedstock Partnership is a collaborative research effort between the Sun Grant Initiative (through Land Grant Universities), the US Department of Energy (DOE), and the US Department of Agriculture. One segment of the Regional Feedstock Partnership is the evaluation of production potential of dedicated perennial herbaceous energy crops and CRP land across environmental gradients in the USA. As evidenced by the Regional Feedstock Partnership, the DOE has an ambitious program to develop and market the necessary technology for dedicated herbaceous energy crops. Dedicated energy crops must be selected that are adapted to the environment in which they will be grown. Certain species (e.g. switchgrass and sorghum) are widely adapted across much of the US while other promising species (e.g. energycane) are more regionally adapted. Land enrolled in the Conservation Reserve Program (CRP) were planted to mixtures of species that have already been identified as optimum for a given environment. Therefore, these lands also may provide excellent sources of herbaceous biomass; however, productivity on CRP land, and responses to agronomic inputs and management have not been thoroughly studied. Various herbaceous energy crops are being investigated at diverse locations throughout the USA. Specifically, this research is being conducted to: 1) assess the potential of genetically diverse, dedicated perennial energy crops and CRP land for sustainable biomass production in environmentally diverse regions of the country; 2) identify critical management issues such as harvest timing and soil fertility for sustainable biomass production; and 3) evaluate opportunities to expand production of herbaceous biomass crops and resources throughout the USA. Data collected from national, replicated field trials of perennial dedicated energy crops will help us better understand benefits and limitations of specific species grown in diverse geographic and climatic conditions. The production potential of a specific bioenergy crop species varies depending on its adaptation to biotic (e.g. weeds, diseases, insects, etc.) and abiotic (e.g. cold, drought, salt, nutrient deficiency, etc.) forms of stress. Thus, it is

critical that adapted species and genotypes/cultivars within species be carefully selected for evaluation in a given environment. Reports for the following species will be provided: switchgrass (Panicum virgatum L.) with sites in AL, IA, NY, OK, SD, and VA; miscanthus (Miscanthus x giganteus) with sites in IL, IN, KY, NE, and NJ; energycane (Saccharum spontaneum) with sites in GA, HI, LA, MS, and TX; and mixtures of grasses on CRP land with sites in GA, KS, MO, MT, ND, and OK. Trials were initiated in 2008 or 2009 and were harvested for biomass for 3 to 5 years by the end of 2012.

Monday, June 17, 2013 | 2:30pm-4:00pm

Bioprocessing Membrane Seperations Technology

Moderator: Dean Tsoupeis, Culturing Solutions Inc

Application Towards Green House Gas Mitigation and Carbon Fixation.
Dean Tsoupeis, Culturing Solutions, Inc

Biogas upgrading with highly selective SEPURAN ® Membranes
Maureen Schaefer, Evonik

Performance of Silicaliete-1 Filled PDMS/PAN Composite Pervaporation (PV) Membranes and Application in Continuous Production of Acetone-Butanol-Ethanol (ABE) by Fermentation-PV Coupled Process
Yinhua Wan, Institute of Process Engineering, Chinese Academy of Sciences

A Breakthrough Fermentation Process is Only the Start
Daniel Bar, Ameridia, Division of Eurodia Industrie

Abstracts

Dean Tsoupeis
Culturing Solutions and the University of Maryland Eastern Shore have collaborated on a project that is designed to mitigate greenhouse gas emissions and Carbon dioxide from a natural gas fired boiler at the Aquaculture and Fisheries Research Center. This project includes the utilization of a membrane technology that captures Carbon dioxide from the flue gas of the boiler that heats the Aquaculture Research Center and dissolves it into the growing media for algae cultivation. This membrane also has the ability to break the bonds of Nitrogen from NOX and the Sulfur from SOX and dissolve them into the growing media as a source of nutrients for algal cultivation. The study begins with a 150-liter tubular photobioreactor that has the membrane installed in the surge tank for directly dissolving the Carbon dioxide, Sulfur, and Nitrogen from the emissions of the boiler. The photobioreactor will be located in a greenhouse collocated with the Aquaculture Research Center at the UMES. The photobioreactor has sensors to monitor and control pH, Electrical Conductivity, Temperature, Dissolved Oxygen and Oxidation Reduction Potential,

these sensors are connected to a control system that has data logging that is retrievable from a built in TCP/IP telnet server. The pH will be controlled by dissolving the Carbon Dioxide form the flue gas from the boiler while simultaneously removing the Dissolved Oxygen from the growing media that results in a properly balanced environment for the algae to propagate. Nutrients will be supplied by a near by hog manure retention pond, this hog waste will be treated and sterilized prior to induction of the photobioreactor. The hog waste will be analyzed by a Gas Chromatograph to determine the level of nutrients being supplied. Results from this project will be shared with the conference and presented to show that this type of membrane system not only can capture Carbon dioxide and mitigate SOX and NOX from a flue gas, but that this dissolved nutrient delivery system has the effect of increasing and intensifying algal cultivation up to 400% above normal growing conditions with the same amount of photosynthetic inputs.

<u>Maureen Schaefer</u>
The first industrial application of gas separation membranes, i.e. the recovery of hydrogen from purge gas streams, was introduced 30 years ago. Currently, the most important applications of these membranes are in the generation of nitrogen, hydrogen recovery, air drying, and removal of sour gases from natural gas. These applications use technically almost solely dense polymer-membranes for gas-separation. Spiral-wound-elements are available made of cellulose acetate or PDMS, hollow fiber modules are available made of polysulfone, polyphenyleneoxide, polyimide and tetrabromopolycarbonate. However, commercial applications in use today are manifold and show significant annual growth rates.
One key use of gas separation membranes is the removal of CO2, which is found in natural gas and biogas and must be removed before the gas can be used.
Biogas is formed by fermentation in which microorganisms anaerobically decompose biomass. Crude biogas contains 55 to 65% methane, 30 to 45% carbon dioxide, and trace gases such as hydrogen sulfide. These impurities must be removed from the methane. The biomethane so produced is fed into the natural gas grid.
So far biogas upgrading to biomethane and injection into the gas grid or usage as a fuel was mainly done by other separation techniques.
Membrane based gas separation is an efficient alternative for the upgrading of biogas because the product, i.e. biomethane, rises on the high-pressure side and the membrane has to be passed by the lower CO2 fraction only. Membrane based separation processes are easily scalable to smaller and bigger sizes, can be started and stopped within minutes and do not need any auxiliaries such as amines or water or regeneration.
In general, current gas separation membrane systems consist of either a single stage system or the dual stage system with a recycle stream. In both cases an vent gas stream (> 7 % of Methane) is produced that contains remarkable amounts of methane which lowers the yield of biomethane and cannot be emitted into the atmosphere without any further post combustion. Therefore, the vent gas is treated either by sending it back to a combined heat and power plant if possible, or by burning it in a regenerative thermal oxidation step.
In this presentation we will show the development and implementation of a new multistage membrane process containing highly selective SEPURAN® membranes.

This process containing only one compression step can be applied to low and high volume gas streams allowing a simultaneous generation of biomethane with pipeline quality and a vent gas stream with very low methane concentrations (< 1%). The setup of the membrane cascade together with the working principle and simulated reactions on fluctuating biogas compositions and flows will be presented and compared with the results of actual pilot testing using real biogas.

<u>Yinhua Wan</u>
The pervaporation performance of silicalite-1 filled PDMS/PAN composite pervaporation (PV) membrane has been investigated for the separation of model butanol solution and continuous acetone-butanol-ethanol (ABE) production by fermentation-PV coupled process at laboratory scale. Depending upon the butanol feed concentration in model solution, butanol selectivities of 30-33 and flux values of 550-708 g m-2 h-1 were achieved at 37?. When the membrane was used in ABE production by fermentation-PV coupled process, ABE could be removed in situ, and hence high solvent productivity and glucose utilization rates were obtained, which were improved to 178% - 303% and 154% - 255% of the control batch fermentation respectively. Furthermore, high solvent productivity reduced the acid loss, leading to more acids reassimilated by cells for ABE production. As a result, a higher yield of 0.37 g g-1 was obtained. With the coupled process, a highly concentrated condensate containing 86.96-160 g L-1 ABE was obtained, the composite membrane exhibited a high ABE separation factor above 30 and flux values of 486-710 g m-2 h-1. Membrane fouling could not be observed during the operation of 268 h.

<u>Daniel Bar</u>
The development of a breakthrough fermentation (or catalytic reaction) for a new bio-molecule in the bio-based chemical industry is usually only the start. It is also critical to work on the downstream purification steps to economically obtain a final product meeting the tight purity specifications of the chemical industry. Ameridia, Division of Eurodia Industrie can provide support in this area: the company has more than twenty-five years of experience in separation/purification processes in industries such the agro-food industry, specialty chemicals and bio-chemicals. The proposed custom processes combine electrodialysis with and without bipolar membranes, chromatographic separation, ion exchange resins, and pressure driven membranes technologies (MF/UF/NF/RO). The recent development of High-temperature Bipolar Membrane electrodialysis (EDBM-HT) is very attractive to efficiently acidify the salts of organic acids: this proprietary technology offers many advantages such as the production of organic acids at higher concentrations and higher acidification rates, in addition to a lower electricity consumption. The EDBM-HT technology is being successfully implemented at the industrial scale in combination with ion exchange resins processes to allow the production of high purity material. The subject of this presentation will be generic industrial cases to illustrate the costs/benefits of the EDBM-HT technology.

Tuesday, June 18, 2013 | 8:30am-10:00am

Renewable Chemical Biosynthesis (L-Malic Acid, Ehtyl Levolinat) and Consumer Application

Kieran Furlong, Virent

Renewable Chemical Biosynthessic (L-Malic Acid, Ehtyl Levolinat) and Consumer Application
Kieran Furlong, Virent

High level production of L-malic acid by fermentation using Aspergillus oryzae: An example of Novozymes' activities in technology development for Biochemicals
Alan Berry, Novozymes, Inc.

Carbohydrates to Platform Chemicals - Challenges and Opportunities in Developing Sustainable Green Technologies
Pramod Kumbhar, Praj Industries Ltd.

Cellulosic Chemicals, Consumers, and Commercialization
Bob Walsh, ZeaChem, Inc.

Abstracts

Alan Berry
In the last decade, there has been widespread interest and investment in developing processes for the production of bulk and specialty chemicals from renewable feedstocks by fermentation. During this period, Novozymes has successfully developed technology for production of a specialty molecule (hyaluronic acid) by Bacillus fermentation and has been very active in developing technologies for the production of bulk chemicals by metabolic engineering and fermentation using several different microorganisms. An example of the latter is L-malic acid. In this presentation, we will describe Novozymes' development of a high performing L-malic acid producing strain of the filamentous fungus Aspergillus oryzae.

Pramod Kumbhar
Carbohydrates represent 75% of the renewable biomass on earth. They constitute a major class of feedstocks having potential to yield products that can replace those derived from petroleum sources. Yet their present non-food utilization is confined to textile, paper and coating industries, either as such or in the form of esters and ethers. Bulk of the organic commodity chemicals are usually of low molecular weight. Accordingly, the constituent repeating units of these polysaccharides such as glucose (cellulose, starch), fructose (inulin), xylose (xylan), etc., are the actual carbohydrate raw materials for basic organic chemicals. Dehydration, etherification, esterification, oxidation and reduction of these monomer sugars have been topics of interest for past several years and many commercial processes do exist for such transformations. However, these processes are still far from adherence to the

Principles of Green Chemistry. In fact, development of commercially feasible technologies adhering to Principles Green Chemistry is challenging especially if the technology has to be developed for large scale production of platform chemicals. Ethyl levulinate is one such platform chemical. Conversion of sugars to levulinic acid at an economical price point would open up huge market potential for this molecule. Leveraging on its experience in handling most of sugar bearing feedstocks across global geographies, PRAJ Matrix Innovation Centre has initiated in–house Bio-Based Chemicals program. The program is currently focussed on development of commercial technologies adhering to Green Chemistry Principles for producing platform chemicals from Biobased feedstocks This paper will highlight the efforts and the challenges faced in the journey towards development of a sustainable technology for converting renewable hexose sugars containing feedstocks to ethyl levulinate.

Bob Walsh
ZeaChem's biorefining process is feedstock flexible, highly efficient, and sustainable for the production of a wide range of economical advanced biofuels and bio-based chemicals. The company's 250,000 gallon per year integrated demonstration production facility and 1st commercial biorefinery site are located in Boardman, Oregon, USA. Through a Joint Development Agreement (JDA) with P&G, ZeaChem is developing a new product platform for bio-based chemicals to be used in products and packaging that will help P&G meet their 2020 target of 25% renewable and recyclable materials in their products. Increasing demand from the consumer product industry is creating market pull through opportunities for bio-based chemicals that is accelerating commercialization and market penetration.

Tuesday, June 18, 2013 | 10:30am-12:00pm

Advances in Sustainable Sugar Technology

Moderator: Fred Moesler, Renmatix

The Role of Supercritical Hydrolysis in Unlocking Cellulosic Sugar
Mike Hamilton, Renmatix

ECONOMICS OF FRACTIONATION OF LIGNOCELLULOSIC BIOMASS
Ali Manesh, American Science and Technology Corporation

TBD
Beth Stewart, United Catalyst
Basil Karampelas, Amerian Process

Robust Purification of Cellulosic Sugars Tailor-Made for Your Cracking Process
Thibault Lesaffe

Abstracts

Fred Moesler
The success of the global biochemical and fuels market—estimated to exceed $1 trillion by 2025—hinges on the accessibility of affordable, reliable supplies of sugar. As petroleum becomes more difficult to access, driving up production costs and lowering margins, manufacturers seek affordable sugars as an alternative to meet increased demand for everyday products ranging from paints, plastics, food preservatives, to ethanol and gasoline. Today most available sugars are produced from food-based crops such as sugarcane, corn, or beets; however, such sugars are subject to global population growth, competing food markets, seasonal crop variations and limited regions of production, and it creates a marketplace vulnerable to price volatility and diminishing supplies—similar to today's petroleum market. Large-scale bioindustrial growth at a sustainable level requires a shift to cellulosic sugars, or sugars derived from non-food plant matter; everything from woody biomass, to agriculture residues to energy grasses, even post-consumer urban waste. Traditional methods of producing cellulosic sugar — enzymatic hydrolysis and acid hydrolysis — have been in development over the past few decades. However, these methods incur high costs due to either enzyme procurement or elaborate acid recovery systems, and lengthy process cycles limit the ability of these technologies to scale and compete with first-generation, food-based sugar sources. In this session, Renmatix CTO Fred Moesler will provide an update on the advancements of supercritical hydrolysis, a low-cost alternative to traditional biomass-to-sugar conversion methods. Supercritical hydrolysis uses water at elevated temperatures and pressures — at around 374 Deg C and 221 bar – to deconstruct biomass in a matter of seconds. Under these conditions, distinct liquid and gas phases do not coexist; the water behaves as both a gas and a liquid, serving as a powerful solvent. Renmatix's two-step PlantroseTM process

deconstructs a range of non-food based feedstocks in a continuous reaction, producing separate steams of C5 (xylose) and C6 (glucose) sugar. Clean lignin is produced as a byproduct and can be used as an energy source or as a valuable material in new markets. Though engineered and scaled using woody biomass, supercritical hydrolysis is biomass agnostic. By slightly altering reactor conditions, the technology can support a variety of plant material and waste streams, with studies currently underway investigating the use of post-consumer urban waste. Tapping into the post-consumer waste steam could unlock a world of opportunity for bioprocessing in large urban areas that lack abundant and sustainable biomass, but an increasing supply of waste material. Additionally, Renmatix is testing supercritical hydrolysis with more than 50 sustainable biomass sources available in North America, South America, Asia, and Europe.

Ali Manesh
In the last few years, sugar is emerged as the main feedstock to derive several potential biofuels and chemicals. The cost and availability of these fuels/chemicals are vastly depends on the source of sugar. Currently most of the processes are based on sugar from corn, sugar cane and sheet beets, etc. use of such food-derived raw materials is not sustainable. Lignocellulosic sugar is sustainable however is not economical compared to other food-based feedstocks. American Science and Technology has developed technologies to produce low-cost sugar from lignocellulosic biomass feedstocks which are not part of nation’s food supply and are readily available. Based on the pilot results, we hypothesize that sugar cost should be less than 20 cents/lb which will make it competitive with the 1st generation food based sugars.

Beth Stewart
TBDA panel outlining examples of novel and game-changing “paths to cheaper sugar”, which will dramatically improve the viability of bio-based chemicals. Panelists may include speakers to the following topics:

• Inert catalysts used in pretreatment and hydrolysis

• Sugar distribution, handling, and logistics (e.g. Sweetwater Energy)

• Supercritical Water (e.g. Renmatix) Each panelist outlines the current technology drawbacks and the solution their new technology might overcome including economics associated with the new solution as well as the stage of technology development and, proposed timing to market.

Example: Inert catalysts used in pretreatment and hydrolysis: Microbial fermentation of glucose to ethanol, and many other valuable products, is a rapidly advancing field of groundbreaking technology. The cost of all fermentations, however, depends strongly on the cost of glucose. The cheapest source of glucose, by far, is cellulose, but commercial-scale hydrolysis of cellulose to glucose remains elusive. Even with advances in the development of enzymes, their use in the production of glucose is generally too inefficient to be cost-effective at large scale. There is an alternative catalyst to be used in hydrolysis, CHIPs, a silica-based catalyst that is stamped, or imprinted, with cellulose while the silicon oxides are soluble. These novel catalysts remain active and stable for months to years under conditions that denature protein-based enzymes in hours. Data collected during optimization experiments demonstrate CHIPs performance in comparison to commercial enzymes, the potential to recycle CHIPs, and the overall operating efficiencies associated with inert silica based catalyst. When used in large scale biomass pretreatment and hydrolysis applications, CHIPs may enable the most inexpensive glucose in the world---permitting production of ethanol at the levels mandated by the U.S. EPA Renewable Fuels Standard and, enabling other bio-based chemicals to replace traditional petrochemicals.

Basil Karampelas

At American Process, we strongly believe that Sugar is the New Crude®. We have developed two proprietary biorefinery technologies for producing low-cost cellulosic sugars from non-food based biomass. The Green Power+® technology is a patented technology for the production of low-cost cellulosic sugars from the hemicelluloses of biomass. The AVAP® technology is a patented technology for the production of low-cost cellulosic sugars from the cellulose and hemicelluloses of any biomass. The two technologies address different market opportunities for biorefineries. For each technology, any biomass may be utilized, including hardwoods, softwoods, and agricultural residues.

The Green Power+ process produces low-cost C_5 and C_6 sugars from the hemicelluloses of biomass feedstocks. These sugars are co-produced along with biomass power, pellets, or pulp. Essentially, sugars are extracted from the solids which are then utilized for existing applications, in synergy with biomass-based renewable power, pellets, sugarcane plants, and many other existing sites. Value is added while minimizing capital costs for commercial implementation.

Our first large-scale implementation of Green Power+ technology is a biorefinery pilot plant located in Alpena, Michigan. The Alpena biorefinery is capable of converting about 20 tons/day of hemicelluloses to sugars and co-products. The plant capacity is up to 2 million gallon/year of ethanol. The Alpena biorefinery started up in third quarter, 2012.

The AVAP process produces low-cost C_5 and C_6 sugars from both cellulose and hemicellulose of biomass feedstocks. The AVAP process employs a solvent for lignin and sulfur dioxide to cleanly fractionate biomass into cellulose, hemicellulose, and lignin. Optionally, the cellulose may be recovered as a cellulose material or precursor for making cellulose derivatives. The cellulose that is produced by the AVAP process is extremely susceptible to hydrolysis by enzymes to produce glucose, thus greatly reducing enzyme costs.

Our first large-scale implementation of AVAP technology is a biorefinery pilot plant located in Thomaston, Georgia. The Thomaston biorefinery is capable of converting about 10 tons/day of biomass to sugars, ethanol, and co-products. The plant capacity is up to 300,000 gallon/year of ethanol or other products, such as butanol, jet fuel, or biochemicals. The Thomaston biorefinery will start up in first quarter, 2013.

Wednesday, June 19, 2013 | 10:30am-12:00pm

Thermochemical Processes with Biological Conversion

Moderator: Loula Merkel, Coskata, Inc.

Advanced Biofuel Production Via Thermochemical Conversion of Biomass
George Boyajian, Primus Green Energy, Inc.

Decentralized Processing of Lignocellulosic Biomass by Fast Ablative Pyrolysis
Sergey Zabelkin, EnergoLesProm LLC, Kazan, Russia

In-Operando DRIFTS-GC/MS Experiments to Study the Catalytic Thermolysis of Lignocellulosic Biomass
Cherif Larabi, LC2P2

Loula Merkel, Coskata, Inc

Abstracts

George Boyajian
Unlike ethanol and other biofuels that are limited by blending or infrastructure constraints, the market potential for drop-in fuels is the entire $3.2 trillion worldwide market for liquid transportation fuels, which includes gasoline, diesel and jetfuel. Seizing this market opportunity, Primus Green Energy (PGE) has focused on becoming a leader in the development of alternative drop-in fuels that are economical, practical, and produced from readily available domestic resources such as biomass. PGE's proprietary system involves making significant improvements on existing technologies that have already been proven at an industrial scale. PGE's thermochemical process involves two major components:

• Synthesis Gas (Syngas) Generation: PGE has developed its own proprietary catalytic biomass-to-syngas gasification system that produces a syngas with hydrogen to carbon monoxide molar ratio of about 2 to1.

• Liquid Fuel Synthesis: The proprietary process STG+ is a significant improvement on the existing Methanol to Gasoline (MTG) technology. STG+ converts syngas to gasoline, diesel or jet fuel with much higher efficiency (yield over 30 wt%). Due to the improvements made, PGE's technology addresses three major challenges facing the biofuel community:

• Economical at the right scale: PGE produces gasoline, diesel and jet fuel that are cost-competitive with petroleum-based products without subsidies.

• Practical to use: PGE's fuels require no engine modifications or changes to the fuel delivery infrastructure.

• Local feedstock: Being profitable at small scale makes it possible to source biomass and produce liquid transportation fuels locally to meet more needs.

Additionally, PGE's process is feedstock flexible: in addition to biomass, the PGE technology can use domestically sourced, low-cost, carbon-efficient natural gas to produce high quality liquid fuels, including 93-octane gasoline and jet fuel. PGE's process is distinct from those of all other alternative fuel companies in that it directly converts biomass or natural gas into a specific target liquid fuel, allowing PGE to produce several times more usable product than competing technologies. Most of PGE's competitors use biological methods to produce an intermediate product (e.g. biobutanol) that must undergo a costly synthesis and refining process to produce a usable fuel. By using a thermochemical process, PGE avoids the yield limitations, scale-up problems and feedstock specificity faced by these competing processes. There are, however, others utilizing thermochemical processes, but these processes are limited in that they produce a synthetic crude oil, requiring additional refining and purification. Enabled by the STG+ technology, PGE produces a "drop-in", ready to use fuel, thus avoiding refining costs and associated loss of yield. Therefore, PGE has significant advantages over both its biological process-based and thermochemical process-based competitors in terms of efficiency, cost and feedstock and end-product versatility, all of which contribute to making PGE's initial commercial plants financially attractive projects. Tapping into PGE's understanding of developing and scaling biofuel technologies, in this paper/presentation, Dr. George Boyajian, VP Business Development at Primus Green Energy, will address how thermochemical processes are key to unlocking near-term commercialization of drop-in biofuels and alternative fuels.

Sergey Zabelkin

In recent years, amide the rise of fossil fuels price, using of renewable energy resources, one of which is biomass, is becoming increasingly important. Annually large quantity of organic wastes is producing at forest-processing and agricultural enterprises [1]. As a rule, the most part of these wastes remains unclaimed and worsens ecological situation and fire hazard at the enterprises. One of the most efficient ways for organic wastes processing is the process of fast pyrolysis. It is thermal decomposition in absence of oxygen at relatively low temperatures 450-550°C, high heating rates 500-1000°C/s and low residence time 2-3 s [2]. The technology allows processing of biomass in such products as combustible gas, char and pyrolysis liquid – biooil [3]. Analysis of existing enterprises shows that a key aspect of enterprises for biomass wastes processing is the limited availability of feedstock in a particular geographic area. Increase of feedstock delivery distance is also increasing its price. When the distance exceeds some value, biomass processing is becoming unprofitable. Current technological solutions are oriented to large-capacity processing. Such technologies as circulating fluid bed, fluid bed, and rotating cone has high capital costs. Their profitability can be reached only with capacity higher than 150-400 tons per day. The authors hold another opinion about lignocellulosic biomass processing. Our approach allows decentralized processing with increase of biomass energy density and, in near future, integration to current energy systems and petrochemical industry. At the present time our specialists are working on creation of effective technology of fast ablative pyrolysis. The technology will be realized in mobile transportable modules with capacity up to 25 tons per day. These modules will allow processing of wastes from small and medium agricultural and forest enterprises into biooil. The biooil can be easily transported. Now we have pilot plant for lignocellulosic biomass processing by fast ablative pyrolysis. We are working on creation of larger demonstration plant. Literature: 1. Bashkirov V.N. Research of thermochemical method of chicken litter processing and determination of the material balance / V.N. Bashkirov, A.Z. Khalitov, A.N. Grachev, D.V. Tuntsev, A.T. Shaymullin // Herald of Kazan technological university, 2012, Vol. 1, pp. 105-107. 2. Bridgwater A.V. A techno-economical comparison of power production by biomass fast pyrolysis with gasification and combustion / A.V. Bridgwater, A.J. Toft, J.G. Brammer // Renewable & Sustainable Energy Review, 2002, Vol. 6, pp. 181-246. 3. ASTM D7544-12. Standard specification for pyrolysis liquid biofuel.

<u>Cherif Larabi</u>

Introduction The decrease of fossil fuels reserves, basically oil and natural gas, coupled with challenges related to environment and sustainable restriction make the use of non-edible biomass feedstocks for generating biofuel and other chemicals more necessary. Wood is one of the most important sources of biomass and will be the focus of this project. Generally, most of the lignocellulosic biomass contains 35–50% of cellulose, 20–35% of hemi-cellulose,and 10–25% of lignin. Clearly, the major component of lignocellulosic biomass is cellulose [1] this implies that weight percent of oxygen is up to 45 in the wood. Currently, the conversion of wood to liquid fuels is afforded by gasification, pyrolysis and liquefaction. However, all bio-oil obtained from fast pyrolysis has a high oxygen content, which makes the product unsuitable as transportation fuel. Hydrocarbons with less than 5 wt % oxygen are needed for fuel applications. Consequently, the process must be able to deal with untreated biomass wood chips to eliminate the cost associated with pre-treatment; to depolymerise and to deoxygenate cellulose, amorphous hemicelluloses and lignin, and to hydrogenate the unsaturated compounds, at moderate temperatures and pressures (= 350 °C, = 50 bars)….The heterogeneous catalysis could answer at least to this scientific, economic, and environmental challenge [2] In this communication, we reported experiments carried out taking in account some of these conditions: using untreated chips pine wood with a mean size ?0.5mm under moderate temperatures and pressures. As hydrotreatment are run under hydrogen atmosphere, we have realized firstly, the thermolysis under hydrogen. No data in these conditions has reported in literature, at our monitored by in situ temperature FTIR cell with online GC-MS allowing when the temperature varies from 25 to 350°C to follow i) the evolution of the wood structure ii) the identification of the volatile compounds before and after their reaction on supported heterogeneous catalyst in continuous flow reactor. This study provided information about the volatiles produced during the thermal decomposition of wood under hydrogen flow. Two different approaches to convert the pyrolysis products to added values chemicals can be adopted. First, by developing multifunctional catalyst, that can depolymerize and deoxygenate the biomass under the same operation condition. Secondly by combining the two systems the pyrolysis and hydrotreatment, in this approaches two different heterogeneous catalysts have been screened under various temperatures. The result showed that that the supported ruthenium particles were more active than the nickel supported catalyst. By decreasing the temperature of hydrotreatment alkanes with higher carbon number were produced. References [1] J. Zakzeski, P. C. A. Bruljnincx, A. L. Jongerlus and B. M. Weckhuysen, Chem. Rev. 6 (3552) 110. [2] C. H. Zhou, X. Xia, C. X. Lin, D. S. Tong, J. Beltramini. Chem. Soc. Rev. 11 (5588) 40 [3] M. Akerholm, B. Hinterstoisser, L. Salmen. Carbohydr Res. 3 (569) 339. [4] M.C. Popescu, C.M. Popescu, G. Lisa, Y.sakata. J. Mol. Struct. 1-3 (65) 988.

Academic Research Presentations

Sponsored by

Monday, June 17, 2013 | 8:30am-10:00am

Conversion of Woody Materials to Fuels and Chemicals

Moderator: Jack Saddler, University of British Columbia

Jack Saddler, University of British Columbia

Adrian Zhang, Concordia University

Hung Lee, University of Guelph

Emma Masters, University of Toronto

Abstract

The NSERC Bioconversion network is a one million dollar a year strategic network that looks at the various process steps in the converting Canada's forest resources into a range of fuels and chemicals. The four main themes of the network include pretreatment, enzymatic hydrolysis, fermentation and co-products/LCA. The network has strong industrial particpation from companies such as FP innovations, Lallemand, Tembec GreenField Biofuels and others. As will described in the four complementary presentations, the Bioconversion network is a consortium of about a dozen Professors and funds about 30+ post-docs and graduate students working on aspects of the four main themes. The presentaions will show how the choice of feedstock, pretreatment and fractionation processes influences the approach taken in the hydrolysis, fermation and co-product components of an overall wood biomass-to-fuels/chemicals approach.

Monday, June 17, 2013 | 10:30am-12:00pm

Improved Fermentation Processes fro Liquid Biofuels Production

Moderator: Jules Thibalt, University of Ottowa

In Situ Removal of Biobutanol During Fermentation
Jules Thibault, University of Ottawa

TBD
Antonio Marzocchella, Università di Napoli Federico II

Fermentation of Organic Waste for Ethanol Production by Z.Mobilis and S.Cerevisiae Strains:Comparison Study
Valeriy Bekmuradov, Ryerson University

Ethanologens vs. Acetogens: Comparing Environmental Impacts of Two Fermentation Pathways to Produce Bioethanol.
Richard Gustafson, University of Washington

Abstracts

Jules Thibault
The renewed interest in the acetone-butanol-ethanol (ABE) fermentation is a result of the demand for renewable fuels that provide a clean, sustainable and environmentally-friendly alternative to petroleum-based fuels. Butanol is considered to be a better alternative to bioethanol as a biofuel because of its higher energy density, lower vapour pressure, and greater compatibility with existing technologies. These characteristics are a driving force behind the development of this potential replacement for gasoline. However, the production of biobutanol is plagued by high separation costs due to the presence of other co-products and low final concentration. Indeed, a number of challenges must be addressed before this biofuel can become a viable competitor to other biofuels. The two most important challenges are the increase in the final concentration of butanol in the fermentation broth and the development of an efficient separation technique. This paper, mainly concerned with the latter challenge, will discuss gas stripping and vacuum fermentation techniques to extract biobutanol from a dilute ABE fermentation broth. A series of simulations for these methods will be presented using UniSim Design R400 (Honeywell) to determine the final concentration of butanol recovered. The objective is to predict the performance of these techniques in biobutanol production processes.

Antonio Marzocchella
The Acetone-Butanol-Ethanol (ABE) fermentation is receiving renewed interest as a way to upgrade renewable resources into valuable base chemicals and liquid fuels (Cascone, 2008). Abundance and un-competitiveness with food sources are desired features of potential feedstocks. These features are fulfilled by lignocellulosic

biomass. This contribution is about the characterization of the ABE fermentation by Clostridium acetobutylicum DSM 792 using sugars representative for hydrolysis products of lignocellulosic biomass: glucose, mannose, arabinose, and xylose. Preliminary tests (according to Napoli et al., 2009) were carried out adopting each single sugar as carbon source to investigate the ability of the microorganism to convert them. Batch fermentation tests with mixtures of two sugars were carried out in order to assess the possible combined effects of the investigated sugars on the fermentation performances. The tests had also the aim of assessing the ability of C. acetobutylicum to simultaneously metabolize different sugars. Investigated sugar mixtures were: glucose/mannose (GM), glucose/arabinose (GA), glucose/xylose (GX), mannose/arabinose (MA), and arabinose /xylose (AX). The total initial sugar concentration was set at 60 g/L and the mass ratio between the two sugars was set at 1:1. The conversion process was characterized as a function of time in terms of biomass, acids and solvents concentrations as well as pH and total organic content. Data were evaluated to assess sugars conversion and the kinetics of cell growth and of the ABE production. The yields for cells, acids and solvents on the carbon source were also assessed. Preliminary tests pointed out that: i) C. acetobutylicum was capable to convert products of lignocellulosic biomass hydrolysates in ABE; ii) glucose was confirmed as the sugar characterized by the best performance (13.2 g/L of butanol); iii) the fermentation performances of the other sugars decreased with the order mannose, arabinose and xylose. Main results of tests with the sugar mixtures were: iv) the couple GM gave the worst results in terms of butanol production (7.7 g/L), even though C. acetobutylicum preferred glucose and mannose as carbon source (results of tests on single sugar); v) the best results were obtained for mixtures of arabinose, in particular the couple MA scored butanol concentration (12.4 g/L) similar to that obtained for glucose fermentation tests (13.2 g/L); vi) the GM mixture was characterized by the worst performances when compared to both the single sugar tests (glucose and mannose); vii) performances of mixtures GA and GX were worse than that of the glucose tests, but they were better than that of tests with the single pentose sugar (arabinose and xylose, respectively); viii) the performances of the tests with mixtures without glucose (MA and AX) were significantly better that that assessed for tests with the single sugar. Results pointed out that C. acetobutylicum could grow on mixtures of hexoses and pentoses investigated, in agreement with Qureshi et al. (2007). In particular, the fermentation performances of glucose got worse when it was mixed (whatever the second sugar). The other investigated sugars, on the contrary, benefited of the combination with a second sugar. Tests with four-sugar mixtures are in progress. Cascone R., 2008, Chem Eng Prog., S4-S9 Napoli et al., 2009, Int. J. Chem. Reactor Eng. 7:A45 Qureshi et al., 2007, Bioprocess Biosyst. Eng. 30, 419-427

Valeriy Bekmuradov
The global demand for ethanol has been increasing in recent years because of its wide use, mostly in transportation and chemical sectors. However, the main challenge in ethanol conversion is high cost of processing in which enzymatic hydrolysis and fermentation are the major steps. This study investigates the fermentation process for source-separated organic (SSO) waste by different bacteria, with the use of separate hydrolysis and fermentation (SHF). Pre-

processing technologies, including the Thermal Screw Press (TSP) and organic-solvent (ethanol) based lignocellulose fractionation (COSLIF) pretreatments, are demonstrated to enhance the fermentation process. Cellulose-solvent (phosphoric acid of 85%) and organic-solvent (ethanol) based lignocellulose fractionation were applied for cellulose extraction. On the average, the s yield from the modified COSLIF pretreatment was impressive at 90%. Evaluation of the enzymatic hydrolysate obtained from COSLIF pre-treatment by batch culture was compared to constructed sugar (with fixed glucose/xylose ratio) model by fermentation with Zymomonas mobilis 8b strain and Saccharomyces cerevisiae (DA2416 strain). In the constructed model, after only 24 hours, 100% of glucose and 40% of xylose were consumed by fermentation with Z.mobilis 8b strain, while 100% of glucose and 80% of xylose were consumed using DA2416 strain. It was found that the S.cerevisiae DA2416 strain fermented cellobiose and xylose simultaneously, and exhibited an improved and much higher ethanol yield and productivity when compared to fermentation with Z. mobilis 8b. Keywords__lignocellulose, organic waste, ethanol, enzyme, bacteria.

Richard Gustafson

Life Cycle Assessments (LCA) for two lignocellulosic bioethanol production pathways utilizing hybrid poplar as a feedstock are developed and compared. Both processes use a SO2 catalyzed steam pretreatment followed by enzymatic hydrolysis. The processes differ in the fermentation process. In the first pathway an ethanologen is used to produce ethanol. In the second pathway, the fermentation is done with an acetogen to produce acetic acid. Acetic acid undergoes hydrogenation to produce ethanol. Both bioconversion pathways are modeled in Aspen simulations. In both processes lignin is recovered and burned onsite to produce process steam and electricity. The critical difference between the two processes is that the acetic acid pathway has a higher product yield but requires hydrogen for the process. Natural gas reforming is assumed to be the source of hydrogen. Greenhouse gases, regulated emissions, and energy use in transportation (GREET) is used to model combustion of ethanol from each scenario in a flex fuel vehicle. All necessary chemicals, transportation, and processes required by each production pathway are included within the LCAs. Each pathway is assessed using TRACI impact indicators to determine environmental performance. LCA results for the two pathways are compared. Comparisons are also made with fuel produced using conventional petroleum feedstock and conversion technologies.

Monday, June 17, 2013 | 2:30pm-4:00pm

New Approached to Biological Oils

Shulin Chen, Washington State University

Cellulosic Lipid Platform for Produce "Drop-in" Biofuels from Agricultural Residues
Shulin Chen, Washington State University

OPERATIONAL CHARACTERISTICS FOR MAXIMIZING SINGLE CELL OIL PRODUCTION FROM LIPOMYCES STARKEYI
Kyle Probst, Kansas State University

Conversion of Seaweed and Seaweed Processing Wastes to Liquid Fuels Through Carboxylate Platform Processing.
G. Peter Van Waslum, University of Maine

Oilseed Triacylglycerol Yields from Plant Leaves
James Petrie, CSIRO Plant Industry

Abstracts

Shulin Chen
Lipid is a desirable feedstock for production of bio-based drop-in fuel. Using oleaginous yeast and fungi to produce lipid from agricultural residues and wastes offer a sustainable lipid supply. The microbial lipid is then converted into bio-oil which will be further upgraded into hydrocarbon fuels. Compared with other lipid based feedstock such as algae, this approach has the potential of near-term commercialization for hydrocarbon production because of the high growth rate and high lipid contents of the yeast and the demonstrated maturity of fermentation technology. Another major advantage of using oleaginous yeast for heterotrophic lipid production is that the organism can efficiently utilize both C5 and C6 sugars derived from lignocelluloses. We have been exploring such a cellulosic lipid platform in the last five years and have demonstrated performance of various yeast and fungal strains and developed processes for converting wheat straw to lipid-based bio-oil. This paper presentation summarizes the most recent research and development results related to this platform, including yield, productivity and estimated production cost.

Kyle Probst
Various biobased products including high-grade biofuels, food ingredients, cosmetic additives, lubricants, detergents, and plastics can be produced from oleaginous yeast single cell oils (SCOs). Oleaginous yeast are species capable of producing high yields of SCOs, up to 70% (wt/wt), from non-edible, renewable feedstocks such as lignocellulosic biomass. For the oleaginous yeast Lipomyces starkeyi the fatty acid profile consists of 58% (wt/wt) C18:1, 11% C18:2, 16% C16:0, and 8% C16:1. Opportunities exist to further understand the effect of different growth

conditions on triacylglyceride and fatty acid production to develop strains capable of producing more valuable lipids for biobased products. SCOs are a secondary fermentation product made independent of growth under aerobic conditions. To induce SCO accumulation, a two-stage fermentation technique is often employed. First, growth and cellular biomass are maximized; then, during the second stage, a nitrogen limited stress-response is induced causing metabolism to shift to SCO production. Essentially, carbon is diverted to oil synthesis when nitrogen becomes unavailable; a natural phenomenon allowing the yeast to store energy in the form of triacylglycerides until favorable conditions return. Based on calculated stoichiometric values, it is evident that nitrogen deficiency in production phase is beneficial, and the oxygen demand for the SCO production is over four times greater than at biomass growth stage. In our research at the 2-liter fermenter scale, we found that very high biomass concentrations up to 100 g/L and SCO yields up to 40% can be achieved by growing the oleaginous yeast species L. starkeyi using glucose as the carbon source and urea as the nitrogen source. Additionally, biomass production and SCO yields can be further increased by controlling the dissolved oxygen content during each stage of fermentation. Experiments to enhance SCO production using a bi-phasic fed-batch fermentation at the 5-liter scale are ongoing. Nitrogen concentration is continuously monitored to initiate production phase by enhancing high oxygen transfer rate. The substrate uptake rate, biomass and SCO production rate will be quantified, and a detailed metabolic flux analysis will be discussed at the presentation.

G. Peter Van Waslum
Process wastes from carageenan production and seaweed fronds from whole kelp were converted by acidogenic digestion to mixtures of carboxylic acids. Raw kelp samples were pretreated with lime prior to fermentation. Fermentations were carried out in batch and continuous, counter-current modes. Testing of different buffer and temperature combinations found that 37 C and ammonium bicarbonate buffer produced the highest yields of acids on volatile solids fed. Nutrient addition and supplementation with mannitol- consuming anaerobes also contributed to acid yields. Thermal conversion of resulting carboxylate salts gave higher yields of product oils when converting calcium salts rather than ammonium salts. The final oil product phase separated from water and had an energy density higher than ethanol but lower than biodiesel.

James Petrie
Demand for plant oils will increase rapidly as the population grows in the coming decades. Limitations on arable land and other inputs mean it may be difficult to meet this additional demand with current oilseed-based production systems. In response, there has been significant investment in the production of high biomass plants with elevated triacylglycerol (TAG) content for both food and oleochemical (fuel and feedstock) applications. We report the production of Nicotiana tabacum events which have been genetically modified to produce in excess of 10% TAG in their aerial biomass. This was achieved by combining a variety of oil increase technologies in a single, coordinated approach to effectively overcome the 'Push' (fatty acid synthesis), 'Pull' (TAG assembly) and 'Accumulation' (TAG storage) limitations in plant cells. We describe surprising synergistic effects between

technologies as well as implications on efforts to achieve TAG secretion in plants. We also describe how the TAG profile has shifted significantly away from polyunsaturated fatty acids toward saturated and monounsaturated fatty acids and describe broader changes to the lipidome. We consider this to be a breakthrough toward the production of a new and viable plant oil production platform.

Tuesday, June 18, 2013 | 8:30am-10:00am

Algae: Overcoming Challenges in Cultivation and Production

Moderator: Sergei Markov, Austin Peay State University

Photobioreactors for Microalgal Cultivation
Sergei Markov, Austin Peay State University

Overcoming the Challenges in the Commercial Cultivation of Algae
George Philippidis, University of South Florida

Outdoor Cultures of Scenedesmus Vacuolatus: Biomass and Biodiesel Production
Giuseppe Olivieri, Università degli Studi di Napoli Federico II

Biomethane from Algal Biomass
Serge R. Guiot, National Research Council of Canada

Abstracts

Sergei Markov

The expression of the biological potential of photosynthetic microalgae for biofuel generation is ultimately determined by their cultivation techniques. Current industrial production of microalgae is achieved in open ponds of some thousand square meters in size. These systems have several limitations such as low attainable cellular concentrations and difficulty to prevent contamination. Alternatively, microalgae can be grown in photobioreactors that provide the most efficient utilization of the solar energy, and monitors culture purity. Photobioreactors are different types of closed systems that are made of an array of transparent to light tubes, bags or tanks, in which microalgae are cultivated and monitored. A great amount of work to design and to optimize different photobioreactor systems for microalgal cultivation has been carried out in the past. The main challenge in photobioreactor design is to create a simple, inexpensive, high-cell density, energy efficient photobioreactor which is scalable to industrial capabilities. A plastic bag photobioreactor (CultiBag photobioreactor) that can meet the above requirements has been demonstrated at the Austin Peay State University. Our research team used a series of novel type 50 L CultiBag photobioreactors to grow green microalgae Neochloris oleoabundans (Neo) under artificial (cool white fluorescent lamps) and natural illumination in a greenhouse for pilot-scale study of biodiesel generation from CO_2 by these microalgae. Photobioreactors were tested in a batch mode for two (or four) weeks. They were supplied with gas mixture (5% CO_2 and air). The gas flow was in the rage of 30-250 mL/min (we started at 30 and ended with 250 mL/min). Microalgal suspension mixing was first provided by continuous rocking of plastic bags, and CO_2 was supplied under elevated pressures. Later, 50 L plastic bags containing microalga N. oleoabundans were placed on the surface of water in a small swimming pool. Electrical fans were used as a wave generating device for the swimming pool in order to mix microalgal suspension inside bags. We exceeded our expectations by obtaining higher volumetric productivity values (3-4 g per L per day) in our CultiBag photobioreactors with N. oleoabundans compared to volumetric productivity data from other microalgae reported in the published papers. We also produced a significant amount of oil from this microalga. Particular attention in this presentation will be is given to the oil separation from algal biomass and the saturation of algal culture with CO_2 in a photobioreactor without losses.

George Philippidis
Algae promise to revolutionize the manufacturing of bioproducts, including renewable vehicle and aviation fuels and a variety of chemicals, but the fledgling industry faces formidable challenges on its way to commercialization. Productivity and yield under real-world outdoor conditions need to be boosted. Water management is one of the major issues as algae need to be cultivated in huge ponds and harvested for further processing. As water represents an increasingly scarce resource, engineers need to identify ways to minimize water usage and handling for both cost and environmental reasons. Moreover, energy use needs to be minimized to render algae technologies sustainable. We have developed and successfully tested a floating algae cultivation platform that is scalable and cost-effective, as it is modular in design and is manufactured from inexpensive plastics. Its novel design reduces water usage by 4-fold over traditional systems and is engineered to increase the mass transfer of CO_2 and nutrients to the algae cells. As a result, consistently high productivities and yields are achieved in semi-continuous outdoor operations under real-world conditions over long periods of time with no contamination problems. We are currently designing a 1-acre scale-up version to demonstrate commercial feasibility and confirm the projected financial performance of the technology.

Giuseppe Olivieri
Biofuels production coupled with carbon dioxide sequestration by means of photosynthetic microrganisms appeared a promising process since the end of the last century (Benemann et al., 1977). Microalgae biomass may be processed to produce liquid fuels (Sheehan et al., 1998; Chisti, 2007; Posten et al., 2009): bio-oil is extracted from microalgae and it may be either adopted as crude fuels or transesterified to biodiesel. A twofold advantage characterizes the potential success of microalgae as biofuel feedstocks. The first advantage: biodiesel-microalgae production rate may be 1–3 orders of magnitude larger than that from oil crops (Chisti, 2007; Wijffels and Barbosa, 2010). The second advantage: microalgal biomass fixes a large amount of CO_2 – 1.83 kg of CO_2 per kg of dry microalgae – and strongly contributes to the reduction of greenhouse gas emissions. However, yield and productivity of biomass and total lipid content are strongly affected by nutrient and light supply strategy. The present work reports the results of outdoor cultures of Scenedesmus vacuolatus in 1.7 L inclined bubble column (IBC) photobioreactors characterized by 250 cm^2 irradiated surface. IBC were operated according to Olivieri et al. (2012). The temperature was set at 23°C. A 2% CO_2 gas stream (50 nL/h flow rate) was sparged at the bottom of the IBC. pH was kept constant at about 7.0 by the CO_2 feeding. Bold Basal Medium (BBM) - $NaNO_3$ as nitrogen source - was adopted. Cultures were carried out outdoor: i) a test

campaign during the May-July period under shadow conditions, irradiance maximum of 450 microE/(m2 s); ii) a test campaign during the September-November period under direct sun light, irradiance maximum of 2000 microE/(m2 s). Cultures were operated under fed-batch or semi-continuous mode. 30% of suspension was withdrawn – and substituted with fresh medium - with a frequency of 1-2 times a week. Two procedures were adopted to induce nitrogen-starvation stress: I) the BBM feeding was stopped for two weeks and the nitrogen content was continuously monitored; II) the gas flow rate was stopped for few hours to separate the biomass by sedimentation and the clarified culture liquid was replaced with fresh BBM without nitrogen source. Harvested microalgae were processed to characterize the lipid and biodiesel composition according to the following steps: I) freeze-drying at -50°C; II) lipid extraction; III) lipid alkaline transesterification; IV) fatty acid methyl esters (FAMEs) characterization. An alternative procedure of direct transesterification of the intracellular lipid content without preliminary extraction was tested. The biomass concentration at steady state conditions was kept within the range 3-4 g/L. Biomass volumetric productivity ranged in the interval 0.17-0.22 g/(L d) - area specific productivity of 11-15 g/(m2 d) - depending on the operation mode. Benemann J.R. et al. 1977, Nature 268, 19-23. Chisti Y., 2007, Biotechnol. Adv. 25, 294-306. Olivieri G. et al, 2012, Effects of Photobioreactors Design and Operating Conditions on Stichococcus bacillaris Biomass and Biodiesel Production. Submitted to Biochem Eng J Sheehan J. et al.,1998, A look back at the U.S. Department of Energy's Aquatic species program: Biodiesel from algae, NREL Report, TP-580-24190. Wijffels R.H. et al 2010, Science 329, 796-799.

<u>Serge R. Guiot</u>

Most microalgae have the capacity, under nitrogen deficiency, to accumulate important quantities of carbon in the form of lipids. It is thus a potent source of biodiesel. However, Sialve, Bernet and Bernard (2009) estimated that if the algal cell lipid content does not exceed 40%, the anaerobic digestion of the whole algae appears to generate a higher energy balance than the biodiesel production coupled to anaerobic digestion of the defatted residue. This reinforces the potential of anaerobic digestion as a key and instrumental unit in an algal biorefinery concept. A recent cost analysis (Zamalloa et al 2011) concluded that methane production and cogeneration from microalgal biomass would become profitable from a feed-in tariff (FIT) of €0.133/kWh for both heat and electricity on an equal basis and a carbon credit of €30/t eCO2. The analysis assumed that the algal culture in raceway ponds can have a minimal productivity of 90 dry t/ha, be concentrated up to 20–60 dry kg/m3 at the harvest, and that the algal concentrate can be processed into an anaerobic reactor at a loading rate of 20 kg VS/m3.d with a conversion efficiency of 75%. We tested a selection of freshwater and marine microalgae for their methane production potential. There was no significant difference in the methane yield from freshwater microalgae (329 ± 43 mLCH4/g total volatile solids (TVS)) and marine microalgae (298 ± 83 mLCH4/gTVS) although it varied greatly within the tested strains. The type of medium was more determinant than the type of microalgae (freshwater or marine) for the methane yield. The strains Scenedesmus sp.-AMDD, Isochrysis sp. and Scenedesmus dimorphus displayed the best methane yield with 410, 408 and 397 mLCH4/gVS, respectively. A number of microalgal strains hence have a methane potential at or above 0.4 Nm3/kg TVS (i.e. corresponding to a conversion efficiency of ca. 75%), which would match or even lower the minimum FIT for profitability in the above case study. The strain Scenedesmus sp.-AMDD was chosen as a model strain for testing with continuously fed bioreactors. Digestion efficiency and methane productivity were studied in 5-L completely stirred tank reactors (CSTR) at several hydraulic retention times (HRT) and influent concentrations of algal feed. The methane yield was estimated at 0.39-0.41 L/gTVS degraded. However, at a hydraulic retention time (HRT) of 16 days only 52-53% of the algal biomass was degraded, primarily due to the slow hydrolysis of the algal cellular material. An increase in influent algal concentration from 11 to 20 gTVS/L led to even lower degradation efficiency. An increase of HRT to 58 days did not improve the degradation efficiency, while promoting growth of sulfate-reducing bacteria leading to high levels of H2S in the biogas. Anaerobic toxicity assays demonstrated a strong inhibition of acetoclastic methanogenic microorganisms at algae/anaerobic bacteria ratios above 0.1 g/g (TVS). Creating micro-aerobic conditions in the anaerobic reactor may reduce the deleterious effect of hydrogen sulfide, while two-stage digestion (acidification followed by methanization) may improve the process performance.

Tuesday, June 18, 2013 | 10:30am-12:00pm

Techno-economic Analysis of Renewable Chemicals and Fuels

The Forest Biorefinery: Successful Product Portfolios and Alternative Business Models
Jamie Stephen, Queen's Institute Energy & Environmental Policy

Technoeconomic Analysis of Renewable Aviation Fuel from Algae, Pongamia seeds, and Sugarcane
Daniel Klein-Marcuschamer, Australian Institute of Bioengineering and Nanotechnology (AIBN)

Techno-Economic Analysis of Hydrocarbon Biofuels from Poplar Biomass
Richard Gustafson, University of Washington

Overview of Oleochemistry in Québec and Canada. From the Field to the Industrial Bioproduct Market
Manfred Kircher, CLIB2021
Viondette Lopez, USDA, NIFA

Abstracts

Jamie Stephen
Many different operating models and product portfolios have been proposed for the forest-based biorefinery. Several pulping facilities are successfully operating as biorefineries with products including pulp, specialty chemicals, and fuels such as ethanol. In contrast, numerous emerging lignocellulosic biofuel technologies have faced significant challenges in moving to commercial scale. Our work seeks to identify the factors that have contributed to financial prosperity and those that have resulted in delay or failure. The potential economic performance of several forest biorefinery operations and technology/product portfolios are assessed using feedstock, logistics, and facility models. Analysis criteria include facility siting and scale, feedstock selection and cost, technology characteristics including platform and risk, facility age, product mix and volume, product pricing, share and size of product markets, market growth and installed capacity, integration with other forestry operations, financing, and policy support. Comparative metrics used to determine relative performance include ROCE and IRR. It is shown that transportation fuels are relatively low-value products and models that maximize fuel production are more susceptible to revenue volatility. Long-term off-take agreements for heat and power can increase revenue stability, while a mixture of high-value pulp and chemical products improve operating margins. However, size of these markets limits the opportunities for new entrants. Technologies that enable flexibility in product mix depending upon market conditions will provide a competitive advantage to biorefineries, while ethanol and other biofuels should be viewed as co-products rather than the primary source of revenue. A two-stage

technology deployment model which includes standardized intermediates could enable feedstock flexibility and reduce feedstock supply risk.

Daniel Klein-Marcuschamer

The replacement of petroleum derived transportation fuels with renewable alternatives is an important step in mitigating green house gas (GHG) emissions, meeting transportation needs in an oil-starved world, and promoting local economies. Jet fuels account for a significant fraction of global transportation needs; for example, in 2010, air transport consumed 10% of global transportation energy and this share is projected to increase to 13% by 2030 (World Economic Forum, 2011). In addition, these fuels represent a segment of the energy market that is unlikely to be met by other alternatives (e.g. battery-powered engines). As is true for all renewable energy sources, deployment of sustainable aviation fuels at scale depends on them becoming economically competitive with fossil fuel alternatives. Technoeconomic analysis of renewable aviation fuels has not been widely considered, despite the interest in the field and the importance of this effort. We present three process models for production of jet-fuel from microalgae, Pongamia pinnata seeds and sugarcane molasses. The models and assumptions will be deposited on a wiki and will be made open and accessible to the community. Based on currently available data, our analysis indicates that the biorefineries processing the algae, Pongamia, and sugarcane feedstocks would be competitive with oil at $1343, $374, and $301/bbl, respectively. Sensitivity analysis on the major economic drivers suggests technological and market developments that would bring the corresponding figures down to $385, $255, and $168/bbl. The dynamic nature of the freely-accessible models will allow the community to track progress toward economic competitiveness of aviation fuels from these renewable feedstocks.

Richard Gustafson

Life Cycle Assessments (LCA) for two lignocellulosic bioethanol production pathways utilizing hybrid poplar as a feedstock are developed and compared. Both processes use a SO2 catalyzed steam pretreatment followed by enzymatic hydrolysis. The processes differ in the fermentation process. In the first pathway an ethanologen is used to produce ethanol. In the second pathway, the fermentation is done with an acetogen to produce acetic acid. Acetic acid undergoes hydrogenation to produce ethanol. Both bioconversion pathways are modeled in Aspen simulations. In both processes lignin is recovered and burned onsite to produce process steam and electricity. The critical difference between the two processes is that the acetic acid pathway has a higher product yield but requires hydrogen for the process. Natural gas reforming is assumed to be the source of hydrogen. Greenhouse gases, regulated emissions, and energy use in transportation (GREET) is used to model combustion of ethanol from each scenario in a flex fuel vehicle. All necessary chemicals, transportation, and processes required by each production pathway are included within the LCAs. Each pathway is assessed using TRACI impact indicators to determine environmental performance. LCA results for the two pathways are compared. Comparisons are also made with fuel produced using conventional petroleum feedstock and conversion technologies.

Manfred Kircher
Viondette Lopez

Development of oleochemistry in Quebec, on-going projects and perspectives. Development of oleochemistry in Canada Development of oleochemistry in North America. Comparison with european model. How to link the world of oleochemistry.

Wednesday, June 19, 2013 | 10:30am-12:00pm

Sustainable Biomass Production and Soil Organic Matter

Moderator: Bram Brouwer, BioDetection Systems

Hans vanVeen, NIOO-KNAW (Netherlands Institute of Ecology)
Carlos Cerri, Centro de Energia Nuclear na Agricultura (CENA) da Universidade de Sao Paulo (USP)
Katarina, Hedlund
Bram Brouwer, BioDetection Systems

Abstract

The next decades, the current world will face a range of environmental, social and economic challenges. Our ecosystems are under pressure by increasing demands for food, feed, fibres and fuels. The transition from a fossil based economy towards a sustainable economy based on biorenewables will significantly contribute to find solutions for these challenges. At the same time this transition will impact our society, as the increasing demand for biomass requires sustainable production, responsible use, and equitable sharing of the resources and products. Climate change mitigation, rural development and sustainable land use will depend upon rigorous debate supported by the best available fact-based information. Optimal biomass production requires agricultural systems that find the balance between maximum biomass production and maintenance of soil fertility. The core element of a fertile soil is soil organic matter. The main question that we will face is how to find the balance between harvest of biomass for the bio-energy and the biobased economy and the return of organic matter into the soil so that soil organic matter content remains at levels that allow for sustainable production. Moreover large scale biomass production is at present not possible without the large scale input of fertilizers and pesticides. This threatens sustainable character of the biobased economy, also because large inputs of chemical fertilizers triggers the production of the greenhouse gas N2O . One of the key elements to reduce the input of chemical fertilizers and pesticides is soil organic matter as organic matter is the natural source of plant nutrients and the substrate for pathogen controlling microbes in soil. In order to support an optimal and sustainable biomass production further a set of bioassays and bioindicators are being developed which can be used to monitor the quality of soil and biomass and to support the development of a certification system soil use and biomass production on a commercial scale. Moderator: Bram Brouwer, Director of BE-Basic, Presenter 1: Hans van Veen Soil

organic matter levels and biomass production Presenter 2: Carlos Cerri, Brazil, sustainable land use and N2O production Title: Economical/societal aspects of worldwide use of Bioenergy Presenter 3: Kathrin Hedlund Title: Economy of soil organic matter Presenter 4: Bram Brouwer Title: Development and application of bioindicators and assays for soil & biomass safety & quality.