

## 2015 BIO World Congress Breakout Program Abstracts

### Track 1: Algae, Biomass Supply, and Specialty Crops



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### **Session 1: Making CO<sub>2</sub> Work for You: Algae Cultivation and Carbon Mitigation** **Monday, July 20 8:30 am -10:00 am Room: 521 ABC**

#### **Moderator: Simon Barnab, University of Quebec at Trois-Rivières** ***Carbon Capture and Microalgae: The Case for Co-Location II***

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 CO<sub>2</sub> 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 two new case studies in Canada and will present the final results of a co-locating project conducted in Quebec with the aluminium industry. This panel is also sequel of a previous panel on the same subject held at the 2012 World Congress on Industrial Biotechnology & Bioprocessing. Simon Barnabé Algae biomass production in colocation with the aluminium industry to reduce its fossil consumption: economics and energy balance. Since 2010, a co-locating project was conducted in Quebec to use industrial wastewater from a smelter for producing lipid-rich algae biomass using native lipid-rich algae consortia. In this project, the algae consortia are grown under heterotrophic conditions and thus need supplement of cheap carbon sources to increase biomass productivity. Highlights of the final report will be presented and discussed. Olivier Sylvestre Algae biomass production in colocation with a landfilling site. A new co-locating project started in Quebec to use the waste nutrients and the waste energy of a landfilling site and a composting platform for producing algae biomass using native algae consortia. It is planned to convert the algae biomass into a biocrude using hydrothermal liquefaction. Preliminary results will be presented and discussed. Nathalie Bourdeau & Patrick Marchand Algae biomass production in colocation with the dairy industry to produce biosurfactant for a local business. In 2014, a co-locating project started in Quebec to use the waste nutrients and the waste energy of an industrial park and produce lipid-rich algae biomass. Waste nutrients and energy from two local dairy industries, one local chemical industry (Sani-Marc) and one local landfilling site are used. Fatty acids C<sub>12:0</sub> and C<sub>14:0</sub> production is specially targeted. These fatty acids shall be used by Sani-Marc to produce biosurfactants. Preliminary results will be presented and discussed.

#### **Sissi Liu, Joule**

#### ***CO<sub>2</sub>-Recycled Fuels: The path to carbon-neutral mobility***

We live in a combustion-centric world, dependent on a cycle requiring millions of years to convert carbon into fuels that enable global mobility. Today it is possible to reduce this conversion to a single step; recycling waste CO<sub>2</sub> directly into sustainable, drop-in fuels. By consuming as much CO<sub>2</sub> in production as they emit when burned, these fuels offer a viable path toward carbon-neutral mobility – a pioneering achievement that will directly support global efforts to tackle climate change. The process recycles CO<sub>2</sub> directly and continuously from industrial emitters, converting otherwise harmful greenhouse gases into the transportation fuels upon which our global economy depends. At full-scale commercialization, a 1,000-acre facility can convert approximately 150,000 tonnes of CO<sub>2</sub> into 25 million gallons of ethanol or 15 million gallons of diesel per year, with no dependence on arable land, crops or fresh water. This presentation will address the progress and future impact of this production platform, including:

- Reversing combustion: how it works
- Advancement from lab to field demonstration
- Global applicability
- Advantages for industrial CO<sub>2</sub> emitters

#### **André Côté, Sani-Marc**

### ***VERTECH I project: producing algae oils with waste streams of an industrial park for local biosurfactant production***

Our society is looking for sustainable resources. Biomass is one of them and there are many types. Despite remaining challenges to achieve low cost production and conditioning, microalgae are very promising biomasses that can be produced from waste nutrients, waste energy and even from carbon dioxide. Many groups are producing microalgal biomass to obtain various biobased products and benefit simultaneously of wastewater phycoremediation and CO<sub>2</sub> capture. Some cities around the world follow this trend by integrating microalgae production to their municipal wastewater treatment plant. As a model for sustainable development, the city of Victoriaville and its local businesses would like to integrate such production in their region. The goal of this project is to utilize nutrient-rich effluents and organic residues from local businesses in the industrial park of Victoriaville (Canlac, Parmalat Victoriaville) and the surroundings (Gesterra ) to produce a lipid rich algal biomass. It is planned to extract these lipids and use green chemistry and oleochemistry techniques to turn them into biobased products for Sani Marc, a business localized in the same area and specialized in manufacturing cleaning products. Looking for environmentally friendly ingredients, Sani Marc is very interested in extracting some components from microalgae and using them to make biosurfactants.

### **Corey Laamanen, Laurentian University**

#### ***Year-round production of microalgae for biodiesel supported by waste industrial CO<sub>2</sub> and heat emissions***

Microalgae have the ability to accumulate lipids, making them a promising biofuel feedstock. There are several characteristics, including increased production per unit area and the ability to utilize non-arable land, that make microalgae a more promising source of biodiesel than higher plants. However, as most commercial mass production of microalgae is in open raceway ponds it is generally considered only a practical option where year-round ambient temperatures remain above 15°C. To expand the operating area it is proposed to couple microalgae production with industries that produce large amounts of waste heat and carbon dioxide. The carbon dioxide acts as a carbon source and increases microalgae growth rate, whilst the heat would allow year-round cultivation despite seasonal ambient temperatures well below 15°C. To demonstrate this concept, a dynamic model has been constructed that predicts the impact on algal pond temperature from both bubbled-in furnace off-gas and heat indirectly recovered from roaster off-gas of a smelter. Simulations were carried out for a variety of global locations using the quantity off-gas and waste energy from a smelter's operations. The results demonstrate the feasibility of year-round microalgae production through cold winter seasons and have led to the construction and operation of an on-site pilot facility linked directly to off-gas.

### **Nekoo Seyed Hosseini, Laurentian University**

#### ***Development of a novel top-lit gas-lift bioreactor for algal cultivation and CO<sub>2</sub> mitigation of industrial off-gas***

Mitigation of CO<sub>2</sub> in industrial off-gasses by sparging the gas through photosynthetic microalgae bioreactors is an attractive concept in the quest for renewable biofuels. Open systems are considered the most economic outdoor large-scale cultivation option but have large land space requirements due to their shallow depths (0.15-0.3 m). Locating them close to fixed off-gas sources on industrial sites is, therefore, a challenge. This paper presents a new design for an open bioreactor that uses a gas-lift system to enable deeper open ponds, thereby significantly reducing the footprint on industrial sites. Growth of *Scenedesmus* sp. in one-meter deep, top-lit gas-lift bioreactors was evaluated with 6% CO<sub>2</sub> rich simulated off-gas. The results indicated comparable volumetric biomass productivity (0.06 gdw/L day), but around 3 times higher productivity per unit area (61.1 gdw/m<sup>2</sup> day) than achieved with traditional raceway ponds.

### **Session 2: Sustainable Biomass: Leading the Way to Improved Outcomes**

**Monday, Jul 20 10:30 am - 12:00 pm Room: 521 ABC**

#### **Moderator: Matthew Rudolf, Roundtable on Sustainable Biomaterials (RSB)**

**Mejda Lortie, Agrisoma**

**Emily McGlynn, The Earth Partners LP**

**Richard Palmer, Global Clean Energy and Sustainable Oils**

***Sustainable Biomass: How new developments in biomass cropping systems can lead to improved environmental conditions, and lower the risk of unintended consequences.***

After always being “five years out,” 2014 will be remembered as the year that cellulosic ethanol finally became a commercial reality. Likewise, 2015 is positioned to be the year of commercial aviation biofuels, with a number of airlines planning to conduct regular commercial flights on biojet fuel. We are at an important juncture in the history of the bioeconomy, and with the advent of advanced biofuels, a variety of novel feedstocks are themselves coming very close to commercial deployment. Moreover, many of these novel crops have the potential to go beyond simply having a better environmental footprint, but can actually provide a mechanism to restore degraded landscapes and improve local environmental conditions. While the first generation of cellulosic biofuels will largely leverage the use of agricultural residues, most people are already looking ahead to the use of dedicated bioenergy crops, such as perennial grasses (e.g. switchgrass, miscanthus). The US Department of Energy BETO office sponsored a series of workshops in 2014 focused on the concept of “sustainable landscape design” which recognized the opportunity for cellulosic biomass to diversify agricultural landscapes, providing biodiversity benefits, improving soil health, reducing soil erosion, and increasing below ground soil carbon. In addition, many companies are now identifying opportunities to restore historical prairie lands to their original state, providing a financial opportunity for perennial grasses native to those regions to be planted and harvested annually for cellulosic conversion, a concept known as conservation biomass (<http://theearthpartners.com/conservation-biomass/grassland-restoration/>). In addition, policymakers and the private sector are already looking at creative ways to demonstrate the use of low indirect land use change pathways, as an alternative to integrating an iLUC factor directly into GHG emissions calculations. The LIIB consortium ([www.liib.org](http://www.liib.org)) has been doing leading work in this area, and has recently finalized a methodology for identifying low iLUC biofuel pathways. This panel will include a number of leading feedstock development companies on the cutting edge of developing biomass cropping systems that turn previous concerns about biomass around, by actually supporting improved environmental performance and lowered risk of indirect land use change. The panel will include three leading biomass crop companies (Agrisoma, The Earth Partners, Sustainable Oils), working on novel energy crops such as carinata, switchgrass, camelina and jatropha, and will be moderated by the Roundtable on Sustainable Biomaterials, who will discuss broadly the opportunities for biomass to support positive environmental outcomes. The aim of the panel is to explore how new technologies go beyond simply incremental improved environmental performance, and actually improve local environmental conditions, in the form of improving soil health, reducing water stress and providing biodiversity improvements.

### **Jacky Vandeputte, IAR Pole**

#### ***Addressing future biobased markets with Oilseed biomass***

Founded in 2012, PIVERT is a start-up company that manage an Institute developing chemistry based on oilseed biomass. One of the challenges for PIVERT is to reduce the lake of competitiveness of oleochemistry relative to petrochemistry. Its research program GENESYS is a key element, it aims to identify the needs of future oilseed biorefinery to address multiple markets. It is based on the tree aspects of the biomass cycle: production, biomass fractionation and transformation, and product’s delivery.

PIVERT: • Formulates new products for various applications to offer new opportunities for biomass valorization; • Develops new processes of biomass fractionation and transformation to improve yields and to minimize impacts on the environment; • Scales up processes to industrial levels in order to facilitate applications for industrial partners; • Formulates and provides pilot series to anticipate products position on the market. During the presentation we will explore the chosen ways by PIVERT to improve the competitiveness of oleochemistry: - How to improve productivity of actual crops - How to produce more adapted fatty acids to industry needs. - New ways to produce adapted fatty acids to industry needs. Finally, following recent scientific publications in magazines like: - Polymer chemistry , - Applied Catalysis or - bioenergy research published online the first results of Genesys program, often the result of a combination of complex processes using Biotechnology, chemistry and other sciences are going to be disclosed to participants.

### **Session 3: Agricultural Biomass Feedstock Supply Chain: Cost Drivers, Time Frames, and Supply Chain Models**

**Monday, Jul 20 2:30 pm - 4:00 pm Room: 521 ABC**

**Moderator: Bill Levy, Pacific Ag**

**Glenn Farris, AGCO**

**Martin Mitchell, Clariant**

**Anna Rath, Nexsteppe**

**Laurence Eaton, Oak Ridge National Labs Presenter**

## ***Agricultural Biomass Feedstock Supply Chain: Cost Drivers, Time Frames, and Supply Chain Models***

It's been said that "sugar is the new crude" yet it has taken longer than many had predicted to get to the Holy Grail – low cost sugars from sustainable, cellulosic sources. Today, we're seeing innovations up and down the supply chain, that, taken together, offer a roadmap to plentiful, reliable and sustainable cellulosic low-cost sugars. This panel will showcase these innovations.

**Session 4: Developing Biomass to meet the World's Biofuels and Bioproducts needs**  
**Tuesday, Jul 21, 2:30 pm - 4:00 pm Room: 521 ABC**

**Moderator: Sarah Hickingbottom, LMC International**

### ***Sustainable Raw Materials & the Perennial Food vs Non-Food Debate***

LMC is an independent economic and business consultancy specializing in agricultural crops, biomass & their industrial products, i.e. fuels & bio-based chemicals. LMC enjoys an unrivalled global reputation for clear, detailed analysis via our off-the-shelf reports & consultancy projects ([www.lmc.co.uk](http://www.lmc.co.uk)). In this paper we consider the drive for producers of bio-based chemicals and biofuels to move away from first generation, food-based feedstocks and towards second generation raw materials. They are motivated by supply chain, policy and sustainability concerns, such as food vs fuel and land use. For fermentation processes, this entails a switch from using starch glucose, derived from crops, to cellulosic sugars generated from biomass sources. However, with the bio-based chemicals sector still in its infancy, the critical question is: will there be sufficient cellulosic sugars, in reliable commercial quantities and at competitive prices, to supply both the fuel and chemical markets? By evaluating the prospects for fermentable sugars derived from woody biomass and agricultural crop residues. LMC has examined the current situation and has forecast the supply of cellulosic sugars out to 2025 as well as, crucially, assessing the competing demand that will determine availability and prices. Our analysis identifies the best options for commercial-scale production by location, process technology and by point in the value chain as well as benchmarking cellulosic sugars against their first generation equivalents in order to evaluate their commercial competitiveness.

**Donal Day, LSU AgCenter**

### ***New Crops for Biofuel/Bioproduct Production***

A USDA funded grant to the LSU AgCenter program to develop crops that can be used for biofuel production across the Southern United States to supply significant quantities of feedstocks for the next generation biofuel/bioproduct industries also offered the opportunity to improve local farm incomes, create manufacturing jobs as well. This program, directed by the LSU AgCenter, is a multi-researcher, multi-unit program that utilizes a wide variety of talents to develop new crops that can be produced sustainably and the technologies to locally convert them to fermentable sugars and biomass. The major constraints on the chosen crops were the ability to tolerate the wide variety of climatic conditions that exist between North and South Louisiana and the need for staggered harvest schedules such that crops can be delivered continuously to processing facilities over a major portion of a year. Two crops, similar in structure and containing fermentable sugars, energycane and sweet sorghum, were chosen for development. Energycane is a variant of sugarcane which is high in fiber and low in sugar containing juice and sweet sorghum, a relative of grain sorghum which produces less seed and also contains a sugar juice. Energycane is a perennial crop and sweet sorghum is an annual crop. Both crops can be harvested and processed in a manner similar to sugarcane. The fermentable sugars present in these juices could support rapid development for biofuel or any fermentation based bioproduct, with lignocellulosic sugars phasing in as conversion technologies develops. The two chosen crops appear to be productive on marginal or underutilized land such that they won't impact current crops. We are now in a position to answer key questions as to the utility of these crops as biofuel feedstocks. Processing of these crops post-harvest, using standard technologies, produces sugar syrups which are storable and contain high contents of fermentable sugars and biomass. The biomass is suitable both for power generation and can be converted to fermentable sugars using technologies that have been developed for converting corn stover to fermentable sugars. The value of these syrup sugars should be competitive with the value of sugars in sugarcane molasses.

**Michael Carus, Nova Institute**

### ***Sustainable biomass potential for food, feeds, bio-based materials, bioenergy and biofuels – a global analysis of biomass supply and demand in 2050***

How much surface area and biomass will be available on a global and European level in 2050 for the sustainable production of food, feed, bio-based materials, bioenergy and biofuels? The new study of nova-Institute investigates this question in different scenarios, considering new options for emerging technologies (e.g. biorefineries, macroalgae, solar and wind power, carbon capture and utilization, solar fuels) and resource efficiency concepts (e.g. recycling, cascading use, electric cars). While the data for the food and feed sector as well as the bioenergy and biofuel sector is more or less available, the analysis of the biomass demand for bio-based chemicals and materials was a great scientific challenge. The first step was to find a balance for supply and demand of biomass on a global level including all kinds of biomass and all demand sectors for the year 2011. This was calculated for the first time ever. In the second step, roughly 100 parameters were discussed and included in five different future scenarios based on different biomass supply volumes and different shares of biomass covering materials and energy demand. The presentation will provide an overview of the global biomass supply and demand in 2011 and 2050, broken down to biomass sources (cultivated agricultural biomass, harvest residues, grazing and wood), its main components (sugar and starch, cellulose, fat, protein and others) as well as the main use sectors (food, feed, materials, bioenergy and biofuels).

**Bradley Saville, University of Toronto**

***Energy Cane Development for Bioenergy and Biofuels***

A key challenge facing the development of a bioeconomy is feedstock availability, and associated logistics. Biofuels plants that use crop residues may be able to harvest 1 – 2 tons per acre; a 20 MMGPY plant with a process yield of 80 USG/dry ton would need about 250 thousand acres of land to support the plant. Canergy's feedstock development team has instead focused upon the development of highly productive energy cane as a bioenergy and biofuel feedstock. The Imperial Valley of California has some of the world's best conditions for crops. The area receives the most sunlight in the United States, and its irrigation-fed water supply allows for precise control of water to crops. Canergy chose this area to develop its energy cane varieties. The Imperial Valley site simplifies feedstock logistics, because cane can be harvested for nearly 11 months per year and delivered directly to a nearby bioprocessing facility, thus mitigating long term storage issues encountered with other lignocellulosic feedstocks. Comprehensive feedstock trials in the Imperial Valley of California are underway, spanning 200+ acres across four fields and >15 varieties of cane. Canergy's feedstock development team has evaluated field attributes (yield, growth rate, stalk heights and weights) and feedstock attributes (sucrose and fiber content, cellulose, hemicellulose and lignin) to identify varieties well suited to specific applications. Yields for the different varieties have ranged from 35 to 100 tons per acre, generally dictated by the stalk weight, which has ranged between 0.7 and 2.0 pounds per stalk for the different varieties at maturity. Brix values (i.e. sucrose) have ranged from 6 to 12, depending upon the age and variety, while fiber content has ranged from 65 to 80%. The fiber content is important as it is part of EPA's specification for energy cane as a cellulosic biofuel feedstock. The dry fiber compositions have been more consistent between varieties, with up to a 4% variation in cellulose content, a 4% variation in xylan content, and 5% variation in lignin content. Ultimately, specific varieties can be selected and developed for different applications, e.g., higher lignin content for biopower applications, or higher fiber/carbohydrate content for lignocellulosic sugars or biofuels. In this presentation, we will present data from field trials and describe key factors and outcomes from ongoing compositional and conversion tests with the different varieties, which have identified optimal varieties for commercial operations.

**Janice Ryan-Bohac, CAREnergy, LLC**

***The eTuber – a High Yielding, Sustainable Feedstock for ABF BioFuels, Plastics, and High Value Co-Products***

The Energy Tuber, or eTuber is a purpose-grown sustainable feedstock that can be used as an inexpensive source of sugar for biofuels, "drop-in" fuels, plastics, rubber, etc. This feedstock is well-adapted to the high temperatures and long growing season in the southeastern United States, Florida, and California. This crop will also be well adapted to many areas of the tropics. It can produce 5 times or more starch per acre than corn, on poor soils with significantly less inputs of water and nitrogen. Fermentation trials have shown it can serve as a "drop-in" feedstock for the corn ethanol plant. High yields with less inputs and development of new production methods will bring the cost of sugar from this crop to be less than sugar produced from corn or sugar cane. This feedstock cost will be beneficial as a source of reasonably priced sugar for organisms such as heterotrophic algae, bacteria, and yeast, without associated inhibitors present or produced by processing cellulosic feedstocks. The eTuber sugar would be the carbon source used by these organisms to produce initial compounds for drop-in fuels (biodiesel, jet fuel, etc.), rubber, plastics, etc. The eTuber feedstock is also an excellent source of valuable co-products. These include a large

amount of vine biomass that is an easily digested, high vitamin, high protein feed for animal production. A second co-product is a very high quality protein for human or animal feed that is easily extracted from the tuber.

**Session 5: Community Scale Biorefineries a Regional Approach to Success**  
**Wednesday, Jul 22 8:30 am - 10:00 am Room: 521 ABC**

**Moderator: Murray McLaughlin, Bioindustrial Innovation Canada**  
**Simon Barnab, University of Quebec at Trois-Rivières**  
**Jean-Philippe Jacques, Innofibre**  
**Patrice Mangin, University of Quebec at Trois-Rivières**

***Community Scale Biorefineries a Regional Approach to Success***

As abundant, available and diversified resources, biomasses have always been crucial for the development and sustainability of many rural regions, and northern remote communities. It may be fresh or residual biomasses, produced by different sectors (agricultural, forest, industrial, municipal) and being often soil-dependant, but not for all (e.g. algae biomass). Even if biomasses are exploited since many years, it gains constantly importance because of actual energy and socio-economic concerns. It is not anymore a question of exploiting a biomass to get one or many products for specific industrial sectors, but rather to get maximum biobased products and coproducts from each components of the biomass for in-house or local uses and then develop new markets or entering fruitful niches outside the region. A biorefinery approach is then needed to revitalize our regions. Issues and challenges remain to achieve success stories in biorefining. Having a community-scale biorefining approach, involving key local organisms and biomass dependant businesses plus possibilities of in-house or local uses of coproducts and focusing on the local socio-economic issues (e.g. revitalizing a near to close plant), can increase the rate of success of biorefining projects and bring social, economic and environmental sustainability aspects to the solution. In fact, resource recovery through a biorefining approach could be the key to relaunch or revitalize rural communities affected by socio-economical problems such as local plant shutting, decline of population, lack of business initiative, reluctance to change... In fact, biomass is at the basis of most rural economics. Diversifying or developing products from fresh or residual biomasses is a new source of incomes for farmers, foresters, waste management businesses, etc. Due to the local nature of biomass availability, the first mandatory steps of any bio-economy implementation based on the exploitation of biomass residues are necessarily regional. However, in addition to strict local demand, any value-added products and wealth creation necessarily requires exporting high value co-products outside the regional immediate proximity context. All of these considerations are at the basis of a "community-scale biorefining" approach that will be presented and discussed through specific regional projects. 1) Biomass processing depots to secure supply and other upstream operations: cases of the industrial park at Sarnia, and the industrial park at Bécancour: Two canadian case studies of biomass processing depots to supply lignocellulosic biomasses for an industrial park with chemical plants will be presented and discussed. 2) Resource recovery, bioenergy network and income from soil remediation at once: the case of the ecotechno-park Vertech at Shawinigan: A new canadian case study of bioenergy production combined to biocomposite manufacture and soil remediation will be presented and discussed. 3) The community-scale biorefinery platform at La Tuque: Since 2009, a community-scale biorefinery platform is being established at La Tuque City, QC, Canada. This platform involves mobile pyrolysis systems for biomass densification and a fix biorefinery to convert the bio-oils into valuable products and coproducts usable locally. The project will be presented and discussed.

**Session 6: Achieving Advancements in Algae Development**  
**Wednesday, Jul 22 10:30 am - 12:00 pm Room: 521 ABC**

**Moderator: John McGowen, Arizona State University**  
***The Algae Testbed Public Private Partnership: A Platform for Engagement and Access to Industry, National Lab, and Academic Expertise, and World-class Algal R&D Facilities.***

The Algae Testbed Public Private Partnership (ATP3), a multi-institutional effort funded by the Department of Energy has established a network of operating testbeds that brings together world-class scientists, engineers and business executives whose goal it is to increase stakeholder access to high quality facilities by making available an unparalleled array of outdoor cultivation, downstream equipment, and laboratory facilities to the algal R&D community. ATP3 utilizes the same powerful combination of facilities, and technical expertise to support TEA, LCA and resource modeling and analysis activities, helping to close

critical knowledge gaps and inform robust analyses of the state of technology for algal biofuels and bioproducts. ATP3 includes testbed facilities at Arizona State University's (ASU) Arizona Center for Algae Technology and Innovation (AzCATI), and augmented by university and commercial facilities in Hawaii (Cellana), California (Cal Poly San Luis Obispo), Georgia (Georgia Institute of Technology), and Florida (Florida Algae), in addition to partners at the National Renewable Energy Lab (NREL), Sandia National Labs (Sandia), Valicor Renewables, University of Texas at Austin, and Commercial Algae Management. ATP3 aims to make significant advancements in the algal biofuels arena by promoting opportunities through an open collaborative testbed network. Our regional testbeds are equipped to value propositions in support of multiple algae market value chains. These activities include strain selection and screening, biomass production/analysis, testing and validation of cultivation systems, method development and validation of analytical protocols and equipment, evaluation dewatering technologies, as well as biomass production and extraction of valuable microalgae co-products. We have successfully served clients interested in water testing and species identification, productivity and analytical measurements from biomass grown in novel PBRs, identification of bioactive molecules that promote animal health and associated scale-up processes, and products testing of novel nutrient additives that may boost algae production over conventional nutrient applications. Our network offers access to such desirable features as open and closed, small to large pilot cultivation systems, access to natural salt water, wastewater and CO2 streams, and integrated harvesting unit ops. We will present on our current projects and engagement with industry, our education and training workshops, describe how companies can engage with ATP3 to accelerate their research and development of algal technologies and de-risk their portfolio through third party validation at our facilities. We'll also describe opportunities to partner through ATP3's support program.

**Nathalie Bourdeau, Innofibre**

***RT-Algae: an integrated cultivation, harvesting, dewatering and conditioning process of microalgae biomass for biofuel and high value compounds production***

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 use to produce fuel and energy, securing the supply of biomass, fuel and energy remain a critical factor for success and profitability. An industry producing its own biomass can overcome this problem. In fact, many industries have CO2 stream, waste nutrients and waste energy that can be used to produce lipid-rich microalgae 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 facility co-locating approach for algae fuel, energy and coproducts production could be profitable for the co-locating industry. A facility co-locating project is conducted in the province of Quebec, Canada, to use industrial wastewaters from an aluminum smelter plant to produce microalgae biomass using native algae consortia. The RT-algae process, a unique microalgae biomass cultivation, harvesting and conditioning process, is used in this project to meet the challenge of reducing production cost. The pilot tank Alga-Fuel™ at Université du Québec à Trois-Rivières is used to produce microalgae biomass. This open pond has a unique agitation system providing maximum homogeneity to achieve optimal productivity. An electrocoagulation technology, the ECOTHOR reactor created by E2Metrix, was then used to harvest the biomass following by a pulp and paper technology available at Innofibre's pilot plant to dewater the algae until dryness rate required for the conversion step. This step is a thermochemical conversion by hydrothermal liquefaction (HTL) of the entire biomass to produce bio-crude oil. The aim of the present study was to investigate the pulp and paper technologies and developed a process to dewater microalgae biomass. A laboratory dynamic sheet former was first used to determine the flocculent concentration and the fiber disposition which allows to achieve the maximum microalgae recovery rate. Three concentrations (0%, 1% and 3%) of flocculent were tested and four types of fiber were tested as precoat on the canvas to prevent clogging and to increase the recovery rate of microalgae (softwood kraft, softwood CTMP, recycled wood powder and recycled cardboard). Flocculent concentration of 1% with the recycled cardboard achieve the highest biomass recovery (73% ±2,5) and an average percentage of 14% dryness. Then, an experimental setup was used to simulate the Fourdrinier of a paper machine to dewater microalgae in the condition previously determined. Results of experiments will be presented and discussed.

**Guillaume Pilon, University of Quebec at Trois-Rivières**

***Hydrothermal liquefaction of microalgae-bacteria consortium harvested using pulp and paper technologies; quantitative and qualitative characterization of co-products.***

During the past decade, increasingly R&D works have dealt with algal biomass as a promising alternative to produce fuel and energy. In the path of industrial applications, microalgae are interesting since they

provide both cellular biomass and oil with high productivity. One of the most attractive conversion methods for microalgal biomass is the hydrothermal liquefaction (HTL). Using wet biomass (10-25% dry solid content), HTL takes place at water saturation subcritical conditions (280-350 °C with respective saturation pressure). At those conditions, part of feedstock is converted into biocrude, which could be further refined as biofuels. Moreover, this biocrude could provide alternative chemicals and building blocks, replacing actual oil-based chemicals. Along these experiments hydrothermal liquefaction was conducted on a microalgae-bacteria consortium dominated by *Chlorella* sp. and harvested using laboratory pulp and paper technologies. Hydrothermal liquefaction experiments were carried within a 600 mL capacity Parr reactor. Factors explored for the hydrothermal liquefaction experiments were the various biomasses harvested by pulp and paper technologies, as well as modifications of the reactor temperatures above 280 °C, remaining at subcritical conditions. Biocrude, biosolids and aqueous dissolved solids were quantified. Biocrude was characterized for its energy density as well as for its chemical composition, which was determined by GC-MS. Aqueous dissolved solids were characterized for their potential reuse in culture medium.

### **Ioannis Dogaris, University of South Florida**

#### ***Development of a low-cost horizontal photobioreactor for high density cultivation of microalgae***

Open pond microalgae cultivation systems enjoy low capital and operating costs, but they suffer from low biomass productivity. On the other hand, closed photobioreactor systems can support higher biomass concentration and productivity, but they come at a considerably higher cost. Development of low-cost and high-productivity microalgal cultivation systems is critical for the cost-effectiveness of algae technologies. We have designed and developed a cost-effective horizontal cultivation system for outdoor algal biofuel production either on land or in water. The horizontal photobioreactor (HBR) is scalable and low-cost, as it is modular and manufactured from inexpensive plastic film. The HBR is engineered to increase the mass transfer of CO<sub>2</sub> and nutrients, hence boosting microalgae productivity under real-world conditions. Its design reduces water usage by 4-fold and decreases energy consumption significantly over traditional systems. Land need could be diminished by floating the unit in a water body, when available, with temperature control being facilitated by heat dissipation to the surrounding water. The HBR is equipped with airlifts to provide adequate culture mixing and with pH and temperature probes. The system's performance was successfully demonstrated in indoor as well as outdoor conditions by growing the marine microalgae *Nannochloris atomus* Butcher CCAP 251/4A in a 65-L HBR unit. High biomass concentration was achieved indoors, 4.0 g•L<sup>-1</sup>, under artificial illumination of 31.3 klux, as well as outdoors under real-world conditions, 4.3 g•L<sup>-1</sup> under peak sunlight of 100 klux. The biomass productivity doubled, when light intensity tripled in the indoor cultivations. The semi-continuous outdoor HBR operation in Florida for a period of 6 months spanning from spring to fall led to average productivities of 16.2 g•m<sup>-2</sup>•d<sup>-1</sup> without significant contamination issues. The scaling up of the unit is currently in progress in our 1-acre facility to demonstrate commercial feasibility of the technology.

### **Anju Dahiya, GSR Solutions LLC**

#### ***Cost-efficient algal biofuel production in the colder climate regions***

Waste-grown algae for biofuels production benefits local ecosystems and addresses two increasingly compelling global issues; the availability of sustainable transportation/ heating fuels, and nutrient waste management. GSR Solutions team brought together the complete supply chain and recently conducted the feasibility of advanced biofuel production in colder regions by utilizing farm and industrial waste materials to achieve positive energy return on investment of algal biofuel production. Identified potential to achieve production of biofuel and fertilizer co-products from waste-grown algae that was investigated at production levels deemed valuable by both fuel consumer and farmer stakeholders, and as a means to mitigate farm nutrient runoff pollution in the Lake Champlain region and other similar climatic areas across the US and Canada. The industries and dairy farms are required to meet regulatory standards for handling and recycling of nutrients including nitrogen & phosphorus, but the commonly used digesters for the treatment of wastewaters are effective only in treating the biochemical oxygen demand but not nutrients removal, and the farm runoff has been affecting the health of natural water bodies. This presentation will provide a perspective of mass culturing of algae utilizing wastes from dairy farms & industries, and discuss the challenges in algae cultivation for oil in the waste media.

## **Track 2: Specialty Chemicals, Food & Nutritional Ingredients**



Sponsored by:  Exceeding enzyme expectations

**Session 1: Novel Applications for Industrial Enzymes**  
**Monday, Jul 20 8:30 am - 10:00 am Room: 518 BC**

**Moderator: Ulrich Kettling, Clariant Germany**  
**Roberto Carrillo, Enmex**  
**Steve Libsack, Blume Distillation**  
**Timothy Wallace, Clariant Germany**

***Novel Applications of Industrial Enzymes***

The increasing demand for safe and sustainable products coupled with global trends such as population growth have brought new technologies into the focus to meet the evolving needs of customers in a sustainable, cost-effective manner. Industrial enzymes have developed from niche products into a major technological cornerstone used to meet these societal challenges. Applications include bioprocesses and chemicals synthesis for biofuels production, use as food processing aids and improved efficiency of feed ingredients. This session will focus on new developments in the industrial enzymes area, giving a broad perspective, extending from specialty enzymes for food, novel enzymatic processes to convert and add value to bio-based materials, to the design and implementation of enzymatic processes for novel biomass conversions. The overarching theme is the development of enzymes for existing and emerging applications. With a strategic emphasis on food-grade products, Roberto Carrillo from Mexican enzyme producer Enmex will present a portfolio of non-GMO fungal and bacterial enzymes for use in the brewing, starch, bakery, dairy, and sugar industries, as well as for feed and other technical applications. Given its Mexican location, Enmex is uniquely situated to serve the growing needs of customers in Latin America, one of the fastest-growing enzyme markets, and North America, the largest global enzyme market. Enmex is the only Latin American manufacturer offering its own enzyme brands as well as bioprocess scale-up services to current and new technological partners throughout North & South America in its food safety-certified facility. Steve Libsack, representing Blume Distillation, will explore novel process concepts and engineering designs to process biomass through the use of innovative enzyme solutions. This provides a rapidly expanding and highly flexible platform of sustainable technical solutions for agricultural feedstocks and biomass processors. The presentations will highlight the breadth of the technology and future potential. Timothy Wallace from Clariant, a Swiss-based global specialty chemical company, will present enzyme products and enzymatic-based processes with novel functionalities and high efficiency-in-use. The range covers conversion of cellulosic feedstocks to sugars and chemicals and further bioprocessing enzymes for various applications. Specific customized enzyme mixes enable the liquefaction of a wide range of organic by-products, allowing processors to improve yield and reduce waste, thereby contributing to improved economics and sustainability. Other applications include enzyme solutions tailored to customer-specific applications in the textile and the pulp & paper industries, as well as for sugar factories, corn mills, and oilseeds processors.

**R. Michael Raab, Agrivida, Inc.**

***GraINzyme®: A paradigm shift in developing novel animal nutrition feed additives***

Agrivida, Inc., is developing engineered corn grain that expresses a variety of feed enzymes used in animal nutrition. Agrivida's GraINzyme® products express high levels of specifically engineered enzymes for use in animal nutrition. The first two products are a grain expressed phytase and a grain expressed glucanase, which both improve weight gain and feed conversion in monogastric animals. These enzymes have been engineered for improved activity and high levels of thermal stability to enable direct use of the grain in feed pelleting processes. These products will be grown on a relatively small number of confined acres and used in animal diets at inclusion rates ranging between 50g and 500g per ton of formulated feed. Because of the relatively low costs of production, essentially the cost of producing and segregating the specialty grain, GraINzyme® products can provide higher dosing levels at competitive costs, which may enable greater inclusion rates of lower value feed inputs to help improve animal production costs. The ability to dose enzymes at higher levels may also provide an opportunity to expand enzyme use to ruminants, where enzyme products have been challenged by high costs to provide a dose that ensures consistent nutritional improvements. As a platform for animal nutrition feed additives, plant biotechnology offers a low cost, integrated mechanism for delivering highly differentiated and functionalized feed ingredients for animal nutrition and health.

**Session 2: The Role of Enzymes: Cost and Performance**  
**Monday, Jul 20 10:30 am - 12:00 pm Room: 518 BC**

**Moderator: Andrew Ellis, Biocatalysts Ltd**

***A Critical Review of Enzyme Development Tools***

Over the past two decades significant time and cost has been invested in the development of protein engineering techniques to enable design of enzymes to meet commercial needs. Specifically gene shuffling, rational (in-silico) design and directed evolution methods, coupled with enabling technology in synthetic biology, have been used to alter enzyme specificity, catalytic optima and stability. There are several examples where these aforementioned techniques have proved successful. However, against the backdrop of millions of dollars of investment, protein engineering techniques remain slow, costly and unpredictable. In this presentation Biocatalysts Ltd will present a balanced view on protein engineering and its practical usefulness in the development of commercial enzymes. Moreover, taking into account the exponential increase in availability of natural genes from genomes and metagenomes, coupled with the corresponding reduction in costs for accessing these natural genes, Biocatalysts will provide insight into natural diversity screening in commercial enzyme development.

**Andreas Buthe, c-LEcta GmbH**

***Customized enzymes on customized enzyme carriers***

The role of enzymes for the production of specialty chemicals, food and nutritional ingredients is becoming increasingly important, pushing a rapid and dynamic development of underlying technologies to enable highly efficient biocatalysts supply in the last decade. Regardless of enzyme availability achieved as of today, the role of biotechnology in this realm is still far from being fully exploited. Sometimes the main reason is given by enzyme cost contributions, which in certain applications can be tremendously lowered if enzymes are immobilized and re-used. Consequently, there is a considerable desire for customized biocatalysts in immobilized preparations that yield profound cost reductions in the respective target application. However, this is only half the truth for a perfect union of two aspects. Key requirement for success is the concomitant access to best-in-class enzymes and best-in class carriers (polymeric resins) for immobilization as well as their optimum matching to each other. Especially the latter can only be reached if the right partners collaborate. Therefore, c-LEcta, as a leading technology company in the field of enzyme development and production, and PuroLite, as one of the world market leaders in polymeric resins, have aligned their technological strengths. The synergy allows bringing value to customers by the creation of truly efficient and effective biocatalytic performers. Within this strategic alliance one high-performance biotech product was already successfully brought into the market: The immobilized lipase B from *Candida antarctica* marketed under the trade name "CalB immo Plus™" is a highly active and stable enzyme preparation outperforming competitive products. CalB immo Plus™ is a perfect example of joining "small" and "big" to indeed make up more than 2 out of each. The talk will summarize the most recent achievements and trends in enzyme development and immobilization. Different strategies and successful application examples will be introduced to demonstrate the power created if two expertise partners collaborate in this field.

**Felipe Sarmiento, Swissaustral USA, LLC**

***Discovery and Development of extremozymes for Industrial Biocatalysis***

The development of enzymes for industrial applications has heavily depended on the use of microorganisms. The intrinsic properties of microbial enzymes e.g. consistency, reproducibility and high yields among others, have pushed their introduction into diverse products and industrial processes. Among enzymatic microbial sources, extremophilic microorganisms provide a highly innovative opportunity. Extremophiles are microorganisms that thrive in extreme environmental conditions of temperature, pH, radiation, and salinity, among others. Many of these extremophiles have adapted their metabolic machinery by developing ultra-stable and highly efficient enzymes (extremozymes), which are customized for each specific extreme environment. Commonly, these adaptations correspond to key changes in the amino acid sequence of the enzymes, which are translated into variations in the structure, charge and/or hydrophobicity of the proteins. However, the evolution of these extremozymes is difficult to mimic in the laboratory even with modern mutagenesis approaches. Therefore, the metabolic toolbox of extremophiles represents a unique and valuable source of innovation for industrial and biotechnological applications where extreme conditions are required. The active bio-prospection of novel enzymes, which can work optimally under extreme conditions, is an efficient option to find extreme biocatalysts. Currently, few companies have the capabilities to find novel extremozymes and the technology to develop them for industrial applications. In Swissaustral, we have developed expertise and technology to bring the seemingly unattainable world of extremophiles to the market by establishing a platform based in a "functional" approach for the screening of enzymatic activities and a specialized strategy for the

development of novel biocatalytic solutions for non-standard technological challenges in Life Sciences and Industrial Biotechnology. Our High-Performance Enzymes(TM) possess a high industrial value because of these intrinsic characteristics: - Performance: optimal activity under extreme conditions of temperature (from 0°C to 110°C), pH and salt concentration among others. - Versatility: high activity in a broad range of different substrates, temperatures, pH and salinity, among others. - Stability: high resistance to proteolysis and organic solvents. Long shelf life, even at room temperature. Through our platform, we have discovered several High-Performance Enzymes(TM) such as hyperthermophilic nitrilase, thermophilic lipase, thermophilic laccase, thermophilic xylanase, thermophilic glutamate dehydrogenase, and psychrophilic catalase, which are in different stages of industrial development. Details about our platform, and specific characteristics of the named enzymes and their plausible industrial applications will be presented.

**Louis Fradette, CO2 Solutions Inc.**

***Commercialization Progress of CO2 Solutions' Enzyme-Based Technology for Low-Cost Carbon Mitigation***

CO2 Solutions Inc. of Québec, Canada has developed a patented biotechnological process for the cost-advantaged, environmentally superior capture, sequestration and beneficial reuse of industrial carbon dioxide (CO2) emissions. Using genetically optimized variants of the enzyme carbonic anhydrase, simple aqueous salt solutions can be enabled within known gas scrubbing equipment to replace costly and toxic conventional chemical processes for CO2 capture from the effluent gases of various industries. The presentation will discuss the basis of the technology and will provide an update on pilot demonstration activities currently underway.

**Mark Emalfarb, Dyadic International**

***The C1 Expression System – An industrial scale platform for enzymes and other proteins***

The C1 Expression System, based on the Myceliophthora Thermophila fungus, a soil-borne saprophyte, is a robust and versatile platform for gene discovery, expression and the production of enzymes and other proteins. Mr. Brooks will discuss Dyadic's commercial developments and progress toward producing cost-competitive enzyme and protein products for a variety of industries including biofuels, bio-based chemicals, biopharmaceuticals and industrial enzymes. Developed over the past two decades through UV-induced mutation and other bioengineering methods, C1 addresses the critical bottlenecks of protein discovery, development, scale-up and commercialization. The technology enables new product introduction with less time, cost and risk. Broad platform capabilities have been validated through 18 years of commercial-scale production (up to 150,000 liters) and 16 years of product sales and partnerships.

**Session 3: Development of Biobased Materials for the Automotive and Construction Markets  
Monday, Jul 20 2:30 pm - 4:00 pm Room: 518 BC**

**Moderator: James Lee, Bioindustrial Innovation Canada**

**Hamdy Khalil, Woodbridge Group**

**Somaieh Salehpour, EcoSynthetix**

**Anne Waddell, BioAmber**

***Development of Bio-Based Materials in the Automotive and Construction Applications***

Innovative agricultural biomass based products when transformed by the right technology can offer a unique value proposition to the market. To compete in the composites and materials markets, these biomass based products must be value competitive -offering equal or better performance characteristics, new or different functionality and demonstrate social sustainability. BioAmber will discuss automotive market applications of succinic acid derivatives made from sugars. The Woodbridge Group will discuss bio-based polyols trends and potential applications in the auto sector. EcoSynthetix will explore novel polysaccharide-based product offerings to serve adhesives and construction applications.

**Allen Barbieri, Biosynthetic Technologies**

***High-Performance, low-cost biobased synthetic oils certified for used in motor oils***

Biosynthetic Technologies (BT) manufactures high performance, biobased synthetic oils that are used in lubricants and other specialty chemical applications. BT is funded by BP, Monsanto, Evonik and Sime Darby among others. BT's molecule structure was developed and patented by the USDA and has been exclusively assigned to BT.

During the past year BT has achieved numerous critical milestones surrounding its breakthrough patented bio-synthetic technology:

1. Working with Infineum (lubricant additive company jointly owned by ExxonMobil and Shell), Biosynthetic Technologies received API SN Resource Conserving and ILSAC GF-5 (automaker OEMs) certifications, validating enhanced fuel efficiency over competing petroleum motor oils. BT has formulated and tested 5W-20 and 5W-30 viscosity grade motor oils. These two grades represent 79% of all motor oil sold in the U.S.

2. Biosynthetic Technologies has developed a highly efficient continuous flow process and has validated this process with a large demonstration plant built and operated by Albemarle. BT's demonstration plant through which this novel ester is manufactured represents a breakthrough in the production of esters, a class of premium petrochemicals used in the lubricants sector. Currently, most esters are produced through inefficient, expensive batch process.

As a biodegradable, non-toxic specialty fluid replacing petrochemical lubricating oils, BT's oils reduce negative impacts on the environment. Over 40% of the pollution in U.S. waterways comes from used motor oil. Multi-pronged pollution from industrial lubricants—primarily motor oil—represents a staggering environmental problem to which no viable solution has emerged. With the introduction of these high-performance biosynthetic oils, makers of industrial lubricants finally have a base oil option that functions impressively across the many severe applications in which lubricants are used. Significant displacement of toxic petrochemicals will occur as these biosynthetic oils are adopted. Biosynthetic oils have also been shown to reduce GHG's by over 70%, as reported by an independent LCA analysis. BT's business model is to sell these oils to manufacturers of motor oils, lubricants and chemicals. As such, BT is now working with over 80 of the world's largest lubricant companies, automobile and equipment OEMs. Many of these companies have already formulated and fully tested a wide variety of motor oils and lubricants they will sell under their brand names. BT has entered into commercialization. BT will soon commence construction of a large commercial scale manufacturing plant. To fund this plant, BT is negotiating a large project financing round, with the equity portion already oversubscribed. With proven premier performance attributes and a lower manufacturing cost than competing petroleum products, these BT's biosynthetic oils are poised to disrupt the petrochemical-dominant industrial lubricant sector and significantly reduce the environmental harm caused by these oils.

#### **Session 4: New Fermentation Platforms**

**Tuesday, Jul 21 2:30 pm - 4:00 pm Room: 518 BC**

**Moderator: Joshua Silverman, Calysta, Inc.**

#### ***Food and Energy Security through Methane Biotechnology***

By 2050, 9.6 billion people will demand 60% more protein than is currently available. Further, arable land and water are finite resources and while crop yields continue to increase, new sources of protein will be required to meet this growing demand. The recent rise in domestic production of methane has driven the cost of natural gas to record lows. Calysta has developed the world's only commercially validated gas fermentation platform using specialized microorganisms (methanotrophs) which efficiently convert methane to high quality protein with properties similar to fish meal. Methane is a highly sustainable feedstock, with a greenhouse gas impact approximately 34x worse than CO<sub>2</sub>. Methane does not compete with the human food chain and Calysta's process has minimal impacts on land and water usage.

Renewable methane is also available through proven technologies such as anaerobic digestion and waste treatment. Calysta is further building on the methanotroph platform to produce a wide range of chemicals, materials, and fuels from methane. This platform technology allows the production of biobased chemicals made from sustainable methane rather than sugar (a feedstock which does directly compete with the human food chain). Calysta's technology provides for a dramatic reduction in feedstock cost for a wide range of current biobased products, while providing a path towards a more sustainable and environmentally friendly bioeconomy.

**Sean O'Connor, Nucleis**

#### ***Production of Unique Oil Blends via Precision Gene Editing and Fermentation Engineering***

Nucleis LLC leverages its proprietary precision gene editing and development platform, the Rapid Trait Development System™ (RTDS), to generate high value, bio-based and sustainable specialty chemicals for the multi-billion dollar cosmetic, personal care, food additives, and flavor and fragrance markets. Integral to the RTDS platform is a suite of gene editing and genetic engineering technologies and techniques that enable specific changes to be made to a targeted gene, and ensure with precision that no foreign transgenic DNA is inserted into the cell's genome. These technologies combined with a versatile

fermentation platform applicable to any microorganism, and extensive downstream processing capabilities, allows efficient production of commercially viable target molecules via an integrated development platform. The initial microbial platform chosen by Nucelis is the oleaginous yeast, *Yarrowia lipolytica*. *Yarrowia* was selected due to its extreme versatility both in regards to feedstock inputs and product outputs. The company's first products being developed from this platform are ergosterol (a natural sterol and immediate precursor to Vitamin D2), and squalene (an emollient that is highly valued by the cosmetic and personal care industries). In addition, *Yarrowia* is known for being a prodigious producer of a wide variety of oils. Using RTDS, Nucelis has enhanced this natural productive capacity for making oils, specifically long chain triglycerides. This unique blend of triglycerides and squalene has significant market potential in the cosmetics and personal care markets, and as an emollient blend can be used in a variety of applications, including skin and hair care. This proprietary oil blend is currently being evaluated by several cosmetic companies for use as a base in custom formulations with a variety of end uses and benefits to the consumer. Each of these three products will be commercialized in 2015 and 2016. The RTDS development process has the power and versatility to be successfully applied to both the generation of new high value products and the optimization of existing manufacturing processes. Future platforms that are targeted for development include programs in bacteria, yeast, fungi, and algae. Nucelis is currently seeking to collaborate with partners on the development of our current *Yarrowia* platform as well as the use of RTDS to improve the efficiency of pre-existing bio-based product manufacturing.

### **Jason Husk, Kiverdi**

#### ***Specialty Chemicals from Waste Carbon***

Kiverdi's Carbon Engineering™ platform, is a novel processes that speeds up the carbon cycle and uses bioengineered microbes that rapidly break down the waste carbon gases that result from solid, liquid, and gaseous waste. In a matter of days, the output of the fermentation process produces sustainable oils that can be substituted for petroleum and plant-based oils in manufacturing the products that we use every day, such as detergents, plastics and fuel additives. Kiverdi's technology platform is at the core of our small-scale localized "mini-refineries" that will make specialty chemicals from non-petroleum and non-food sources in a much cheaper way and with far less consequences on the environment. The combination of low-cost feedstock, high conversion efficiency, and high-value end products enables Kiverdi to offer sustainable chemicals that are not only cost-competitive, but also profitable. Kiverdi's revolutionary technology platform can be summed up as follow:

**Supply Stability:** Our microbes use low-cost and abundant waste carbon to produce high-value oils and specialty chemicals that out-perform incumbent chemicals, disrupting the chemical industry supply chain in the process and avoiding commodity price volatility by removing requirements to source raw materials that have geographical constraints or are available seasonally. **Low-cost feedstock utilization:** With increasing levels of waste generation and decreasing available space for disposal, each year several thousand tons of waste generated around the world in form of municipal waste, forest / agricultural residue as well as waste carbon from industrial processes is an untapped resource that Kiverdi's breakthrough Carbon Engineering™ platform can convert into high value chemicals. **Flexible product portfolio:** Kiverdi's flexible platform allows for a capital-lite business model where existing equipment and 'product-specific' Kiverdi biocatalysts can be combined in our bioprocess with minor tweaks to target specific specialty chemicals of interest for our customers enabling us to create an array of new products to grow the product portfolio of our customers. Kiverdi's innovative bioprocess lends us product flexibility to create an optimized portfolio of sustainable specialty chemicals for our customers based on their market needs with minimal capital investment to produce new chemicals each time.

### **Peter Nieuwenhuizen, Akzo Nobel**

#### **Timothy Cesarek, Enerkem**

#### ***Squaring the circular economy: Renewable chemicals from waste***

The circular economy is a much talked-about phenomenon that is considered by many as the holy grail for a sustainable world. Certainly one of the first targets for a circular economy would be to take useless waste, and convert it into valuable feedstocks which can be starting materials for new and useful consumer products. To this end Enerkem, a waste-to-chemicals producer from Canada, and AkzoNobel, a leading global paints and coatings company and a major producer of specialty chemicals, have decided to join forces and partner to explore the development of waste-to-chemicals value-chain partnership in Europe. Together, we are developing an alliance of partners and make the circular economy come alive. Waste is a sustainable and cost-effective feedstock for the chemical industry and the potential offered by Enerkem's technology is in line with AkzoNobel's Planet Possible approach to sustainable manufacturing.

Each year, 1.3 billion metric tons of municipal solid waste ("MSW") are generated around the world (source: World Bank, 2012). Approximately 66% of this municipal solid waste is either landfilled or incinerated. By using municipal solid waste as a feedstock to produce renewable chemicals, a technology such as Enerkem's provides a sustainable alternative to the challenges associated with waste disposal, reduces dependence on oil and contributes to a greener economy. It equally answers the question of how to dispose of rapidly accumulating non-recyclable and non-compostable garbage, while avoiding methane emissions from its decomposition in landfills and creating value-added products from otherwise waste materials. Enerkem's unique biorefinery process enables the use of MSW as an unconventional and low-cost feedstock. This patented technology is deployed through an exclusive process that converts non-recyclable MSW into a pure synthesis gas (or syngas). This syngas is then synthesized into biofuels and other widely used chemicals using catalysts. In less than 5 minutes, waste destined to landfill becomes clean transportation fuels or renewable chemicals, which can then be used to form other value-added products. The process is being piloted in Edmonton, Canada, AB, where Enerkem has built one of the first commercial biorefineries in North America. With the Enerkem partnership, AkzoNobel has activated another component of its biobased strategy which it presented at BIO Orlando 2012, presented first alliances at BIO Montreal 2013, and reported on the how-to's of alliance formation at BIO Philadelphia 2014. At BIO Montreal 2015, in 2 x 15 minutes we aim to share with our audience how Enerkem and AkzoNobel are collaboratively knitting together a value chain alliance comprised of waste managers, municipal, provincial and national governments, investors and plant owners. Without a doubt, the key to success for such first-of-kind facilities using transformative technologies is to develop multi-party win-win partnerships where we share benefits and investments (of many kinds) fairly and equitably.

**Session 5: Generating More Value from Canadian Biomass and Waste Streams**  
**Wednesday, Jul 22 8:30 am - 10:00 am Room: 518 BC**

**Moderator: Denise LeBlanc, National Research Council Canada**

**James Johnston, National Research Council Canada**

**Bob Chapman, National Research Council Canada**

**Stephen O'Leary, National Research Council Canada**

***Generating More Value from Canadian Biomass and Waste Streams***

The National Research Council of Canada (NRC) is Canada's premier Research and Technology Organization (RTO). A strategic focus on Aquatic and Crop Resource Development is one of NRC's priority research areas. Efforts to support extracting value from Canadian biomass and waste streams have focused on algal technologies, natural products chemistry, ingredient characterization (safety and efficacy), biomass development, bio-processing, fermentation and enzyme technologies. To support the growing biobased industry, multi-disciplinary research teams are conducting projects to develop biobased functional ingredients and nanomaterials. These initiatives are leading to the development and commercialization of new products in the fields of specialty chemicals, food and nutritional ingredients. NRC clients benefit by leveraging this research for licensing opportunities, new product development and market expansion. This panel session will provide an overview of the latest research efforts and highlight opportunities in the areas of natural health products, algal carbon conversion, biomass valorization and biobased specialty chemicals. Commercializing Nutritional Oils: New Sources & Advanced Characterization Methods. This presentation will focus on two key areas of investment from NRC's NHP program and partners. (1) New sources of nutritional oils being developed which include: shrimp oil from Canadian shrimp processing waste, a phospholipid rich blue mussel oil, Omega 3 and lutein rich oils from algal strain collections and nervonic acid rich oil from plant production systems in Brassica carinata. (2) Product differentiation is important for market success and advanced analytical solutions help. NRC goes far beyond fatty acid analysis and includes specific lipid class profiling, omega-3 triacylglyceride positional isomer determination, and phospholipids quantitation/profiling. Optimizing the Algal Carbon Conversion Value Proposition: Protein and Nutritional Products. One of the most promising avenues for product development from algal biomass is the use of whole or lipid extracted biomass in animal feeds. Algal biomass can have substantial amounts of protein (15 - 50%) in addition to lipids and carbohydrates, and shows excellent potential as an ingredient for aquaculture and livestock feeds. Additional high value products from algae are the carotenoids such as  $\beta$ -carotene, lutein and astaxanthin, and the omega-3 fatty acids. Converting Waste Streams into High Value Nanomaterials. Chitin is an abundant natural biopolymer found in the shells of crustaceans. Chitin and its derivatives are found in applications for the biomedical, food, cosmetic and textile industries due to their antimicrobial, anti-fungal, biocompatible and biodegradation properties. The NRC has discovered a green, simple and versatile method to produce chitin

nanocrystals (ChNC) without using concentrated mineral acids. As a natural alternative to chemical antimicrobial agents, ChNC exhibited very high inhibition activities that are comparable with triclosan, against gram negative bacteria such as Escherichia coli and gram positive bacteria such as Staphylococcus aureus. This technology is expected to lead to new applications for antimicrobials, cosmetics, food preservatives, water treatment, wound dressings and personal hygiene products.

## **Session 6: Processes for Biomaterials and Nutritional Products**

**Wednesday, Jul 22 10:30 am - 12:00 pm Room: 518 BC**

**Moderator: Olga Selifonova, Reluceo**

### ***C5 Chemistry Platform for Value Creation from Non-Food Agricultural Biomass***

We view the non-food agricultural biomass as the valuable "carbon ore" for the eventual sustainable future of humanity beyond the age of fossil carbon. C5 carbohydrates are the most accessible and the most undervalued major parts of non-food cellulosic biomass from agriculture and managed forestry. Our technology enables selective isolation and utilization of C5 carbohydrates (hemicelluloses) and opens up new economics for conversion of biomass to benign-by-design sustainable industrial products. Our product pipeline caters to markets for impactful industrial materials such as performance bioplastics, special function polymers, and for functional health food ingredients useful for prevention and management of the global pandemics of diabetes affecting nearly 400 million people. Our process is devoid of economic risks associated with technologies for separation of cellulose from lignin. The process co-generates captive energy along with some useful amount of ethanol for self-sufficiency of our operations. The simplicity of our C5-centered hydrolysis process and the use of optimally-sized equipment permit a fractal consolidation approach for biomass processing and downstream steps, thereby enabling (i) dramatic reduction of biomass transportation costs from the point of origin to the point of primary processing and (ii) staggered deployment of CapEx for ramping-up production. Our technology and product pipeline carry the potential to double economic output and earnings of existing agriculture through smarter use of biomass without calling for planting new land or increasing crop yields, thereby enabling a non-incremental step toward sustainability of the world economy.

**David Demirjian, zuChem, Inc.**

### ***Nutritional Sweetener and Saccharides from Renewable Feedstocks***

Carbohydrates play an important role in human biology because of their involvement in a myriad of biological functions – from nutrition to cell targeting and the differentiation of disease states. Despite their importance, the development of novel food, nutritional and pharmaceutical-based carbohydrate products has been held back both because of the lack of efficient process methods to make them and the availability of good fermentative feedstocks for their production. In order to address these challenges, a platform of novel and economic industrial manufacturing methods has been developed (both fermentation and enzyme catalysis). As abundant supplies of inexpensive new feedstocks such as C5 sugar streams are finally becoming available at scale and the technologies that can interconvert C5, C6, and other sugars mature, many new sugar and saccharide nutritional products are finally making their way to commercialization. One example of this is the polyol xylitol, a sweetener with tremendous potential because of its flavor profiles and oral hygiene applications. An efficient process for the production of xylitol from a mixed C5/C6 sugar stream has been developed and is now in commercial scale-up. In this process, xylitol is produced at high yields and productivity with no other contaminating sugars or polyols and minimal need for removal of fermentation inhibitors. In another example, a novel engineered dehydrogenase is used to produce a dozen different C5 and C6 high value rare sugars with both nutritional and pharmaceutical applications. Finally, with the availability of unique saccharide building blocks complex nutritional prebiotics such as the human milk oligosaccharide lacto-n-neo-tetraose and many others have been produced at large yield. Here we will detail the development of the most important features of these processes and many of the main obstacles that encountered from development through commercialization.

**Emmanuel Petiot, DEINOVE**

### ***Exploring the commercial potential of a 6,000 strain bank for the production of renewable specialty chemicals***

DEINOVE is a biotech company that develops breakthrough production processes based on a yet to be fully exploited bacterial genus: the Deinococcus. Deinococcus bacterium, being 3.5 billion-year-old, is one of the oldest life forms on earth and features an extraordinary biodiversity. Taking advantage of the unique genetic properties and robustness of the Deinococcus, DEINOVE optimizes metabolic capabilities of

these bacteria to produce bio-based molecules from renewable feedstock, including from lignocellulosic biomass. The company is segmented into several projects. Its program focused on second-generation biofuels is called DEINOL. Similarly, DEINOCHEM is focused on renewable chemicals and isoprenoids in particular. Practically, only a limited number of candidates serve as host strains for the genetic engineering needs of the DEINOL and DEINOCHEM projects, where the introduction of new metabolic pathways or optimization of existing ones are undertaken. In complement, DEINOVE leverages its large biolibrary via the creation this year of a new project that is considering the compounds which are naturally produced by its strain bank, (without performing genetic modifications). Indeed, through a meticulous screening process leading to the full structuring of the bank, it was found that the remaining untapped strains naturally produce a wide array of molecules of industrial interest. DEINOVE's 6,000 strains (Deinococcus and other genera), were isolated from extreme environments, such as deserts, glaciers, hot springs, volcanoes, lagoons, tropical forests... They were all isolated by UV-radiation selection, giving rise to the recovery of UV-resistant strains. This characteristic is notably due to naturally occurring carotenoids of varying types and colors in their cell wall, some being specific to Deinococcus, like "Deinoxanthin" for example. These compounds are sought-after for their antioxidant activity and/or their pigmentation effect, for use in cosmetics or in animal feed in particular. Sofiprotéol (now the Avril Group), a major European agro-industrial group, signed in 2014 a collaboration agreement with DEINOVE to develop a production process for this type of natural feed additives for specific applications. Furthermore, the Deinococcus and the other DEINOVE's novel bacteria, in their natural state (non-GMO), are also truly interesting for the extraction of other molecules of industrial interest, such as surfactants, exopolysaccharides, enzymes, fatty acids, and other osmolytes. All are high-added-value industrial ingredients, providing applications in cosmetics, food/feed, home and personal care products... DEINOVE is the sole company exploiting these bacteria for industrial processes, it holds more than 180 worldwide patent applications. Its high quality and diverse strain bank and its ability to optimize fermentation conditions enable the company to develop processes for manufacturing industrially relevant commodities, intermediates and specialties in a wide range of applications.

**Jochen Forster, Technical University of Denmark**  
***Engineering Polyphenol Production in Bacteria***

Polyphenols are plant secondary metabolites that are derived from the polypropanoid pathway. They are ubiquitous in nature and it is estimated that there exist more than 100,000 different polyphenols. In plants, polyphenols serve various protective function i.e. antimicrobial functions, preventing damage by UV radiation, chelation of toxic heavy metals, and many more. They have been subject to intense research with respect to health benefits and application in pharma. Besides this, various polyphenols can find applications as pigments, preservatives, monomers for bioplastics, and composites, and they can directly be applied as food, feed, nutraceutical or cosmeceutical ingredients. The aim of the present project is the design of platform strains for production of polyphenols. Results will be presented on trans-resveratrol and fisetin production. Trans-resveratrol is a promising polyphenol that may find application in treating obesity and diabetes Type II, and fisetin is a promising potential candidate to prevent Alzheimer's disease and to prevent complications associated with diabetes type I. The activities are part of a larger EU project, BACHBERRY ([www.bachberry.eu](http://www.bachberry.eu)) aiming at the development of BACTerial Hosts for the production of Bioactive phenolics from BERRY fruits.

**Peter Milic, Microbiogen Pty Ltd**  
***Maximising Revenues and Reducing Risk in Fuel and Feed Biorefineries***

Lignocellulosic bio-refineries today produce bioethanol as the main product while co-products may provide power. However corn ethanol facilities in the US are profitable due in part to the production of relatively high value co-products such as DDGS and corn oil. Is it possible to maximise revenues from a 2G biorefinery by increasing the value of co-products? Microbiogen has patented a unique strain of the yeast *Saccharomyces cerevisiae* and fermentation process that will allow the development of a "fuel and feed" bio-refinery. The MBG biorefinery will produce ethanol and high protein yeast for animal feed applications as a high value co-product. By producing both yeast and ethanol, the biorefinery can overcome many of the issues associated with the food versus fuel debate. A key aspect of the Microbiogen bio-refinery is a robust solution to fermentation. This is critical as inferior organisms and fermentation pathways will negatively affect economics and process dynamics. In the MBG process the same organism is used to convert C6 sugars to ethanol within 24 hrs while the C5 sugars and fermentation by-products are converted to high protein yeast within 30 hrs. Yeast can then be used to initiate another round of ethanolic fermentation at high cell densities to overcome toxicity and inhibitor issues and enhance fermentation speed. In this process most of the carbon is converted to high value products while

minimising carbon lost to lower value applications such as biogas production. Analysis of commodity price and internally generated data suggests that by producing ethanol and high quality feed yeast as co-products the volatility in revenues and net cash flows are expected to half and assuming yeast is priced at the mid-point between soy meal and fishmeal the net cash flows for a fuel and feed biorefinery are estimated to double that of an ethanol only facility.

### **Track 3: Synthetic Biology and Genomics Research**



Sponsored by:

#### **Session 1: Synthetic Biology Products: Cost Competitive and Performance Driven Monday, Jul 20 8:30 am - 10:00 am Room: 522 ABC**

**Moderator: Kevin Jarrell, Modular Genetics  
Karl Sanford, DuPont**

#### ***Synthetic Biology, Industrial Biosciences and DuPont***

This presentation will highlight several examples of products that we have commercialized using methods that can be described as synthetic biology – even before this term was created. The presentation will include examples from our enzyme, biochemical and biofuel sectors.

**Stephan Herrera, Evolva  
*Responsible Innovation***

There are a number of ways that a biotech company can incorporate "responsible innovation" into their R&D strategy today. One size does not fit all. Indeed, Evolva's approach is just one approach among many. However, Evolva's technology platform and fermentation-produced products continue to be the subject of a great deal of ink in the media and among NGOs. As such, Stephan Herrera, VP of Strategy & Public Affairs at Evolva, is in a rather unique position to share with the industry his learnings from the sharp end of the debate over product development in this branch of biotech, and his views on what lies ahead.

**Darren Platt, Amyris  
*Dawn of a Golden Age for Microbial Engineering***

Over the last 10 years, Amyris has successfully brought three molecules to commercial scale, and now has 17 additional molecules in the development pipeline, spanning industries from industrial solvents to pharmaceuticals. Along the way, we have created a highly automated strain improvement process that dramatically increases the speed and quality of rational strain design. These gains not only enable us to tackle increasingly more complex strain development projects, but also drive down the cost and time needed to get new molecules to market. Focused effort on the development of advanced robotics, custom computational tools, strain construction and assay quality, and quality control have contributed to the success of this approach. We have applied the lessons learned by other manufacturing industries to microbial engineering, automating routine tasks, data capture, and quality systems to create a robust pipeline for the creation of microbial factories. Ultimately we intend this to culminate in a largely automated strain improvement cycle, incorporating machine learning algorithms to assist in future metabolic engineering designs. Combined with ongoing improvement in DNA synthesis and sequencing technologies, we are now entering a golden age of microbial engineering. In this talk I will describe how we intend to cost-effectively produce thousands of molecules biologically, and rapidly bring them to market.

**Oliver Peoples, Metabolix Inc.  
*Accessing the Unique PHA Biopolymer Design Space through Metabolic Engineering for High Value Applications***

Metabolix is a twenty year veteran and pioneer in the development of the industrial biotechnology industry. The company is focused on the PHA family of biopolymers. PHA biopolymers have typically been viewed as biobased and biodegradable replacements for a range of commodity plastic resins such as polyethylene and polypropylene, the lowest value and most cost sensitive markets. While the regulatory framework and composting infrastructure continues to develop for those applications Metabolix has focused its technology and commercial development activities on the use of PHAs as performance

materials. PHAs have a broad range of physical properties and Metabolix has leveraged its advanced metabolic engineering platform to access unique PHA material properties. The business is focused on three key market segments: polymeric modifiers for PVC; performance modifiers for PLA; and functional biodegradation. The PVC and PLA modification markets are enabled by the new high performance PHA with a set of physical properties unique to the polymer industry. This PHA is completely amorphous, has a high molecular weight and a low glass transition temperature enabling its use as a rubber toughener in a range of other materials.

## **Session 2: New and Innovative Technological Advances**

**Monday, Jul 20 10:30 am - 12:00 pm Room: 522 ABC**

### **Eric Althoff, Arzeda**

***Arzeda is a synthetic biology company focused on providing new bioprocesses for the green manufacturing of chemicals.***

Arzeda is a synthetic biology company focused on providing new bioprocesses for the green manufacturing of chemicals. As a technology development and product company, we leverage our industrially validated enzyme and pathway design technologies to create superior value for our partners in the chemical and biotechnological industries. The recent emergence of industrial and synthetic biotechnology has the potential to radically transform the chemical industry using biomass as a primary feedstock. To this end, we have developed novel computational technologies and applied them to rationally engineer enzymes with a wide range of activities. To complement our previous techniques, we have recently developed a new algorithm, called Enzyme Identification™, to rapidly engineer enzymes with known catalytic mechanisms for non-native substrates. For a given chemical reaction, our algorithm screens "in silico" large databases of protein structural and sequence information to allow the rapid discovery of existing enzymes that possess both the necessary catalytic machinery and an appropriate substrate-binding pocket. For those enzymes that possess the necessary catalytic machinery but lack an active site that can accommodate the substrate(s) of interest, Enzyme Identification automatically redesigns and remodels the active site pocket thus enabling catalysis of the desired reaction. In addition to the design of new enzymes, Arzeda has developed a complimentary technology which is able to design metabolic pathways to new molecules not found in nature. Arzeda is applying its technology to develop Designer Cell Factories to produce these new bio-based chemicals. The demonstrated success and wide applicability of our methods open the way for the design of a variety of novel biocatalysts necessary for the efficient development of biosynthetic pathways for the industrial scale synthesis of high value chemicals from biomass. In partnership with INVISTA, the world leader in nylon fibers, Arzeda is working on the development of new metabolic pathways for the production of bio-based butadiene, with its \$10B dollar current market made produced from petroleum. Additionally in a partnership with DuPont Pioneer, Arzeda has successfully applied its enzyme design technology to develop a novel trait for corn and soybeans and potentially other crops that will increase agricultural productivity. The traits are continuing through the development process and will be commercially available in the future. This presentation will delve into these recent successes as well as discuss new opportunities for Arzeda.

### **Frédéric Pâques, Global Bioenergies**

***Pathway to Commercial Production of Light Olefins via Direct Fermentation***

Most industrial bioproduction processes are based on naturally existing metabolic pathways, limiting the scope of industrial biology, and preventing access to many of the chemistry's largest markets. The purpose of Global Bioenergies is to develop innovative metabolic pathways for the production of light olefins from renewable resources, by direct fermentation. However, light olefins are not naturally produced by microorganisms and no bioprocess to convert renewable resources to these molecules has been industrialized so far. Global Bioenergies has developed an artificial metabolic pathway to isobutene. Importantly, production of a volatile compound such as isobutene by direct fermentation presents two major advantages: first, in contrast to ethanol or isobutanol production, the product is spontaneously removed from the culture broth, which alleviates the significant challenges associated with product toxicity. Second, the purification process is considerably easier and cheaper since no energy consuming methods such as distillation or phase separation are necessary to purify the end product.

Commercialization efforts took a step forward with the announcement of the successful production of isobutene at industrial pilot scale, and Global Bioenergies continues to expand its partnerships, which now include Audi and Synthos. Finally, while isobutene production moves towards industrial scale, Global Bioenergies is also developing new artificial pathways enabling direct bio-production of Butadiene and Propylene.

**Sean Simpson, LanzaTech**

***Lanzatech's Unique Platform for Recycling Waste and Low Cost Resources into Valuable Commodities***

LanzaTech has developed novel technology that recycles the carbon from local, highly abundant, waste and low cost resources into sustainable, valuable commodities. The patented process converts waste gas containing carbon monoxide (CO) or CO<sub>2</sub> (from industrial sources like steel mills and processing plants) or syngas generated from any biomass resource (e.g. municipal solid waste, organic industrial waste, or agricultural waste) into a range of fuels and chemicals. Such feedstock flexibility and product diversification are important parts of ensuring favorable production economics for this breakthrough technology.

**Bruce Dannenberg, Phytonix**

***Phytonix's Utilization of Synthetic Biology to Create Photosynthetic Chemical Factories***

Phytonix and its organism development partners are using a synthetic biology approach to develop efficient photosynthetic microbial cell factories for the direct and sustainable production of n-butanol – a valuable industrial chemical intermediate and potential “drop-in” gasoline replacement fuel – from solar energy, utilizing carbon dioxide as the sole, direct feedstock. In our minds, the production of biofuels (e.g. ethanol/butanol) via fermentation has fundamental environmental and sustainability flaws, as over one third of the biomass feedstock processed – feedstocks that in some cases are, or may be, in competition with food crops – converts into waste carbon dioxide rather than into the desired biofuel. Moreover, sourcing and processing the biomass also adds significant cost and economic viability challenges to the fermentation production process and the resulting products. In fact, the provision of an affordable, available and sustainable carbon source has been one of the greatest barriers to the production of economically viable, affordable biofuels and renewable chemicals. Phytonix’s photobiological process uses carbon dioxide as the sole, non-biomass feedstock and along with solar energy and water produces the desired biofuel/chemical with only oxygen and residual biomass as by-products. This is a significantly carbon-negative and sustainable process. The Phytonix technology/IP synthetic biology approach essentially allows for the streamlining of the key genetic code (genes) for butanol synthesis pathways, creating new and effective DNA constructs, based on natural, non-photosynthetic organism pathways, and engineers them into the genome of a photosynthetic cyanobacteria. The competing starch hydrolysis and glycolysis pathway is disabled. This enables butanol to be efficiently generated via a photosynthetic/photobiological “engine”, using carbon dioxide as the sole feedstock/carbon source. Phytonix has implemented strategic alliances with academic institutions and companies. By working with its partners through its capital-light, distributed business model Phytonix can build on the strengths of each when it comes to biofuel and renewable chemicals development and commercialization. This distributed and collaborative business model enables the firm to achieve breakthrough development and realistic commercialization results and improved time-to-market with limited capital, a clear necessity in the currently capital-constrained environment for earlier stage, environmentally focused industrial biotechnology companies. This 2015 BIO presentation will review Phytonix’s breakthrough technology, business model, commercialization milestones and timeline, and the economic and environmental opportunities that new advances in industrial biotechnology, enabled by synthetic biology, provide in terms of a rapid transition to a new bio-economy and ultimately to a CO<sub>2</sub>-based economy for the production of consumer products, chemicals and fuels.

**Joshua Silverman, Calysta, Inc.**

***Using Synthetic Biology to Develop a Novel Platform for the Production of High Value Feed and Chemical Products from Methane***

The recent rise in domestic production of methane has driven the cost of natural gas to record lows. This relatively inexpensive source of carbon is an attractive feedstock alternative to sugars and petroleum. Calysta has developed a genetic engineering platform for host organisms (methanotrophs) capable of metabolizing methane to protein (for animal feed) and biochemicals. The genetic tools, together with innovative fermentation and bioprocess approaches, enable the rapid implementation of well-characterized pathways to utilize both natural gas and biogas as feedstock. Methane’s 34x higher greenhouse gas contribution relative to CO<sub>2</sub> implies that capturing these sources will have a significant environmental benefit. This presentation will showcase Calysta's latest results in developing this novel platform for robust commercial biochemical production.

**Session 3: The Promise of Synbio from Enabling Tools**

**Monday, Jul 20 2:30 pm - 4:00 pm Room: 522 ABC**

**Moderator: Martha Marrapese, Keller and Heckman LLP**  
***The Promise of Synbio from Enabling Tools***

**Zach Serber, Zymergen**

***Turning Strain Optimization into a Search Function***

Optimizing microbes to consistently and efficiently generate useful chemicals necessitates a search for non-obvious solutions. Historically, those working in the field have come upon these solutions through a process of mechanistic dissection. That is, they've sought to understand the underlying cellular processes through a series of hypotheses and testing. Given how incredibly complex cellular metabolism is, this is an immensely time-consuming and difficult task, and one that isn't a foundation for a successful or cost-efficient business. Zymergen co-founder Zach Serber and his team are pioneering an entirely new approach – one that eschews understanding how cells work in favor of identifying how to consistently get them to produce a product through thousands of simultaneous trials. By relying on vast amounts of data and analysis rather than on human intuition, and through a process of constant testing and elimination, Zymergen turns strain optimization into a search function. In this presentation, he'll discuss Zymergen's approach.

**Ian Fotheringham, Ingenza**

***Development of SynBio Tools to More Predictably Clone, Express and Select Biocatalytic Activities for Metabolic Pathway Optimization***

Replacement of petroleum-based products and manufacturing processes with competitive bio-based alternatives is attracting increased attention due to environmental concerns surrounding petroleum's sustainability. Replacement of conventional processes to manufacture valuable industrial products and the selection of optimal biosynthetic routes requires the construction, and in most cases subsequent context-dependent evaluation, and optimization of multicomponent biosynthetic pathways, to generate intermediates and commercial end products. However, unlike the situation for physical/computer engineering, the rules for predictive bioengineering are not well understood. Synthetic biology offers the prospect of making bioengineering more predictable, shortening today's lengthy design/build/test/reiterate cycle and enabling the rapid construction of functional metabolic pathways to enable the realization of the biobased economy. In this talk I will describe the application of Ingenza's proprietary synthetic biology tools to enable more predictably engineered biological production systems with reference to commercially relevant examples. These tools include protein engineering to address poor response controls during the control of gene expression, the development of synthetic "landing pads" to optimize the genomic operating environment around delivered genes, the use of genome editing and RNA trafficking systems to control gene expression, the application of transcriptomics and metabolomics to enhance cell system performance, the development of synthetic gene expression regulatory elements to better control gene expression and the deployment of our proprietary inABLE® combinatorial genetics platform for large scale gene/pathway assembly and optimization. Together these tools have been used to rapidly clone, express, select and optimize target activities for many separate enzymatic reactions, from thousands of independent genes derived from metagenomic and phylogenetic discovery approaches. Obvious synergy exists between this approach and versatile, solid phase screening and selection methods using growth-based, crossfeeding or colorimetric methods to identify engineered cells of interest. This synergy is illustrated through the rapid identification of critical pathway enzymes, optimal gene coding sequences and enzyme variants from inABLE®-derived variant libraries for industrial applications in bio-based polymers, chemicals and personal care products with our commercial customers. We will also describe the success of modeling approaches to gene design that enhance the predictability of heterologous gene expression in diverse hosts. In developing this suite of technologies we aim to bring increasing predictability and overcome persistent limitations associated with today's iterative and empirical processes for microbial strain improvement.

**Claes Gustafsson, DNA2.0**

***Leveraging Synthetic Biology and Machine Learning to Build Better Biomolecules***

Biological engineering is a multidimensional optimization problem. The same protein can be encoded by a googol different DNA sequences, initiation of transcription and translation can be controlled over three orders of magnitude, thousands of host genome genes can be edited - all with dramatic effects on protein expression yield. We here will illustrate how gene synthesis, Design of Experiment (DoE), cloud computing and big data analysis software can be used to assess, model, predict, and experimentally validate the

sequence-function correlation between primary nucleotide sequence and key quality attributes (e.g. desired function, expressibility, solubility) thereby enabling Quality by Design (QbD) very far upstream of the manufacturing process.

**Alexander Beliaev, Pacific Northwest National Laboratory**  
***Multi-Modular Platform for Engineering Self-Sustained Scalable Microbial Consortia with Programmable Output***

As design principles are implemented to improve resilience and stability of engineered microbial systems, the behavior, scalability, and performance of such systems becomes the critical limiting factor for their deployment in non-controlled environmental settings. The current state of synthetic biology relies heavily upon cultivation of single species of model microorganisms in tightly controlled laboratory environments. Such, often highly engineered, domesticated strains suffer from poor stability and resilience in natural settings due to fluctuating environmental conditions and competition from communities of indigenous microbes. To address these challenges, we have developed a generalizable framework for design and engineering of autonomous synthetic microbial consortia. The proposed S3MicroCon (Self-Sustained Scalable Microbial Consortia) platform acts as a stand-alone unit capable of operating safely within unpredictable and dynamic natural environments. The functional outputs and interaction network between modules (species and consortial units), and subsequent emergent properties (i.e., robustness, resilience, and functional stability) are programmed via synthetic regulatory circuitry. At the center of the S3MicroCon platform lies photoautotroph-heterotroph interactive partnership. Such associations, which naturally assemble to take advantage of services carried out by individual members, are ubiquitous in nature and mediate key ecological processes such as energy capture, carbon fixation, and nutrient cycling. Genetically tractable photoautotrophic organisms, such as cyanobacteria, can sustain and drive an engineered consortium through production of O<sub>2</sub>, organic C, and, in some cases, fixed inorganic or organic N. This presentation discusses opportunities for metabolic engineering using robust, multi-cellular modules that can be stabilized by metabolic coupling and obligate interdependency.

**Session 4: Genomics Offer Unique Opportunities**  
**Tuesday, Jul 21 2:30 pm - 4:00 pm Room: 522 ABC**

**Moderator: Shulin Chen, Washington State University**

*Re-configuring Yarrowia lipolytica lipogenesis platform towards free fatty acid and biofuel production*  
Converting lignocellulosic biomass to microbial lipids provides a unique route for sustainable production of important oleo-chemicals and biofuels. Many efforts devoted to develop related platforms involve optimization of cultivation conditions and engineering of the lipogenesis pathways in the microorganisms. Our laboratory has developed a series of molecular tools for genetic modification of *Y. lipolytica* with enhanced frequency of homologous recombination. The availability of these tools and protocols makes it possible for us to reprogram the metabolic pathways to produce a variety of bio-products such as long-chain dicarboxylic acids, fatty alcohols, and free fatty acid (FFA). As an example, we accomplished enhancing FFA production from glucose by re-configuring *Y. lipolytica* lipogenesis pathway through disruption of intracellular FA activation, elimination of non-essential FA usage pathway and tailored hydrolysis of accumulated triglycerides (TAG). We have implemented a strategy to maximize FA productivity while minimizing adverse effect on growth. The de novo synthesized FAs were detected mainly in cell biomass and also in supernatant. Eventually, FFA yield of more than 0.5 g/l was obtained in production medium with shaking flask culture that is comparable to engineered *Saccharomyces cerevisiae*. This result shows the potential of engineered *Y. lipolytica* platform for production of FA that can be further processed by the cell for the production of other FA-based bioproducts.

**Bogumil Karas, J. Craig Venter Institute**

***Novel synthetic biology tools for eukaryotic algae: efficient assembly method to clone entire diatom chromosomes in yeast and development of diatom designer plasmids.***

Synthetic genomic approaches offer unique opportunities to use powerful yeast and *Escherichia coli* genetic systems to assemble and modify chromosome-sized molecules before returning the modified DNA to the target host. The model diatom *Phaeodactylum tricornutum* has an average G+C content of 48% and a 27.4 Mb genome sequence that has been assembled into chromosome-sized scaffolds making it an ideal test case for assembly and maintenance of eukaryotic chromosomes in yeast. We present a modified chromosome assembly technique in which eukaryotic chromosomes as large as ~500 kb can be assembled from cloned ~100 kb fragments. We used this technique to clone fragments spanning *P. tricornutum* chromosomes 25 and 26 and to assemble these fragments into single, chromosome-sized molecules. We

found that addition of yeast replication origins improved the cloning, assembly, and maintenance of the large chromosomes with moderately high G+C content in yeast. We also present a novel, episomal vector for diatoms and a high efficiency delivery method by conjugation from *Escherichia coli* to the diatoms *Phaeodactylum tricornutum* and *Thalassiosira pseudonana*. We identified a yeast-derived sequence that facilitates stable replication of the episomes even in the absence of antibiotic selection and determined that episomes were maintained as closed circles at copy number equivalent to native chromosomes. This system removes significant barriers to large scale genetic manipulation of diatoms, and will accelerate both basic and applied biomass-related research.

**Helge Zieler, Primordial Genetics Inc.**

***Creation of yield and tolerance traits in yeast and bacteria with Function Generator™ combinatorial genetic technology***

Primordial Genetics Inc. is a synthetic biology startup biotechnology company focused on developing and commercializing Function Generator™, a novel, combinatorial genetic, gain-of-function platform technology designed to improve product titers & yields and enhance stress & product tolerances in microbes employed for production of a variety of chemical and biological compounds. Function Generator™ facilitates strain improvement and development of complex traits by increasing the phenotypic diversity of an organism from which desirable variants can be selected. This is achieved through large combinatorial libraries of novel genes that are assembled in-frame from precisely amplified or synthesized starting sequences covering an entire genome's worth of protein coding genes. Each of the newly created compound genes present in the library represents a novel, transferable and patentable sequence combination with the potential to modify the native genetic program of an organism and dramatically alter its phenotypes. This transformative empirical approach enables the production of complex traits that are otherwise difficult to engineer, such as those related to cell growth, stress & product tolerance and product titers & yield. Function Generator™ has been applied successfully in both baker's yeast (*Saccharomyces cerevisiae*) and *Escherichia coli* to develop a broad array of useful traits. A yeast Function Generator™ library consisting of approximately 20 million sequence combinations was created, from which 63 compound genes were isolated that confer alcohol and stress tolerance. Several of these genes boosted butanol tolerance from 3.5% butanol. Comparison between the Function Generator™ library and a single-gene overexpression library showed that the Function Generator™ approach on average results in >200x higher levels of cell survival, demonstrating the superiority of this technology for generating transferable traits. In addition, 'deconstruction' of 6 active genes showed that their phenotypic effects surpass the additive activities of the individual sequence components. An *E. coli* Function Generator™ library with approximately 17 million sequence combinations was also created and used to select transformants capable of expression of refractory proteins as well as soluble expression of proteins that are ordinarily 100% insoluble. In a single, rapid selection step with Function Generator™ we were able to surpass the phenotypes achieved in multiple rounds of mutagenesis performed over several months. In summary, our data indicates that Function Generator™ is a superior method for creating enhanced traits in microbes, and is able to produce larger phenotypic gains than are possible with current methods. The technology is highly suited for genetic refinement of industrial microbes to enable economical production systems. It is equally applicable to organisms producing chemicals & fuels as well as those producing more complex biomolecules such as enzymes and therapeutic proteins. Function Generator™ has the potential to broadly enable microbial improvement and to accelerate productivity gains of microbial production systems in multiple industries.

**Andrew Diamond, University of Quebec at Trois-Rivières**

***Metabolic engineering of microalgae for the production of valuable plant phenylpropanoid compounds.***

For centuries, natural products from plants have been used as dyes, aromas, cosmetics, functional foods, medications or drugs and several of these natural bioactive compounds have powerful pharmacological activities. The commercial exploitation of these natural and valuable products is frequently limited by the availability of the producing plants, the low accumulation of the compound in planta and the laborious and expensive extraction of these molecules. To overcome these limitations, cosmetics and pharmaceuticals industries have produced some synthetic plant molecules by organic chemistry. Although faster and cheaper, synthetic chemistry cannot always reproduce the structural complexity of the molecules found in nature. Moreover, these methods do not always respond to the environment-friendly standards sought by consumers. For several years, there is an increasing demand for non-synthetic bio-based products made by non-polluting method. Therefore the synthesis of valuable plant product by engineered microorganism represents an alternative solution to the aforementioned challenges delivering a green production

platform. Plant phenylpropanoids (PPs) are beneficial molecules for human health and are used in pharmaceutical, cosmetic and food preparation. PPs are widely distributed in plants, but in low quantities and their extraction yield rarely exceeds 1% of the dry weight. Most of genes involved in the PP biosynthetic pathway have been isolated and characterized. Some of these biosynthetic plant genes have been functionally expressed in recombinant microorganisms such as bacteria or yeast with different successes and PP yield. In order to produce higher amount of valuable PPs, the microalgae *Chlamydomonas reinhardtii* was genetically engineered with genes of plant-producing PPs. Specifically, diverse combinations of genes encoding biosynthetic enzymes involved in the early steps of PP production were used for functional expression and production studies. Results indicate that *C. reinhardtii* is a promising candidate in biotechnology processes for the production of PPs.

### **John Wilson, TERAGANIX**

#### ***Use of Effective Micro-organisms in treatment of organic waste material***

Biological microbial treatment of the waste and the establishment of healthy bacterial colonies has proven to be very successful at solving a wide variety of problems, and has many financial and health benefits. wt1000 is the waste treatment product derived from the EM bacterial combination of microbes.

1/ Description of the components of the EM-1 microbial consortium and why it is effective because of the combination of bacterial and microbial ingredients

2/ History of the development of EM-1 and wt1000 and its uses around the world . Examples to include: tsunami in Japan and the 2002 floods in Germany ;use in Lithuania to remedy serious odor problems in beet waste;clean-up and remediation of the Seto Sea in Japan;increase in oxygen levels and reduction of B.O.D. in Lake Titicaca in Peru.

3/ Examples of application in U.S. recently.

A/ODOR CONTROL at MILLER/COORS Brewery, Eden, NC for spent grain

B/ WATER TREATMENT AND REDUCTION OF B.O.D AND SLUDGE;Gonzales , LA Municipal Facility Moorefield, West Virginia mixed municipal and agricultural water treatment facility

C/REDUCTION OF CORROSION ;Lubbock, TX; Meridian concreteTX

There are many other uses of EM microbes , but for the purposes of this presentation I would like to concentrate on the advantages in waste treatment. The 3 areas outlined above are relevant to most water and organic waste facilities and are inter-related in that once the bacterial colony is established in a system all of the benefits listed will accrue.

### **Session 5: Risks and Benefits from Synbio Processes**

**Wednesday, Jul 22 8:30 am - 10:00 am Room: 522 ABC**

#### **Moderator: Thomas Ishoey, Synthetic Genomics, Inc.**

#### ***Advanced synthetic biology engineering applied to evolutionarily advantaged microbes accelerates development of industrial processes.***

Achieving commercially necessary metrics for industrial processes has proven challenging in many traditional microbial host systems. Interacting metabolic networks and competing physiological demands during production are complex, poorly understood and challenging to resolve. SGI has developed a flexible, integrated synthetic biology toolbox composed of NGS and metabolic analytical pipelines, bioinformatics and biodesign software, automated scaled DNA construction and advanced cell engineering technologies. This robust toolbox is broadly applicable to resolve complex metabolism in both traditional hosts and novel microbes, which may naturally possess more desired metabolic attributes. SGI develops new hosts for specific programs through intelligent bioprospecting and rapid laboratory domestication. This combined approach of applying advanced synthetic biology engineering tools to selected, evolutionarily advantaged microbes enables accelerated development of known and novel products. Applied examples for this integrated approach to microbial engineering to quickly obtain key product and process objectives impacting several market opportunities will be discussed.

#### **Nigel Mouncey, Dow AgroSciences LLC**

#### ***Advancing Natural Product Development Using Engineering Biology***

The advent of Engineering Biology has revolutionized the bio-engineering of organisms that span all Kingdoms. However, the development of full Engineering Biology platforms for non-typical organisms still lags behind that of the prototype organisms such as e.g. *E. coli* and yeasts for microbial chassis. In this talk, I will provide an overview of the Engineering Biology capability that Dow AgroSciences has built out and is applying to Natural Products development. I'll highlight specific challenges and our progress in solving these. Furthermore, I will discuss how the interplay between Systems and Engineering Biology

informs on the Design and Learn stages and how we are using both platforms leading to advances in our strain improvement programs for Natural Products.

**Arlene Fosmer, Cargill**

***Integrated BioRefining - Feedstock through Product - Perspectives on Bring Products to Reality***

Delivering a new biotechnology product through from concept to a sustainable business is not an easy path. To be successful, deep expertise in a broad set of skills must be brought to the table not just in chemistry, metabolic engineering and fermentation but process engineering, risk management, as well as sales and marketing. Furthermore, the job isn't done once start-up is complete. Being able to drive operational excellence including organism improvements is key to long-term profitability. As a global leader in food, feed and industrial chemicals produced via fermentation, Cargill is committed to helping our customers thrive. We live the concept of delivering value from biotechnology through new product development and process optimization on a day to day basis and have for over 30 years. Examples will be given of leveraging biotechnology to bring new products from concept to reality and to deliver profitability of existing bioprocesses.

**Rishi Jain, Praj Matrix- R&D Center**

***Challenges with synthetic biology***

Synthetic biology based processes are appearing on the commercial horizon. Fermentation based processes are being developed for fuels and chemicals. Synthetic biology is being used to develop the biocatalyst for these processes - microbial platforms that convert sugar or gases to the molecule of interest. This talk will focus on some of the challenges that lay ahead with synthetic biology based processes. Technical challenges vary from basic understanding of biological processes that affect microbial development programs to fermentation processes that affect the techno-economics of the process. A second set of challenges are the ones related to regulatory affairs. Regulatory challenges vary from environmental clearances to product approval with a new set of impurity profiles. Finally, societal acceptance is also a challenge.

**David Glass, D. Glass Associates, Inc.**

***Government Regulation of Synthetic Biology: Is the existing regulatory framework sufficient to address the uses of synthetic biology technologies in industrial biotechnology?***

Biotechnology regulatory frameworks in the U.S. and in most other industrialized nations were created in the 1980s and 1990s, and have generally not been substantially revised since that time. With few exceptions, these regulations have been effective in ensuring that appropriate risk assessments are carried out for proposed biotechnology activities, particularly including applications that involve agricultural or other environmental use or large-scale industrial uses, even as the range and power of biotechnologies have increased over the years. The emergence in recent years of the technologies categorized together as "synthetic biology" has caused some observers, particularly in environmental groups, NGOs or academia, to question whether additional regulations are needed to address the potential risks that the new technologies may involve. Others, particularly within industry, maintain that synthetic biology, in spite of its power, can be viewed as an extension of traditional genetic engineering technologies, and that organisms created using the newer techniques fall within the scope of existing regulations, and that the potential risks posed by such organisms can be adequately assessed under the current regulatory framework. This presentation will address this controversy, and will analyze whether existing regulations and their associated risk assessment provisions are adequate to assess the potential risks of synthetic biology and other newer techniques used in modern biotechnology. This will be done largely in the context of U.S. regulations administered by the Environmental Protection Agency and the Department of Agriculture, but select international regulations will be considered as well. David J. Glass, Ph.D. is an independent consultant specializing in renewable fuels and industrial biotechnology regulatory affairs, with over 25 years of experience with U.S. biotechnology regulations, and extensive familiarity with international biotechnology and renewable fuel regulations.

**Session 6: Bioconversion, Separation, Recovery & Techno-Economic Analysis**

**Wednesday, Jul 22 10:30 am - 12:00 pm Room: 522 ABC**

**Moderator: Norman Marsolan, Georgia Tech**

**Idan Chiyanzu, North-West University**

### ***Bioconversion of crude glycerol to hydrogen and light olefins by two recombinant microorganisms***

Crude glycerol is the major by-product from the transesterification of triacylglycerol with alcohol (methanol or ethanol) that also generates fatty acid alkyl esters (biodiesel). For every fatty acid alkyl ester produced, about 10 wt. % dry weight of crude glycerol is formed. Since biodiesel production is projected to increase to 240 million litres by 2016 in South Africa alone, approximately 24 million litres of crude glycerol will be expected annually. Although glycerol may be used as raw agent for food, cosmetics and pharmaceuticals industries it contains impurities and the current technologies for glycerol purification are complex and expensive methods. This study investigated the production of light olefins (C<sub>2</sub> - C<sub>4</sub>) from crude glycerol using two recombinant microorganisms. Light olefins such as ethylene, propylene and butylene are widely applied in the petrochemical industry as precursors for variety of industrial chemicals. Bio-based olefins would represent a secure, renewable and environmentally safe alternative to those obtained from crude oil and natural gas. The biological conversion of crude glycerol to olefins is an interesting process, since it produces high added-value compounds from waste products. *Escherichia coli* K12 was successfully used to produce ethanol at higher yields and conversions from crude glycerol and the production of olefins from ethanol was done by another *E. coli* that had dehydratase enzyme genes was cloned and expressed into it. The fermentation process was conducted at 37 °C, agitation of 150 rpm, for 96 hours at pH 7.0. Particular attention was given to co-culture fermentation that was advantageous for production of olefins compared to the two-step route. In batch fermentation under co-cultures gave high molar yield of 80 % for the total gases (hydrogen, ethylene and propylene). These results demonstrate that the use of the two recombinant *E. coli* systems harnesses the metabolic process to convert abundant and low-priced crude glycerol into advanced value products, thus creating a route economically viable for application in the biodiesel industry.

**Niloofer Abdehagh, University of Ottawa**

### ***Bio-butanol separation and recovery using adsorption***

Bio-butanol is considered as one of the potential biofuels attracting attention of scientists and industrialists in recent decades. Bio-butanol has several advantages over other biofuels such as ethanol. These advantages include lower volatility and higher net heat of combustion, closer to gasoline. However, there are some challenges to be addressed in acetone-butanol-ethanol (ABE) fermentation process to make it an efficient and commercially-viable process. One of the most important challenges is the toxicity of the product to microorganism, resulting in very low butanol concentration in the product. It is therefore essential to develop an integrated separation technique to recover butanol from the dilute fermentation broth as the final product. Adsorption, as an energy efficient process, was selected in this study to achieve this objective. In the present study, activated carbon (AC) F-400 was selected as the butanol adsorbent amongst different activated carbons and zeolites since it showed the fastest adsorption rate and the highest adsorption capacity amongst different adsorbents tested in adsorbent screening experiments. The selected adsorbent was then used to perform the adsorptive recovery of butanol from butanol-water, ABE model solutions and real fermentation broths produced in ABE fermentation using *Clostridium acetobutylicum* (ATCC 824). It was observed that AC (F-400) has the highest selectivity to butanol amongst all the components present in the fermentation broths such as ethanol, acetone, acetic acid and butyric acid. In addition, the butanol adsorption capacity was not affected by the presence of ethanol, glucose and xylose while the presence of acetone led to a slight decrease in adsorption capacity at low butanol concentrations. On the other hand, the presence of acids (acetic acid and butyric acid) showed a significant effect on the butanol adsorption capacity over a wide range of butanol concentration and this effect was more significant for butyric acid. Although a wide range of materials has already been tested as butanol adsorbent, less effort has been devoted to desorption of adsorbed butanol as the final product. In this study, thermal desorption with a purge of carbon dioxide was performed and the operational conditions were optimized to reach the best results in butanol recovery. It was also observed that after six cycles of adsorption-desorption the adsorption capacity and butanol recovery remained unchanged which leads to the conclusion that this method could be considered as an efficient butanol desorption method. As the next step, the adsorption method was combined with gas stripping which is one of the separation techniques used for bio-butanol. In this method, CO<sub>2</sub> was sparged in the ABE solution (both model solutions and fermentation broths) to strip the solvents and then the vapour stream was passed through an adsorption column. This process is a combination of two separation methods to benefit from advantages of both.

**Kelly Zering, North Carolina State University**

### ***Integrating Biology and Techno-Economic Analysis to Create BTEA***

Decision-makers considering new feedstock to bio-product supply chains need to understand the potential cost, revenue, profit, and risk associated with various deployments of the system. This paper describes an integrated modeling approach that spans the supply chain from genetic characteristics of the seed to the shipment of wholesale products from processing facilities. The model internalizes critical supply chain features including production parameters (inputs per output), stochastic factors (probability distributions of weather and prices), site specific crop productivity factors, transport and storage logistics, processing plant design and scale, product/co-product characteristics and market prices (stochastic), and effects of contracts, insurance, financing, and short-term management strategies to control risk. Output from the model states the investment required and critical values describing the specific scenario being modeled with probability distributions (predicted frequency) of profit over the life of the investment. Comparison of various scenarios illustrates effects of changes in critical values; identifies near optimal deployment, scale and risk control strategies; and informs researchers and developers of the value of marginal improvements in limiting parameters (such as yield levels and variability). Data and Methods Multiple data sources are combined in the integrated model. The integrated model is expressed in an Excel workbook. Engineered systems are modeled in Aspen and Icarus to produce process models, mass and energy flows, and estimates of investment, annual costs, revenues, and profits for specific arrays of facilities. Icarus and Aspen output passes to the Excel workbook as input data. Historical market prices from various published sources are used to develop probability distributions around current prices. Site specific weather, land use and soil data characterize growing conditions at specific locations across the USA and across growing seasons. In the case of *Camelina sativa*, published data for field trials and commercial production were used to statistically estimate crop yield prediction functions dependent on weather, soils, variety, nitrogen fertilization, and other factors. Camelina input data from published enterprise budgets are modified to reflect current, site specific conditions. Results Sample output from the integrated model to be presented includes: cost of feedstock may be more than half of total costs; higher crop yields reduce feedstock cost by 50%; co-product revenue is important (camelina meal may be at least 50% of revenue); co-location of oilseed crushing and oil to fuel processing reduces investment substantially; capital cost of storage is relatively large; dedicated crops with substantial yield variability impose real costs; contracts, insurance, and loan guarantees can offset the magnitude and frequency of losses over plant lifetime. Conclusions Bio-techno-economic analysis (BTEA): the integration of biological models with techno-economic analysis, is needed to properly characterize and analyze the design and economics of crop based biochemical supply chains. Crop production introduces important variability to quantities and costs that drive supply chain economics. Integrated supply chain modeling techniques demonstrated in this study enable more realistic system design and project financing.

#### **Track 4: Research Presentations**

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#### **Session 1: New Approaches for Lignin Processing and Use Monday, Jul 20 8:30 am - 10:00 am Room: 519 A**

**Moderator: Sagadevan Mundree, Queensland University of Technology**  
**Tom Browne, FPInnovations**  
**Arvind Lali, Institute for Chemical Technology**  
**Eddie Peace, West Fraser**  
**Robert Speight, Queensland University of Technology**

#### ***New Approaches for Lignin Processing and Use***

Lignin is a major component of plant biomass and one of the most abundant polymers on earth. Despite many challenges, lignin has tremendous potential to generate valuable and useful products such as resins and adhesives. Lignin offers the agriculture, forest and wood product industries with an opportunity to generate new revenue from existing waste streams and diversify their product range. This panel session will bring together experts from Australia, India and Canada to discuss various approaches to process biomass and generate value from lignin. Queensland University of Technology has a strong track record in biomass generation and processing as well as plant biotechnology, enzyme development and production with pilot scale facilities for biomass processing and fermentation up to 10,000 litres. QUT has developed lignin separation and thermochemical treatment technologies based on a proprietary catalytic hydrothermal liquefaction process to generate bio-oils. QUT is also developing a range of enzymatic

approaches towards the selective modification of lignin. New developments in these areas will be presented by Associate Professor Robert Speight and the panel session will be chaired by Professor Sagadevan Mundree. The DBT-ICT Centre for Energy Biosciences was established by the Department of Biotechnology of Ministry of Science & Technology, at Institute of Chemical Technology (formerly UDCT) Matunga, Mumbai. Dr. Lali and his team have been engaged in translational research in frontier areas in Separations Technologies, Bioprocess Technology and Biofuel Technologies and Dr. Lali works with a range of biotech and chemical companies in India and abroad. Dr. Lali will discuss novel concepts in bio-separations, enzyme catalysis and biotransformations developed at the centre. FPIInnovations is a not-for-profit world-leading R&D institute that specializes in the creation of scientific solutions to support Canadian forest sector. It is ideally positioned to perform research, innovate and deliver solutions for every area of the sector's value chain, from forest operations to consumer and industrial products. Its R&D laboratories are located in Québec City, Montréal and Vancouver, and it has technology transfer offices across Canada. West Fraser is an integrated North American wood products company, operating 40 mills across Western Canada and the southern United States. In light of the recent announcement regarding new lignin production facilities in Canada and elsewhere, Dr. Tom Browne, Research Manager at FP Innovations will describe the LignoForce™ process for extracting lignin from pulp and paper processes as well as the role of the Centre for Research and Innovation in the Bio-Economy in the development of the process. Dr. Eddie Peace, Bioproducts Coordinator at West Fraser, will describe the construction and start-up of a new lignin plant at West Fraser's pulp mill in Hinton, Alberta, and will cover some of the anticipated end-uses and market applications.

**Session 2: Frontiers in Bioaromatics: Characterization, Refining, and Applications**  
**Monday, Jul 20 10:30 am - 12:00 pm Room: 519 A**

**Moderator: Alex Berlin, Novozymes**  
**Guy Barker, The University of Warwick**  
**Lindsay Eltis, University of British Columbia**  
**John Kadla, University of British Columbia**

***Frontiers in Bioaromatics: Characterization, Refining, and Applications***

Bioaromatics are aromatic chemicals and materials derived from natural sources. Among all industrially available bioaromatics, the most abundant ones are technical lignins. Technical lignins are produced in vast quantities at pulp mills, primarily, by the kraft pulping process. In addition, new types of technical lignins, characterized by very low sulfur content, are becoming available as the plant biomass biorefinery industry emerges. It is generally accepted that valorization of bioaromatics streams will boost the economy of the existing pulp mills and of the future plant biomass biorefineries. Refined bioaromatics from these plants have the potential of replacing a significant share of the industrial aromatic petrochemicals. However, wide commercialization of bioaromatics in traditional chemical and material markets remains challenging. The main reasons for the slow market penetration of bioaromatics include: poor compatibility with existing supply chains, limited supply and understanding of their physicochemical properties, and the need for expanding their applicability in traditional and novel market segments. These shortcomings can be addressed by intensifying activities in dedicated bioaromatics R&D programs, such as, those focused on advancing analytical methods, novel valorization chemistries, development of novel and adaptation of traditional applications in the chemical and material industries. This international expert panel will cover cutting edge topics concerning the use of bioaromatics in today's and future industrial applications, novel methods for characterization of bioaromatics, and advanced technologies for bioaromatics valorization. The panel will host presentations by international leading experts in this field: Presentation #1: Functionalized lignin nanofibres: An alternative platform to value-added lignin-based materials; Authors: John Kadla, Frank Ko, George Gao (Canada). Presentation #2: Enzymatic modification of technical lignins; Authors: Alex Berlin, Feng Xu (USA). Presentation #3: Novel lignin degradation biocatalysts; Authors: Guy Barker (UK). Presentation #4: A bacterial platform for developing biocatalysts to transform lignin; Authors: Lindsay Eltis (Canada).

**Frank Liotta, Virent**

***Advances in Renewable Aromatic Chemical Production from Virent's Novel Catalytic BioForming Process***

Virent is pioneering the BioForming® process that uses propriety catalysis to convert biomass-derived feedstocks to commercially viable, drop-in bio-based chemicals and biofuels. We are leveraging our existing strategic relationships with Cargill, Royal Dutch Shell, The Coca Cola Company, and others

throughout the global supply chain to bring bioproducts and fuel co-products to the market. The hydrocarbon chemicals produced by the BioForming process are recognizable platform chemicals and match petroleum derived organic chemicals in composition and offer superior environmental performance, including a reduction in overall greenhouse gas when compared to petrochemical sourced materials. Demonstration-scale production of the key platform chemicals, including paraxylene, toluene and benzene, has been shown to produce products meeting the commercial specifications for their petrochemical analogs. These bio-aromatic chemicals have successfully undergone and continue to undergo rigorous customer qualification processes. Virent also continues to make good progress on developing renewable hydrocarbons for specialty applications. This presentation provides an introduction to Virent's BioForming process and provides an update on Virent's progress for the deployment of fully renewable bioproducts using aromatic chemicals and other hydrocarbons.

**Session 3: Advances in Oil Producing Crops and Algae Based Feedstocks**  
**Monday, Jul 20 2:30 pm - 4:00 pm Room: 519 A**

**Marilyn Bruno, Aequor, Inc.**

***Industrial biofilm, contamination, and fouling, their impacts on industrial surfaces and operations, and technologies to control them.***

Aequor's presentation will be supported by a slide deck reviewing the following: I - New research on bacterial biofilm that shows the critical it plays in causing industrial microfouling (corrosion, contamination, fungi, slime), and macrofouling (the attachment of barnacles, mussels, and algae to surfaces in contact with fresh and salt water). Biofilm is the root cause of the resulting operational inefficiencies that cost time, manpower and money to remedy. Examples reviewed include the following: - biofilm on the surface of water itself in cooling towers for all power plants (traditional and renewable), captures heat and increases concentrations of total dissolvable solids (TDS) and corrodors, necessitates constant change-over of tower waters; --microfouling on all surfaces in contact with water, such as inside closed circuit water loops in heat exchangers, inside plumbing, and on membranes of reverse osmosis filters used in desalination and water treatment processes, necessitates increased energy to maintain flow velocities and treatments to disinfect surfaces; --micro-and macrofouling contaminate open pond algae production, reducing yields and necessitating manual cleaning (because current biocides on the market kill the algae under production); --macrofouling on surfaces in contact with water, such as inside water intake pipes for all power plants (renewable and traditional) and on ship hulls, require up to 50% more fuel to maintain forward propulsion, resulting also in 50% additional noxious emissions. II - Various methods for testing the level of biofilm, including those required by the EPA for products making antibiofilm claims, and flag the point at which treatment is required before major operational inefficiencies result. III - Current options for biofilm removal and mitigation, and their efficacy. For example, biocides (antimicrobials, disinfectants, antifouling agents) can kill free-floating bacteria, but require certain concentrations to penetrate biofilms and inhibit the formation of new biofilms. Several tests can be used to assess the efficacy of biocides at different concentrations against biofilms and foulers without triggering bacterial resistance. The pros and cons of each test will be described, along with step-by-step guidelines for doing these tests in a lab.

**Simon Barnab, University of Quebec at Trois-Rivières**

***Two-phase microalgae growth using various alternative carbon sources for enhancement of lipid production in an open system***

Microalgal biomass represents a sustainable alternative to fossil consumption. Value may be retrieved from microalgae in the form of neutral lipids (triacylglycerides) that can be used for biofuel (biodiesel), bioenergy and high-value co-products. To maximize biomass productivity, cultivation of microalgae in mixotrophic and heterotrophic conditions is recommended. The uses of second generation carbon sources from agriculture and industrial waste might decrease the cost of overall cultivation. Furthermore, to enhance the intracellular lipid content, altering the culture growth condition by varying mixotrophic and photoautotrophic state to attain deprivation of inorganic nitrogen might represent an interesting strategy. This study sought to determine the efficiency of two-phase growth, first a mixotrophic phase to attain high biomass concentration using various alternative organic carbon sources (residual corn crop hydrolysate, corn silage juice, alfalfa hydrolysate and pulp kraft hydrolysate). Then, once the deprivation of inorganic nitrogen is attained, a photoautotrophic state might enhanced the lipid accumulation. Growth and fatty acid composition of a *Chlorella* spp – bacteria consortium will be measured. Algal biomass, chlorophyll a, neutral lipid content, and reactive oxygen species were measured using flow cytometry. Photosynthetic activity was measured with a Plant Efficiency Analyzer (PEA). Residual corn crop hydrolysate, alfalfa

hydrolysate and pulp kraft hydrolysate were mainly composed of glucose, xylose, and arabinose, but their proportions differ. Silage juice also contained glucose and xylose but volatile organic acids such as acetic acid are also present. Our study sought to determine the impact of alternative carbon sources on the growth of our microalgae using a two-phase growth to enhance intracellular lipid production. Results will be discussed in further details.

**Jean-Claude Frigon, National Research Council Canada**

***Systematic approach for the pretreatment of algal biomass in order to maximize solubilization and methane production***

The microalgal biomass conversion into methane as a biofuel has received increased interest in the past years, as it offers the best energetic balance among the different biomass-to-biofuel scenario for microalgae containing less than 40% lipids. The methane yield from a wide variety of strains has been established with an average microalgal biomass conversion into methane of around 50%. This limitation emphasizes the need for the development of an efficient pre-treatment technique to improve the hydrolysis and solubilization of algal biomass to obtain higher methane production. *Scenedesmus* is a green microalgae that often forms small colonies of 4 individuals with spines. *Scenedesmus* has been described as having one of the most resistant cell wall amongst microalgae. This study was performed using *Scenedesmus* sp. AMDD as a model strain, because it can achieve high biomass yield within a culture, is robust and grows well in wastewater from WWTP (nitrogen and phosphorous recycling). The pretreatments were divided into three categories: enzymatic, chemical and thermal. Over 20 series of different pretreatments were evaluated, alone, or in sequence. The enzymes pretreatments were performed with pectate-lyase and cellulase at loading of 1400 – 3000 U and incubation time from 2 to 24 hours. Chemicals pretreatments were done with H<sub>2</sub>SO<sub>4</sub>, NaOH or H<sub>2</sub>O<sub>2</sub>, at 0.2N and 2N and 2 to 24 h of reaction time. Physical and thermal treatments were completed in an oven or a pressure vessel at 121 – 180°C or using a microwave (175 – 300°C). The incubation of *Scenedesmus* sp. AMDD during 24 hours with a loading of 1370 U/g total volatile solid (TVS) of pectate-lyase and 914 U/g TVS of cellulase, followed with a three hours incubation in NaOH 0.2N resulted in one of the best hydrolysis treatment with 75% solubilization on a soluble chemical O<sub>2</sub> demand (sCOD)/VS basis. Similar results were found with a sequence consisting of a three hours incubation in 0.2N NaOH followed with autoclave (121°C, 20 psi, 20 minutes) and also by using a pressure vessel operating at 2000 psi, 25°C, during 30 minutes. Series of bottles were launched to evaluate the methane potential following the most promising pretreatment, e.g. enzymatic coupled with NaOH, and NaOH coupled with thermal. NaOH and thermal pretreatments improved the methane production by around 12% compared with the digestion of untreated algal biomass, at 335 ± 28 ml CH<sub>4</sub> STP/g VS added. The results from the enzymatic pretreatment were less encouraging with improvement of 2-7% of the methane production only, at 432 ± 31 versus 404 ± 5 mL CH<sub>4</sub> STP/g VS added. In this case, it is however possible that the very high background “noise” from the methane obtained from the digestion of the enzymes themselves interfered with the final results. In effect, the methane potential of the raw controls reached 677 ± 31 ml CH<sub>4</sub> STP/g VS added. In conclusion, a combination of enzymatic or chemical treatment coupled with a thermal treatment successfully solubilized up to 75% of *Scenedesmus* sp. AMDD biomass. The resulting methane production, although up to 15% higher than for the control biomass, did not fully correlate with the increased dissolved organic matter. Continuously fed digesters experiments are now underway to evaluate long term performance using solubilized biomass.

**Allan Green, CSIRO**

***Biomass oils - game-changing new technology for biofuels and bioproducts.***

Triglyceride plant oils offer great technical potential to provide much-needed renewable replacements to petroleum-derived fuels and chemicals, due to their natural abundance, their ability to be engineered to provide specific fatty acid structures as feedstocks for industrial chemistry, and their ready processing into liquid fuels such as bio-diesel and aviation fuel. However to fully realise this potential requires two major obstacles to be overcome - they must be able to be consistently produced, firstly, at a feedstock cost that is competitive with petroleum, and secondly, on very large agricultural scale without negatively impacting the food security of our burgeoning global population. These requirements have so far seriously hindered the widespread use of seed oils and algal oils as petroleum replacements. In a potentially game-changing breakthrough that simultaneously addresses both challenges, CSIRO has recently developed technology for engineering production of high levels of triglyceride oils in leaves and other vegetative parts of crop plants, providing a scalable, low-cost, additional source of plant oils. Plant leaves do not normally accumulate triglycerides, and typically have < 1% oil content. Our metabolic engineering technology has achieved astounding levels of oil accumulation, in excess of 35% of leaf dry weight. If deployed on high

vegetative biomass crop platforms this achievement could translate to oil productivity in excess of up to 7T/ha, which is greater than that obtained from oil palm, the world's current richest source of oil. The technology could also be used to develop dual purpose food and fuel crop systems, where oil produced in the leaves is in addition to the main food grain, thus intensifying production and raising profitability. Under such systems it is feasible to produce renewable oils at a feedstock price that is highly competitive with the current crude oil (petroleum) price. This presentation will describe the latest results in our biomass oil technology development and deployment on a range of crop platforms, and the conversion of these oils to biodiesel, and will also delineate CSIRO's prime patent position.

**Pascale Champagne, Queen's University**

***The Benefits of Wastewater and Waste Co2 Use in Biodiesel Production From Microalgae: A Lca Analysis***

In last decade, the use of energy, fuel consumption and CO2 emissions have been important challenges to solve and different approaches to contrast global warming have been presented. A number of studies have analyzed different types of feedstocks used as possible alternatives to fossil fuels and non-renewable energy sources. Using Life Cycle Analysis (LCA), this study assesses the potential environmental impact and economic viability for the production of biodiesel from microalgae. The priority to move to this third generation biofuel is often related to the potential for first and second generation biofuels to cause an important increase in market food prices in the ongoing food or fuel debate. A few LCAs on biodiesel production are available in the literature, however, none have emphasized the use wastewater and CO2 from cement plant as process inputs. These two kinds of input represent real situations in Canada and could produce a significant positive impact on the final result of this analysis. In addition, each inputs can, firstly, provide a significant reduction of the nutrients required for the algae production phase and, secondly, provide a benefit to the entire process. To date, no existing LCA analysis has combined environmental benefits of microalgae production for energy, fuels and chemical co-products in the Canadian context. This study present the development of a model that reflects real situations in Canada and illustrates a series of results of relevance to this kind of technology.

**Session 4: VC's Perspective on Financing Research to Commercialization for Renewable Chemical and Biofuel Projects**

**Tuesday, Jul 21 2:30 pm - 4:00 pm Room: 519 A**

**Moderator: Thomas Huot, Vantagepoint Capital Partners**

**Michael Krel, Sofinnova Partners**

***A VC's Perspective on the Evolution, Challenges and Opportunities in the Biobased Chemical Industry***

We would like to discuss evolution, challenges and opportunities in the biobased chemical industry (and industrial biotech) through examples and lessons learnt from our portfolio companies. Some of the topics that we will touch, with a VC perspective, will include scaling up, funding, go to market strategies and exit options.

**Mark Riedy, Kilpatrick Townsend & Stockton LLP**

***The Status of Available US and International Debt and Equity Mechanisms for Advanced Biofuels, Renewable Chemicals and Bioenergy from Waste***

Mr. Riedy will discuss available debt, equity and non-dilutive funding sources and mechanisms for advanced biofuels, renewable chemicals and bioenergy technology companies and their US and international projects using waste feedstocks. These funding sources and mechanisms include the use of credit enhanced debt; protective insurance products; strategic investor equity; non-dilutive grants and tax equity; regulatory incentives; capital and institutional markets; green funds from states and banks; and new capital equity expansion mechanisms such as MLPs, REITs, High Yield Bond Funds, Yieldcos and other hybrid structures.

**Ludwig Goris, Capricorn**

***Pitfalls, Challenges and Opportunities in Growing Industrial Biotechnology***

Ludwig Goris is investment manager at the Capricorn Cleantech Fund, a dedicated fund for early stage, technology backed companies with a sustainable product, process and/or business model. Since 2006, the fund has been investing in various sectors of the broad cleantech theme with a heavy exposure towards novel and bio-chemistry, solar materials, waste recycling and valorization, clean transport and

semiconductors. Ludwig is strongly involved with the novel and bio-chemistry portfolio and will talk about the pitfalls, challenges and opportunities that are particular for the sector. He will also give an outlook to the future of investing in this field and formulate some suggestions to combine technology and financial success.

**Ganesh Kishore, Malaysian Life Sciences Capital Fund Ltd.**

***White biotechnology needs Green backing!***

Regulations and necessity in the fuel sector have largely driven the industrial bioeconomy during the last decade. But bio-industry needs to compete against at \$30-45 a barrel of crude oil – not the \$85 to 105 that had been the opportunity until recently. At current prices, fuel is not competitive as a target for investments. Entrepreneurs have to repurpose their aspirations if they are to successfully attract investment from venture capitalists. Several fuel companies are now focused on higher value products, an appropriate business objective with a more viable investment thesis. Biology is uniquely geared to make highly functional and complex molecules. While this has been the focus of the application of biology in agriculture, human and animal nutrition, wellness and disease management, most of the applications in the industrial sector have been focused on chasing hydrocarbons with a low degree of functionality and toxicity to the organisms producing them. Entrepreneurs need to focus on reducing capital dependence via technology. Reducing capital needs not only adds value to the entity, but it reduces the barrier to commercial introduction and expansion of capacity. It also makes securing financing an easier proposition. There is a realization within the industry that the biocatalyst design, while an important element of the overall production cost, needs to take into account the overall process for effecting the conversion of the feedstock substrate into the end product. One of the greatest advantages of biocatalysts offer over other forms of catalysts is the ease with which the catalysts can be repurposed to either take a new feedstock, or adapt to a new process condition. This advantage has not been fully leveraged at this time. Breakthrough applications are a better objective than drop-ins. While it is understandable that drop ins require less infrastructure changes, it also means that the competition is geared towards either cost, sustainability, or diversification of the supply chain from a customer perspective. It does not play to the strength of bio-products, such as simplification of the supply chain, or minimal additional processing, use of additives to elicit the desired end property/feature etc. Some of these opportunities will be discussed in this presentation. There is no question that the industrial bioeconomy has the potential to be a bigger element of our global economy and spawn businesses that enhance global sustainability and availability. As entrepreneurs and venture investors, we believe that we have to focus on a new industrial sector that can serve customer and consumer needs that are either unmet or underserved, and the value created is significant and tangible.

**Session 5: Separation and Process Methodologies for Feedstocks**

**Wednesday, Jul 22 8:30 am - 10:00 am Room: 519 A**

**Jonathan Burbaum, Advanced Research Projects Agency-Energy**

***ARPA-E's approach to biological solutions***

Jonathan Burbaum will describe ARPA-E's approach to biological solutions to energy problems, including the completed program Electrofuels, running programs PETRO & REMOTE, and recently-launched program, TERRA.

**Ian McGregor, Drystill Technologies**

***How Advanced Distillation Will Supercharge Industrial Biotechnology***

While the Biotechnology Industry has made impressive progress in the pretreatment, hydrolysis and fermentation of bio feedstocks, its all-important separation technique remains a primitive form of distillation characterized by high operating temperatures and high energy consumption. New alternatives exist which will bring economic benefits to many industries that rely on thermal separation. There is a special reason why the biotech industry stands to gain more than any other industry. When conventional distillation is applied to a fermentation broth, high temperatures kill the organisms, precluding any subsequent fermentation. Consequently the conversion of sugars must be complete before product removal can begin. Product concentration in the broth will almost always reach levels toxic to the organism, causing many costly problems reviewed in this paper. These problems can be mitigated or eliminated if product can be selectively removed from the active broth without harming the organisms. Membrane separation has been tried and abandoned. Fermentation under high vacuum has been successfully demonstrated at lab scale but found impractical at a large scale. Low temperature distillation using a refrigerated condenser is a technology that can work in principal, but may never have been

applied at a large scale commercially because it is much more energy intensive than conventional distillation. Advanced Distillation, as defined by this paper, is any distillation technology that will provide low boiling temperatures while using less energy than conventional distillation. Drystill Technologies is one company that offers an Advanced Distillation technology suitable for the Biotechnology industry.

**Adriana Gaona, University of Toronto**

***Enhancing the Operation of High-Solids Enzymatic Hydrolysis of Pretreated Aspen and Mixed Hardwood by Using Reactor Design and Fed-batch Strategies***

Lignocellulosic substrates are widely available, renewable, and suitable materials for production of liquid biofuels. The polymeric substrate comprises cellulose, hemicellulose, and lignin, and requires a pretreatment step to disrupt the structure of the biomass, followed by use of a mixture of hydrolytic enzymes to cleave the polymer bonds. If the enzymatic hydrolysis process operates at high substrate loadings (> 15 wt%), there is a potential to increase sugar titers, decrease water requirements, and enhance downstream processes, leading to lower operational and capital costs. However, laboratory enzymatic hydrolysis experiments have shown that soluble sugar titers are not proportionally increased as solids content increases. The problem stems from the formation of a viscous and heterogeneous slurry when the substrate and the water are mixed. The conventional systems with high solids enzymatic hydrolysis may not provide adequate mixing to the complex slurry. This causes segregation of the fluid, leading to challenges in mass transfer and enzyme-substrate interactions. Consequently, this interplay adversely affects soluble sugar titers and overall biofuels yields. To enhance enzyme-substrate interactions, the reactor and operating conditions should be designed so that a uniform or pseudo-homogeneous slurry is generated, which may increase soluble sugar yields and enhance viscosity reduction during hydrolysis. Therefore, the objectives of this study are: 1. Evaluate different reactor configurations to improve mixing and reduce the apparent viscosity of the bulk of the slurry. 2. Investigate the effect of different feeding strategies on slurry mixing and sugar yields. A 4-L reactor was used to conduct enzymatic hydrolysis of steam-pretreated Aspen and mixed hardwood substrate at 20 wt% solids. Torque measurements were used to assess the effect of the number and frequency of substrate addition. The results showed that different types of impellers and their configuration impacted the fluid distribution, and made it possible to improve mixing and increase glucose yield. The fed-batch strategy used in this study helped to reduce the viscosity of the slurry and reduce power demand by decreasing the rotational speed from 60 RPM to 30 RPM. We also observed that the enzymatic hydrolysis of aspen showed a higher glucose yield than the mixed hardwood. pH control may have been one of the factors that influenced the glucose yield. Therefore, pH control was studied by varying buffer type and concentrations. Preliminary results showed that glucose yields were slightly higher for acetate buffers than citrate buffers. Most of the buffers enabled better control of the pH during the first 24-h of hydrolysis compared to pH adjustments made with sodium hydroxide; however, after 24-h of hydrolysis, sodium hydroxide could be used to maintain pH at its optimal value. The results obtained from this study show that reactor design, impeller configuration, feeding strategies and pH control can enhance hydrolysis of high-solids biomass slurries, overcoming conversion limitations while optimizing the hydrolysis process.

**Shawn Jones, Elcriton, Inc.**

***Acetogenic Mixotrophy for Enhanced Yield Improvements in Biofuel and Biochemical Production***

A common disadvantage of sugar fermentation for three carbon and longer-chain biochemical production is the limited mass yields due to decarboxylation reactions. One way to overcome the poor mass yields is to reassimilate evolved CO<sub>2</sub> and/or exogenous gaseous substrates (e.g., CO<sub>2</sub>, CO and H<sub>2</sub>) into the desired products. Several carbon fixation pathways could be employed, but the Wood-Ljungdahl pathway (WLP) provides several benefits such as high ATP conservation, activity under anaerobic conditions, and no requirements for inorganic electron acceptors. Moreover, WLP exists in acetogenic bacteria, several of which exhibit butanoate metabolism and ferment a diversity of complex carbohydrates. Butanoate metabolism is a well-characterized, 'metabolic chassis' that can be harnessed for the production of many industrially relevant three carbon and longer-chain oxy-chemicals. Accordingly, we propose and are demonstrating a novel Anaerobic, Non-Photosynthetic (ANP) mixotrophic fermentation approach. ANP mixotrophic fermentation is characterized by the concurrent utilization of sugar and gas, resulting in three moles of acetyl-CoA and at least one mole of ATP per mole of hexose consumed. Consequently, mass yields for a myriad of fermentation metabolites can be dramatically increased. For example, the theoretical, homo-fermentative mass yields for ethanol, n-butanol, and succinic acid can be increased by 50% and the mass yields for acetone and isopropanol can be increased by 100%. Interestingly, and as we describe in our talk, ANP mixotrophic fermentation can be implemented in a diversity of acetogenic bacteria without catabolite repression. We also describe our work in genetically engineering acetogenic

hosts that do not have butanoate metabolism to produce three and four carbon metabolites. In several examples, we demonstrate the ability to produce 95% of ANP mixotrophy theoretical mass yields for three carbon solvents. Overall, we believe the ANP mixotrophy platform is a robust approach to significantly increase sugar fermentation product yields, which improves process economics and has significant implications for biochemical life-cycle analysis.

**Regis Benech, Greenfield Specialty Alcohols Inc.**

***GreenField's Answer to Producing Gen2 Sugars***

Biochemicals produced from renewable raw materials meet a global need for innovative and sustainable alternatives to crude oil-based chemicals and transportation fuels. Gen2 sugars derived from lignocellulosic biomass and oils from oilseed crops are needed as the primary building block to produce a menu of biobased chemicals - from advanced biofuels such as cellulosic ethanol, bio-butanol and biodiesel, to succinic acid, gluconates, polyamide nylon and others. This is the function of pretreatment by fractionation, the first and most challenging step. Simply put, pretreatment is a combination of a process with well-defined targets (KPI's), and the equipment train to execute it. And both must be both technically efficient as well as capex and opex cost-effective. GreenField has developed such a complete technology. Our superior pretreatment process results in the fractionation of the major biomass components into discrete process streams. Our combined process and equipment technology allows for the recovery of the highest amount of C5 and C6 sugars in their inhibitor-free form from a wide range of low-to-high lignin biomass or suspended solid-free oils. Our unique equipment technology operates in a versatile, largely mechanical manner, without the use of acids or solvents. At its core is our proprietary filtering system incorporated into a highly-modified twin-screw extruder, which in one piece of equipment not only separates the C6 and C5 fractions but also activates the C6 fraction. Proof-of-concept of our Extruder Technology was established through the extensive operation of our 1 tonne/day continuous Pilot. In parallel, we generated the data to engineer, design, build and operate our 5 tonne/day pre-commercial mobile system which has enabled us to generate the data for commercial scale-up. We expect to commercially deploy and exploit our technology this year. Our model is to control the manufacturing of the equipment and to market our systems on a worldwide basis - all protected by a patent strategy covering more than 50 countries.

**Session 6: Clustered Research and Development of Ag-Based BioProducts**  
**Wednesday, Jul 22 10:30 am - 12:00 pm Room: 519 A**

**Alexander Marshall, Moderator**

***Clustered Research and Development of Ag-Based BioProducts***

The BioProducts AgSci Cluster is a Canadian national initiative, supported by Agriculture and Agri-Food Canada's Growing Forward 2 Program, focuses on the research and development of agriculture based chemicals, materials, transportation and biomass supply chains that are sustainable and economically viable. The cluster facilitates this development through Bioindustrial Innovation Canada by providing strong connectivity to academia, government, finance and industry to help provide development pathways to address emerging market needs. This panel explores the areas and use of agriculture based materials in construction, automotive and biomass processing that demonstrate strong potential in emerging applications. Dr. Amir Fam, Munro Chair of Engineering and Applied Science at Queen's University will demonstrate the potential of agriculture based materials in construction applications. The National Research Council Canada will provide insights in the development of cost effective biocomposites from flax and hemp fibre for the transportation and construction markets. Dr. Louis Vezina, TH Alfalfa, will explore different pathways to bioproducts from alfalfa.

**Amit Goyal, Southern Research Institute**

***Process for Biomass Conversion to Acrylonitrile- Precursor for Production of Carbon Fibers***

The industrial sector anticipates an 11-18% annual increase in the market for carbon fiber, specifically driven by motivation to reduce weight for vehicles [1]. Currently, micron-sized carbon fibers which meet mechanical specifications (250 ksi tensile strength and 25 Msi Young's modulus) for automotive applications are made from poly-acrylonitrile (PAN), obtained from acrylonitrile (ACN) synthesized using propylene and ammonia. World ACN production in 2010 was 5.7 million tons, and is highly dependent on volatility of propylene prices. Additionally, production of propylene (a byproduct of naphtha cracking for ethylene) is undergoing reduction due to growth of the natural gas-derived ethane-based process for production of ethylene. Previous attempts to directly make carbon fiber from biomass-derived lignin have largely met with failure due to the fiber's inability to meet the required specifications. Furthermore,

attempts to make carbon fiber via the ACN route from bio-derived sources have been limited to the conversion of glycerol obtained as a byproduct from biodiesel production from oils. However, the glycerol to ACN pathway has been found to be economically unattractive compared to the conventional petroleum based ACN pathway. In light of these facts, the goal of this work is to develop cost-effective process with low environmental impact, for production of ACN utilizing biomass derived sugars with comparable properties that can directly replace conventional ACN. Southern Research is developing a biomass to ACN (B2ACN) process under a cooperative agreement with the Department of Energy [2]. B2ACN is a multi-step catalytic fixed bed process for conversion of sugars from non-food biomass to ACN at mild conditions. The process utilizes known pretreatment methods for recovery of sugars from any type of biomass. In the first reaction step, sugars are converted to oxygenates using a novel multi-functional catalyst, oxygenates are then converted to a gas phase intermediate followed by conversion of the intermediate to acrylonitrile. The results and initial estimates show a significant reduction in greenhouse gas (GHG) emissions of up to ~37% and cost reduction of up to ~22% compared to conventional ACN. The GHG benefits and cost reduction are achieved by using mild conditions, minimizing catalyst use, minimizing separation costs, increasing net carbon yield and use of industrially acceptable fixed bed reactors.

[1] Global market opportunities for carbon fiber: Carbon fiber world conference, Washington DC 2011 [2] <http://energy.gov/eere/articles/energy-department-announces-11-million-advance-renewable-carbon-fiber-production>

**Tan Ton-that, National Research Council Canada**  
**Peter van Ballegoie, Ecosynthetix Corporation**

### ***Clustered Research and Development of Ag-Based BioProducts***

The BioProProducts AgSci Cluster is a Canadian national initiative, supported by Agriculture and Agri-Food Canada's Growing Forward 2 Program, focuses on the research and development of agriculture based chemicals, materials, transportation and biomass supply chains that are sustainable and economically viable. The cluster facilitates this development through Bioindustrial Innovation Canada by providing strong connectivity to academia, government, finance and industry to help provide development pathways to address emerging market needs. This panel explores the areas and use of agriculture based materials in construction, automotive and biomass processing that demonstrate strong potential in emerging applications. Dr. Amir Fam, Munro Chair of Engineering and Applied Science at Queen's University will demonstrate the potential of agriculture based materials in construction applications. The National Research Council Canada will provide insights in the development of cost effective biocomposites from flax and hemp fibre for the transportation and construction markets. Dr. Louis Vezina, TH Alfalfa, will explore different pathways to bioproducts from alfalfa.

**Aman Ullah, University of Alberta**

### ***Modified Bio-based sorbents for treatment of industrial wastewater***

The industrial wastewater produced during the extraction or refining of natural resources is highly contaminated with organic and inorganic contents, which requires a complex and expensive treatment. Therefore, water contamination and its treatment has become a global issue of concern. Particularly oil sands operations consume large amounts of water in bitumen extraction process. Our study involves the use of chemically modified keratin protein (poultry feathers) as a sorbent for treating waste water. Poultry feathers, abundant waste material and huge source of keratin biopolymer (over 91%), have tremendous potential to be used as sorbent for large-scale applications. The overall goal of our research is to provide industry with a sorbent material that is both effective as well as economically viable for industrial scale wastewater treatment. The results of our lab scale trials show that through proper tuning of functionalities, the biopolymers can be highly effective for sorption of trace metals and organic contaminants such as naphthenic acids. The chemically engineered biopolymers played an effective role to adsorb a number of toxic organic and inorganic components.

Different modified biopolymers were used as sorbents to treat oil sands process-affected water (OSPW) to sorb metals and naphthenic acids present in wastewater. The modified biopolymers were tested against OSPW maintained at ionic strength of 0.05 and spiked with up to 50 ppb of 9 trace elements (Se, Cu, Zn, As, Pb, Ni, V, Cr, and Co). The OSPW solutions were treated with 1% modified sorbents and controls for 24 hours followed by centrifugation and analysis using ICP-MS and FTIR spectroscopy. Different modifications led to different sorption trends. Some sorbents showed high sorption capacity for both type of contaminants (naphthenic acid and metals). In some cases removal of certain elements such as Se, V, Cu, Pb, and Cr were greater than 90% and naphthenic acids more than 50%. The results demonstrated that through proper tuning of functionalities, the developed sorbents can be highly effective for sorption of

trace metals and naphthenic acids. The high sorption capacity, cheap bioresource, and simplicity of the modifications suggest that there is great potential for an industrial scale viability of the process.

## Track 5: Technical Presentations



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### **Session 1: Innovative Processes to High Value Biobased Products Monday, Jul 20 8:30 am - 10:00 am Room: 519 B**

**Moderator: Hans van der Pol**

#### ***Building new fermentative platforms based on lactic acid based capabilities***

Based on over 80 years of experience in biobased products, Corbion is built on a strong foundation of leading edge fermentation and down-stream processing technologies, deep market understanding, strong customer relationships and a unique global supply chain. Sustainability is in the heart of Corbion's business. Based on the strong foundation in technology, sustainability and cooperation, Corbion has a strategy of building new business based on the strong lactic acid core. Thus, Corbion products are designed by science, powered by nature, and delivered through dedication. This presentation will focus on the biobased chemicals landscape, the analysis that was made to select new products and the recent expansion of the Corbion products and project portfolio -into area's such as L and D- lactides, PLA, succinic acid, FDCA and second generation feedstock developments- and highlight key partnerships, capabilities and technologies that form the basis for the development into a full-fledged biobased products company.

**Daniel Bar, Ameridia, Division of Eurodia Industrie**

#### ***Bio-Based Chemicals Require Innovative Purification Processes***

For the industrial production of bio-based chemicals or biofuels, purification and separation steps can be difficult, costly, and inefficient. The difference between a good and a great purification process can mean the difference between a successful demonstration project and an unsuccessful one. Such difficulties are apparent in both the production of chemicals and in the production of sugars derived from biomass or Second-Generation Sugars destined for use in chemical and fuel production, Due to the diversity of the raw materials that can be sourced for a conversion process, the impurities can be very different in nature and quantities, and the overall process must be sufficiently forgiving for a successful implementation. Purification technologies are many and, while the selection and purchase of such components might seem like a straight-forward process, the right components in the right arrangement could mean the difference between the technical and economic success of a new plant or its failure.

Eurodia Industrie (and Ameridia, its North American division) is focused on the development of separation processes that are specifically developed for each purification challenge with twenty-five years of experience in industries such as dairy, wine, sugars & sweeteners, specialty chemicals, and bio-based chemicals. In 2013, Eurodia established CHEMISTRIA, a division dedicated to the purification challenges of the Biotech and Bio-based (or Green) Chemical Industry. Its offering includes membrane technologies, chromatography, electrodialysis and ion exchange, now enhanced with an innovative uninterrupted ion exchange technology. A world leader in the design of separation trains, the Eurodia process development team uses proprietary modeling and design techniques to determine the optimal mix, design and delivery of these technologies to provide efficient, cost effective, and reliable separation processes.

**Greg Kennan, Penford Products**

#### ***Advancements in Starch Derived Biomaterials and Chemicals***

For more than a century Ingredion has been a leading provider of biobased ingredients and solutions for industrial and food applications. Leveraging expertise in carbohydrate chemistry, starch modifications and polymer science Ingredion has commercialized a number of biobased materials that provide economic, functional and sustainability benefits over petroleum derived materials. This presentation will address the opportunities and challenges associated with renewable materials from the perspective of a vertically integrated starch supplier. Innovations developed by Ingredion and our strategic partners will be discussed. This includes recent successes in the commercialization of starch derived materials for use in industrial coatings, packaging and personal care.

**Sagar Gadewar, Greenyug**

***Specialty Chemicals from Bio-ethanol: Capitalizing on the Biofuels Infrastructure***

Greenyug develops and commercializes breakthrough technology to produce drop-in renewable specialty chemicals at significantly lower cost than identical petroleum-based products. Greenyug is leveraging \$150 billion global biofuels industry investment using bolt-on strategy by co-locating at existing bio-ethanol facilities to significantly reduce capital needs. Greenyug is commercializing a highly profitable process to manufacture value added products from inexpensive, renewable, abundant bio-ethanol. We are targeting the specialty chemicals sector which is a category of relatively high valued, rapidly growing chemicals with diverse end product markets. All of our products are drop-in replacements and are not only renewable but also have a lower fixed and variable cost of production compared to the fossil-based current state of the art. Applications include paints, coatings, pharmaceuticals, packaging, construction, automotive interiors, cables, fabrics, household goods, and cosmetics. There is a growing demand for renewable and sustainable chemical products primarily driven by consumer interest in sustainability and climate change mitigation. At the same time, the market is not willing to pay a premium for "green" products. Our superior economics allows us to compete with conventional petroleum based products on market economics alone and, therefore, our products do not require a "green" premium to succeed commercially. Greenyug is commercializing its technology at a large bio-ethanol facility in the US Midwest.

**Session 2: Engineering Industrial Biotechnology Projects**

**Monday, Jul 20 10:30 am - 12:00 pm Room: 519 B**

**Moderator: Marlene Beyerle, Novasep**

***Efficient purification solutions for your bio-based chemicals, an industrial reality***

The emergence on the market of bio-based products is linked to the development of efficient industrial-scale processes that can produce high volumes of pure product at a cost-competitive price.

The treatment of biomass and its conversion into platform chemicals involve multiple process steps. While some of these steps are still the focus of extensive development work (microbial strain selection and engineering, development of chemical conversion routes), the purification steps are already an industrial reality. Novasep's purification technologies for which many references can be cited have been proven at industrial scale through years of operation. They include continuous chromatography, ion exchange, membrane filtration, electrodialysis, evaporation and crystallization. The technical and economical specificities of each technology as well as local economic constraints are taken into account throughout process development phases and scale-up so as to select the best combination of technologies for implementation at commercial scale. A special attention is paid to maximized product recovery, reduction of waste streams and limitation of costs associated to chemical/ energy consumption. Based on specific case studies, Novasep will present innovative process designs and illustrate costs associated with the industrial scale purification of bio-based products.

**Alan Propp, Merrick & Company**

***Capital Cost Estimating Tutorial for Industrial Biotechnology Projects***

One of the deliverables that Merrick, as an engineering firm, provides for almost every one of our clients is a capital cost estimate. Not infrequently do I get a call from a potential or even current client that asks for, for instance, a plus or minus ten percent capital cost estimate. While it is certainly possible to provide an estimate with such a high degree of accuracy, doing so requires a lot of engineering and may not be at all what the clients really wants or needs. It is also uniformly the case that our clients underestimate the cost of their projects, often by 100% or more. One of our most challenging tasks is to educate our clients on the true cost of their proposed projects. There is always sticker shock when our estimate comes in much higher than they envisioned. This talk will explain how capital cost estimating is performed, and will educate the listeners on the process. I will also provide rules of thumb and general approaches that will help technology companies better estimate their capital costs themselves, so that neither they nor their investors are shocked when they learn the true cost of implementation of their technology at whatever scale they plan.

**Markus Wolperdinger, Linde AG, Engineering Division**

***Scale-up of the "Organosolv" Process to Commercial Dimensions***

The "Organosolv" process for the fractionation of lignocellulosic feedstocks into lignin, cellulose, and sugars has been subject of intensive R&D, piloting, and initial commercial activities in the past. Several "Organosolv"-based technology approaches have been pursued or are currently under development,

making use of a variety of feedstocks, specific process implementations or specific product properties. Linde Engineering, together with the Fraunhofer Center for Chemical-Biotechnological Processes in Leuna, Germany, has developed a modular plant concept based on the "Organosolv" process with significantly improved characteristics regarding product properties and purity, overall yield, and cost. This work has been based on results achieved with a dedicated pilot-plant at the Fraunhofer facility in Leuna. The pilot plant which has been in operation since 2013, was engineered and implemented by Linde Engineering and is designed for a throughput of approx. 315kg dry wood/week. Based on experimental results obtained during more than two years of operation of the pilot plant, as well based on feedback received from a selected group of early users of lignin, cellulose and sugars produced with the plant, Linde Engineering is now in a position to scale-up the "Organosolv" process to a commercially relevant dimension. This paper will present key results achieved during the development, engineering and scale-up work and will discuss relevant parameters for a commercially viable deployment of the technology.

### **Joachim Venus, Leibniz-Institute for Agricultural Engineering**

#### ***Bioconversion of renewable feedstocks and (agri/food) residues into lactic acid***

Objectives Besides the quantity and availability of raw materials together with their properties and quality the feedstock costs are very important for the production of bulk chemicals like lactic acid. Especially for biotechnological processes, in which the carbon of various substrates should be converted into microbial products, there is an increasing interest in the use of cheap raw materials. Methodology Renewable feedstocks (crops, lignocellulosics, green biomass, residues etc.) are already being used as raw materials for the production of bio-based products. However, these feedstocks cannot be used normally for fermentation directly because the fermentable sugars are bound in the structure especially as cellulose and hemicellulose. They have to undergo a pre-treatment to release these sugar components. Results Investigations dealt with the optimization of different process steps (e. g. disintegration and hydrolysis of biomass, filtration, sterilization, fermentation, downstream processing etc.) and were performed subsequently in form of coupled process sequences. In this context different fermentation regimes were tested for the development of an innovative and environmental benign lactic acid production. Special detoxification steps can help to improve the fermentability and conversion efficiency of complex biomass hydrolysates. According to the difficulties mentioned in the mobilization of fermentable sugars a range of other, easy accessible substrates are suitable for subsequent fermentation processes (such as residues from fruit and vegetable processing, by-products from starch and sugar factories or from the baking industry). Depending on the further processing of the lactic acid the separation of impurities after fermentation is a major process cost too. Therefore an optimization is necessary to find a balance between the substitution of expensive nutrients and the limitation of interfering or undesirable components of natural raw materials. Conclusion The entire processing chain has been implemented: from the feedstock, the pre-treatment/hydrolysis for releasing C5 and C6 sugars, the fermentation to lactic acid and the downstream processing of fermentation broth to generate marketable lactic acid of high enantiopurity and quality. Exploitation of L(+)- and D(-) lactic acid for the production of biopolymers is one of the recent applications. References [1] Venus, J. (2011) Feedstocks and (Bio)Technologies for Biorefineries. – In: G.E. Zaikov, F. Pudiel, G. Szychalski (Eds.), Renewable Resources and Biotechnology for Material Applications (pp. 299-309), Nova Science Publishers [2] Koch, T.J.; Venus, J.; Bruhns, M. (2014) Sugar beet syrups in lactic acid fermentation – Part I. Sugar Industry 139, No. 8, 495-502 [3] Pleissner, D.; Venus, J. (2014) Agricultural residues as feedstocks for lactic acid fermentation. - ACS Symposium Series, Vol. 1186 "Green Technologies for the Environment", Chapter 13, pp 247-263

### **Bernard Roell, RSC Bio Solutions**

#### ***Engineering Environmentally Acceptable Lubricants (EALs) to meet the demanding EP/Antiwear Performance of Marine equipment OEMs***

Environmentally Acceptable Lubricants (EALs) have the proven performance to meet the demanding specification of Marine equipment OEMs. The 2013 Vessel General Permit (VGP) requires the use of EALs in all oil to water interfaces, as well as being readily biodegradable, minimally toxic and non bioaccumulative. This session will demonstrate how EALs can be engineered to meet the most demanding OEM specifications for Brunvoll and Rolls Royce applications. We will also compare and contrast four types of EALs. We will demonstrate that Hydraulic Environmental PAO and related hydrocarbons (HEPR's) have the extreme pressure, anti-wear and frictional qualities compared to their petroleum counterparts. Several performance tests will be covered in the session: FE8 bearing wear testing, clutch friction and durability testing and FZG variants testing. Through this session, attendees will gain a better understanding of EAL properties and their real-world application in marine and offshore oil and gas industry pumps and gears.

**Session 3: The Growth Projection for Renewable Chemicals**  
**Monday, Jul 20 2:30 pm - 4:00 pm Room: 519 B**

**Moderator: Carolyn Fritz, Fritz Consulting, LLC**

**Michael Krenek, Deloitte**

***The Viability of Biochemical Feedstock in the World of \$50 Oil***

Within the past five years, the hopes for the expanded commercial viability of biochemical alternatives for fuel and chemicals were beginning to be realized. For example, in a key advance to move beyond the food versus fuel debate in the United States, three (3) biomass-based cellulosic bioethanol plants moved into commercial production in 2014, with a fourth scheduled during the first quarter 2015: • Quad County Corn Adding Cellulosic Ethanol (ACE), Galva, Iowa, July 2014 • POET-DSM Advanced Biofuels, Emmetsburg, Iowa, September 2014, • Abengoa, Hugoton, Kansas, October 2014 • DuPont, Nevada, Iowa, 1Q15. And more specifically addressing the use of bio-based products to produce chemicals feedstock (the topic of this paper), a recent study in Europe by an industry group showed the commercial viability of making chemicals from sugar beets: Opportunities for the fermentation-based chemical industry. An analysis of the market potential and competitiveness of North-West Europe. Now, though, the petroleum cost basis for comparison with bio has changed considerably. The price of global benchmark crude oil has fallen into the range of 50 USD per barrel at the time of this writing. And while no one can forecast crude oil price with any accuracy over the medium to long term, current market dynamics suggest oil prices could stay depressed for some time. So, how will bio-based chemical feedstock fare versus petroleum-based with oil at ~\$50/barrel? This paper will primarily address two major questions: • What is the economic impact of falling petroleum-based feedstock prices on bio derived specialty chemical projects? • Looking at the non-financial aspects of bio-derived chemicals, e.g., climate change, where are there sufficiently strong driving forces to overcome the cost gap? This paper will include insights and analysis that come from Deloitte's work with the Chemicals and Materials Industry Agenda of the World Economic Forum, as well as from its recent chemical industry studies.

**Julia Allen, Lux Research**

***Bio-based Materials and Chemicals Industry Overview***

The Bio-based Materials and Chemicals (BBMC) industry is maturing and commercializing, growing capacity 28% annually from 2005 to today. The leading technologies are aligning the financing, corporate relationships, and research muscle necessary to scale in a era of lower priced crude, rising feedstock costs, and a push towards non-food biomass inputs. We examined over 200 production facilities throughout the world, that were planned, operating, or shuttered between 2005 and 2018 to determine the current state of the market, planned growth, megatrends, and what products are winning the hearts and minds of investors and end-users. This presentation will highlight the growth of key chemicals and will discuss an assessment of industry growth trends and commercialization activities, with lessons to be learned for rolling out applications with other bio-based products.

**Joshua Velson, Nexant**

***Whitespace Opportunities in Biobased Chemicals***

Innovative bio-chemicals players have increasingly explored the idea of producing lower-volume, higher-value chemicals in an attempt to reach higher profitability. As this trend continues, these players will begin to address sectors that no longer resemble traditional commodity chemicals. Many high-end molecules occupy a space where market dynamics are obscure and the competitive landscape is murky, perhaps even including other bio-based competitors that are not based on modern biotechnology. In addition, it is often difficult to determine if biotechnology can even address relevant markets. Thus, innovators in the bio-chemicals space will face a dilemma: the most potentially profitable and exciting opportunities will be in more valuable, smaller volume chemicals; however, the commercial and technical feasibility of addressing these markets will be unclear. To address this need, Nexant has studied possible opportunities that have yet to be addressed by any major player in industrial biotechnology - the whitespace. This presentation will present some selected findings.

**Todd Campbell, United States Department of Agriculture**

**Session 4: Open Source Facilities to Scale-up Renewable Chemicals and Biobased Materials**  
**Tuesday, Jul 21 2:30 pm - 4:00 pm Room: 519 B**

**Moderator: Bhima Vijayendran, Redwood Innovation Partners, LLC**

**Hendrik Waegeman, Bio Base Europe Pilot Plant**

***Bio Base Europe Pilot Plant: An Open-Innovation Pilot Plant for Bio-based products and processes***

Based in Ghent, Belgium, Bio Base Europe Pilot Plant is one of Europe's first pilot and demonstration plants for bio-based products. Founded in 2009 and operational since 2011, it has grown to a leading initiative that serves small and large companies to bridge the gap in the innovation chain and bring innovative products faster to the market. In 2009, in the middle of the financial and economic crisis, Europe was awakened by the fact that it was losing industrial significance to emerging economies. To counteract, the European Commission launched the concept of Key Enabling Technologies (KETs), new technologies that should result in the reindustrialization of the Old Continent, stimulate competitiveness and generate jobs, growth and wealth in the economy. Six technologies were selected and among other emerging technologies industrial biotechnology was put forward as a cutting edge technology. In the framework of the KET assessment study, executed by a high-level expert group, the EC investigated what was hampering the implementation of industrial biotechnology in sectors such as the energy, chemical and food-industry. One of the main observations in that report: the valley of death, i.e. the phase where many prototype processes or products fail when going from research level to market entry and the lack of public funding for scale-up and demonstration activities to avoid this valley of death. Compared to the other two economic superpowers in the world, the USA and China, Europe was supporting hardly any scale-up and demonstration activities. With the results of the assessment report in hand, the EC took action. Several new funding instruments were created, e.g. (1) Horizon2020, which in comparison to its predecessor FP7, in general will focus more on the collaboration between academia and industry, (2) within Horizon, the special Public Private Partnerships BBI (Bio-Based Industry) and SPIRE (Sustainable Process Industry through Resource and Energy efficiency) with financial support for pilot and demonstration activities, and (3) also within Horizon, the SME instrument, a program to support small and medium-sized enterprises to get their developments faster to the market. What else is hampering industrial biotechnology and more in general the bio-based economy to take off? Well, although, SMEs and large companies can obtain financial support to scale-up their processes, for many of these companies and especially for SMEs, piloting is not the core of their activities. SMEs typically do not have the infrastructure to accommodate pilot lines, nor have the skilled personnel to run the tests. To obtain faster learning curves and shorter time to market, these activities are better outsourced. To allow this outsourcing, the necessary pilot infrastructure should be readily available, and companies should have easy access, without conflicts of interest with the organization or company that is running the pilot plant. Furthermore, the infrastructure available should be diverse and comprehensive, to allow the scale-up of a wide range of processes and finally, the pilot plant organization should have a critical mass of people to cover the many aspects of the bio-based economy. This presentation will show how Bio Base Europe Pilot Plant addresses these concerns, how the pilot facility is set up, what bio-based processes are run and how it can help companies to bridge the gap in the innovation chain.

**Arno van de Kant, BPF**

***Improving commercial success by using experienced Pilot plant facilities***

Having great results with new products and processes on lab scale, doesn't mean it will work on commercial scale also. Piloting is a crucial phase to be able to scale up the bioprocess. How to tackle new challenges in pretreatment, fermentation and downstream processing on larger scale? How to make it a commercial viable process? What is the benefit of using an open access facility, with ample experience in multiple projects with multiple customers? What are the challenges and risks? Confidentiality, leak of knowledge? With examples of companies like Corbion, DSM, Verdezyne I will show the benefit of working with an open access pilot facility, to scale up bioprocesses. Based in the Netherlands, the BPF main purpose is to help companies in biobased and biotechnology to scale up their processes. Biochemicals, Biofuels, Enz

**Ally Latourelle, Bioeconomy Partners**

***Fermentation on Demand Capability to Accelerate Industrial Biotechnology Commercialization Capability and Strategic Partnerships***

Abstract for presentation on the development of fermentation on demand capability to accelerate industrial biotechnology Commercialization Capability and Strategic Partnerships by BioEconomy Partners Managing Partner, Ally LaTourelle, Esq. If the biobased economy is to grow at the predicted pace, commercialization strategies will continue to be a critical factor to hurdle the well known

commercialization gap. However, biobased technology companies are often forced to make the difficult choice between high cost contract fermentation or capital intensive construction. BioEconomy Partners is currently the developer of FermCo, Inc's fermentation toll manufacturing plant called the Bioscience Manufacturing Center in Rochester, NY. This company will bridge the gap for emerging biotech companies and reduce their "front end" capital expenditures. FermCo, Inc. fills a critical market gap for cost-effective, timely, toll fermentation for biobased technology companies and their partners. FermCo's Bioscience Manufacturing Center is a 60,000 square-foot advanced manufacturing facility to be located at Eastman Business Park in Rochester, NY. This will be a uniquely product flexible, state-of-the-art, 2,000,000-liter general purpose fermentation facility for the production of biobased chemicals and fuels. FermCo will be fully equipped with an IP protected facility design, private analytical labs and a staff experienced with bacteria, yeast, fungi, algae, organic acids, amino acids, solvents, biomass/ single cell protein, foods/food ingredients, feed ingredients, and enzymes to help guide strain development alongside a customer's technical team. The uniquely flexible process system design of three trains of pilot scale fermenters and six commercial scale fermenters will allow companies an ability to model and develop at pilot size, or produce at commercial scale, or both. Each of the three trains will have one 5,000-liter pre-seed fermenter, and one 40,000-liter seed fermenter. These trains can be used as stand-alone pilot tools, or as seed fermenters for full scale production with any or all of the six 350,000-liter production fermenters. This process design allows for both start-up and established biotechnology companies to quickly and effectively scale up laboratory fermentations, and then move to batch fed or continuous fermentation at commercial scale as needed. The development of a Fermentation on Demand capability will accelerate industrial biotechnology companies into greater Commercialization Capability and Strategic Partnerships. This presentation will outline the development strategy of the FermCo, Bioscience Manufacturing Center, its Fermentation on demand capability, and the emergence of collaborative strategic partnerships that make it possible to move technologies in tandem, to commercial scale, at multiple points in the supply chain.

#### **Nathan Hillson, Joint BioEnergy Institute**

##### ***The Berkeley Open Biofoundry: A biological foundry to support US biomanufacturing***

Lawrence Berkeley National Laboratory and the University of California, Berkeley seek to establish the Berkeley Open Biofoundry (BOB), a unique public-private partnership to rapidly advance the state of the art for biomanufacturing. BOB will be an open collaboration facility, providing researchers and manufacturers across industry, government, and academia the ability to develop, test, and implement state-of-the-art biological designs for robust production of desired targets (e.g., engineered microbes that produce drop-in chemicals, engineered plants that produce novel polymers, etc.). BOB's core research and development mission will enable the use-inspired application of biomanufacturing across a broad range of industries, from renewable fuels, chemicals and materials to pharmaceuticals and agriculture. Biomanufacturing holds great promise to deliver new drugs, new chemicals, new materials, new agricultural techniques, and more, but the current cost and time required to develop a product limits its impacts. The typical process for engineering biology involves an iterative loop of Design (D), Build (B), Test (T), and Learn (L). Due to the unpredictability of much of biology, the complexity of the D, B, and T steps, and the lack of learning incorporated into future designs, one cycle of the loop can take months and benefits minimally from previous cycles. BOB targets the inefficiencies in engineering biological systems to improve the state of the art from its current ad hoc status to one that is robust, predictable, and scalable. BOB will use both formal representations of biological and process knowledge with process modeling and machine learning to integrate the DBTL cycle, advancing the process of engineering a biological system from years to weeks and improving the success rate of that engineering effort from 2.5% to ~50-70%. Beyond better organism design, BOB will also improve the process of scaling biomanufacturing so that the systems developed will make it to market with higher success rates and less development time (and thus less money). By developing methods to predict how organisms will perform in reactors, BOB will take bioprocess development from a time-consuming process done one strain at a time to a process that is predictable and reliable. As an open collaboration facility, BOB will bring together researchers across industry, government and academia to develop and apply innovative biomanufacturing technologies for key applications. In doing so it will become a premier source for publicly available materials and data, including well-characterized, predictably engineerable host organisms, genetic expression systems, biosensors, metabolic pathways and enzymes, and protocols and technologies for strain construction, characterization, and production optimization.

#### **Session 5: Potential for Increased Productivity, Through Enzyme Optimization**

**Wednesday, Jul 22 8:30 am - 10:00 am Room: 519 B**

**Moderator: John Perkins, DSM**

**Subramani (Subbu) Ramachandrappa, Richcore Lifesciences**

***Novel patent pending enzyme solutions for treating Industrial waste water / sewage and replacing sulphur in production of plantation white sugar from sugar cane***

**RICHECOSOL TECHNOLOGY: AN ECO-FRIENDLY SOLUTION FOR TREATING INDUSTRIAL AND DOMESTIC WASTE WATER.** Background: Although there have been continuous efforts to develop an efficient enzymatic technology to treat industrial and domestic waste water, the application of the idea so far has not been fully practical because of one important reason: The Cost. Richcore Lifesciences has developed a cost effective technology platform that enables developing a medley of enzymes to process complex substrates. The platform can be used to custom design, develop and produce an optimum mixture of specific enzymes at a cost that is a fraction (1/10th) of conventional enzyme manufacturing method, enabling the use of greener, enzyme based solutions in highly price sensitive applications such as industrial waste water and sewage treatment. Technology (patent pending): The RichEcosol technology enables co-culturing multiple strains to produce a mix of 35+ enzymes in single fermenter using minimal energy and equipment. This consortium of enzymes is effective in hydrolyzing various substrates such as dyes, aromatics, phenolic compounds & bio-molecules which are generally found in waste water in various proportions. Application: Increasing the efficiency of industrial waste water/sewage plants without additional Capex and with reduced chemical usage. Improving bio-methanation and bio-remediation processes. Benefits: Incrementally, up to 50% reduction in BOD & COD, 60 to 90% reduction in color, 20% reduction in sludge, 60% reduction in phenol and with additional savings of 30% in total costs. Status: Being commercialized across various industries including paper and pulp, textiles and refineries. Global Potential: In excess of USD 1 billion/year. **SULPHREE: A TECHNOLOGY TO REPLACE/SUPPLEMENT CURRENT PRACTICES FOR REMOVING COLOR DURING SUGAR MANUFACTURING PROCESS.** Background: Color of sugar is an important commercial attribute; hence, color removal is a very critical step in manufacturing plantation white sugar. In Asia & parts of Latam, Sulfur Dioxide (Sulphitation) is still used to produce white sugar. Sulfur use leads to severe health risks for employees in the plant and to the end customers consuming sugar with residual Sulfur. Also, Sulfur use leads to increased corrosion in the plant, and pollutes surrounding areas through effluents. Technology (patent pending): The enzyme complex in Sulphree breaks down color forming compounds such as pigments and phenol compounds; thereby preventing color formation and reducing the color of the juice. The enzymes also catalyze the breakdown of hemi cellulose polymers in cane juice; thus reducing turbidity, enhancing juice clarity, and preventing formation of high molecular weight colorant-polysaccharide complex. Application: Eliminates or reduces the use of Sulfur in production of plantation white sugar. Benefits: Eliminates health risks to operators and Sulfur in discharged effluent, reduces corrosion in sugar plants, and leaves no residual Sulfur in final sugar. Sugar mills benefit through direct cost savings, increased yield (3-5%) and a better pricing by offering Sulfur free white sugar. Status: Commercially tested and validated. Global Potential: Close to USD 800 million/year. Company is in advanced commercial licensing discussions with global chemical companies. **RICHCORE LIFESCIENCES** is an innovation led biotech company developing novel solutions for Cleantech and Biopharma.

**Thu Vuong, University of Toronto**

***Enzyme engineering for enzyme-based devices and biomaterial applications***

*Sarocladium strictum* gluco-oligosaccharide oxidase was known to effectively oxidize cello-oligosaccharides and lactose; however, our current characterization indicated that this enzyme oxidizes xylo-oligosaccharides and other sugars at a similar extent. Site-directed mutagenesis (14 mutations) and domain fusion (7 fusion constructs) created variants with broader substrate specificity and lower substrate inhibition, allowing to regioselectively modify numerous plant-derived sugars for biomaterial and nutraceuticals applications. We are also interested in using those enzymes to create enzyme-based devices for directly detecting or converting sugars; therefore, a number of immobilization techniques, based on hydrophobic and charge interactions between the enzyme and solid surfaces have been applied. Enzyme actions on solid polysaccharide surfaces were analyzed by quartz-crystal microbalance with dissipation and X-ray photoelectron spectroscopy.

**Mathilde Gosselin, Materium**

***Hollow Mesoporous Silica Microspheres: Potential for Increased Fermentation and Enzymatic Process Productivity.***

Historically, fermentation has been done in suspended growth and increased productivity was obtained via bioreactor operational parameters optimization, microbial strain selection and genetic engineering. Similarly, enzymatic reactor productivity was increased via reactor and enzyme optimization. One area that has been too often overlooked in both fermentation and enzymatic processes is the possibility to increase productivity via adsorption to a mobile media support. Materium Innovation has developed a hollow mesoporous silica microsphere (MATSPHERES Series) that can be used as both a microorganisms' carrier and as an immobilization support for enzymes. MATSPHERES' high specific surface area and surface chemistry are well suited for microorganism or enzyme adsorption. Results demonstrate that fermentation incubation time is reduced by several hours and productivity is increased up to 30%. Results also shows that immobilized enzymes activity is increased compared to free enzyme. Furthermore, immobilized enzymes are protected against pH and temperature changes. Finally, immobilization has an advantageous impact on process costs since it reduce microorganism's washout and allow enzymes recycling.

**Session 6: The Importance of Feedstock and Product Strategy**  
**Wednesday, Jul 22 10:30 am - 12:00 pm Room: 519 B**

**Moderator: Bob Walsh, Intrexon Corporation**

***Natural gas bioconversion to chemicals, lubricants, and fuels***

The objective of Intrexon's natural gas upgrading program is to develop a microbial cell line for industrial-scale bioconversion of natural gas to chemicals, lubricants and fuels, as opposed to employing standard chemical routes. Intrexon's unique cellular engineering capabilities will enable the genetic manipulation of a microbe to convert natural gas to higher carbon content compounds at ambient temperatures and pressures, thereby reducing capex and opex requirements compared to standard gas to liquid (GTL) processes. At present, Intrexon has two different engineered microbial hosts: One that converts methane into isobutanol in a laboratory scale bioreactor and one that converts methane to farnesene in a laboratory scale bioreactor. Natural gas is currently one of the most economical forms of carbon as it is both highly abundant and is the least expensive form of energy other than coal. Moreover, unlike sugar, natural gas is a highly reduced source of carbon, allowing conversion of the entire feedstock to highly reduced products. Methanotrophs have the innate ability to "upgrade" natural gas, by oxidizing methane as the sole carbon source to support cellular metabolism and growth. Unlike many industrial hosts, methanotrophs are challenging to genetically engineer as the requisite tools are generally not available and detailed microbial regulatory and physiological information are lacking. Intrexon's synthetic biology team has developed an advanced suite of tools that enables rapid manipulation of methanotrophic organisms including gene knock in/out, direct transformation/electroporation, and plasmid-based expression systems. Using these tools, we have generated methanotroph strains that are capable of upgrading natural gas to fuels and chemicals. Fermentation of wild type methanotrophs has been performed at commercial scale for conversion of natural gas into cell mass. Intrexon's engineered methanotrophs that produce isobutanol or farnesene, however, present a unique series of challenges for commercial scale up. Expression of a heterologous pathway for product generation places additional metabolic burdens on the cell, as carbon is diverted from primary to exogenous metabolic pathways for heterologous product production. We have developed a fermentation bioreactor protocol that supports growth of an isobutanol producing engineered methanotroph at industrially relevant cell densities. The current focus is to scale to a pilot facility. In addition, we developed a high-throughput platform to systematically test and iteratively optimize media composition and strain performance while also facilitating rapid design and testing of new pathways for improved isobutanol production from engineered strains.

**Michael Drozd, Arbiom**

***Leveraging the complete chemical value of the biomass: the enabler of viable second-generation bio-refineries***

Most recent development and industrialization efforts in the field of non-food biomass (ligno-cellulose: wood, straw...) have focused on large-scale production of bio-ethanol. This approach uses known technology (steam explosion, dilute acid) and addressing a mature and subsidized market (bio-ethanol). The challenge is that this approach greatly limits the ability to generate value from non-food biomass because most of the biomass can only be burned for energy and bio-ethanol is a fairly low value commodity. These limitations combined with the ever increasing cost of biomass itself (both in terms of raw cost due to increasing competing usages, and in terms of logistics) and the declining price of fossil oil, put at risk the economical viability of this approach. The true chemical value of the biomass goes beyond bio-ethanol, and leveraging it offers a short and long term economically viable opportunity for biomass.

Biométhodes has developed a bio-compatible and economically viable process for extracting the complete value of biomass. Biométhodes uses a gentler process (low temperature, bio-friendly reactants) so that each and every fraction of the biomass can be recovered in a non-degraded, inhibitor free state. This opens up a wider range of higher value applications based on C5 and C6 sugars as well as lignin, and enables the operation of more flexible, higher return bio-refineries. This presentation outlines the benefits of using a low temperature, phosphoric acid based process, combined with custom enzyme cocktails, to deliver high quality intermediates to the bio-economy.

**Ravikumar Rao, Praj**

***Production of Xylitol from Biomass based Hemicellulosic Substrate***

Production of renewable fuels, specifically bio-ethanol from lignocellulosic biomass, holds remarkable potential to meet the current global energy demand. It also ensures an improved energy security, job creation, strengthened rural economies, improved environmental quality through nearly zero greenhouse gas emissions, and sustainable environment. Production of Cellulosic Ethanol can be made more attractive with the introduction of Biochemicals as value added product. The concept is termed as Biorefinery which is an essential requisite for Biofuel economy. One of the Biochemical is Xylitol, a five carbon sugar alcohol which is presently produced from the catalytic hydrogenation of synthetic xylose. Hydrogenation of pentose stream from cellulosic feedstock faces lots of technical challenges and expensive purification steps. Production and purification of xylitol from biomass is critical due to the occurrence of impurities cogenerated during pretreatment used for fractionation of sugars. Praj Matrix has developed a unique technology for the production of Xylitol from cellulosic feedstock which is based on proprietary pretreatment and proprietary microorganism for the conversion of as is pentose sugars at high yield. The technology platform offers lowest capital and operating cost; has capability to use variety of lignocellulosic feedstocks to produce hemicellulosic streams in a highly efficient and cost-effective manner. The fermentation and down streaming processes have been optimized to gain more than 99% xylitol crystal purity. The technology has been validated at bench scale and will be scaled up to run end to end operations in 1 metric dry ton pilot plant. A scale up of 20-25 times in terms of order of magnitude is projected from the laboratory studies to the pilot plant.

**Todd Pray, Lawrence Berkeley National Lab**

***Integration and Chemical and Fuel Intermediate Production from Post-Consumer Municipal Solid Waste***

As populations grow and consumer packaged goods (CPG) consumption increases worldwide, the re-utilization and valorization of municipal solid waste (MSW) will become increasingly critical. Product and market development using this abundant feed-stream will require process optimization, integration, validation and scale-up demonstration and prototyping to mitigate environmental impact and carbon emissions. Incineration or landfill disposal is not a sustainable practice in the long term, and simple recycling may not always be feasible due to waste stream composition and logistics. To address this global environmental sustainability and economic issue FATER, a leading European CPG supplier and joint venture of Procter & Gamble and the Angelini Italian industrial group, is collaborating with the Advanced Biofuels [and Bioproducts] Process Demonstration Unit (ABPDU) at the Lawrence Berkeley National Laboratory. The ABPDU has been funded and managed by the US Department of Energy's Bioenergy Technologies Office (BETO) within the Office and Energy Efficiency and Renewable Energy (EERE). This presentation will highlight the process and product development FATER and the ABPDU have teamed on. We will provide an overview and strategic insights into the novel technologies, markets and molecules accessible via efficient and value-added waste stream utilization. This unique public-private partnership demonstrates how biomass and MSW conversion and upgrading via bioprocessing can influence key pathways to address global environmental sustainability barriers.

**Track 6: Renewable Chemicals and Biobased Materials**

Sponsored by:  **BERGESON &  
CAMPBELL PC**

**Session 1: Bioplastics Market Overview and Road to Hundred Percent Bio-PET  
Monday, Jul 20 8:30 am - 10:00 am Room: 520 CF**

**Moderator: Yu Shi, The Coca-Cola Company  
Michael Knutzen, The Coca-Cola Company**

## ***Bioplastics market overview and the road toward to 100% bio-PET with a successful story to tell***

Market demands of bioplastics including biodegradable ones and bio-based ones have increased in recent years. This presentation will give a brief market overview of bioplastics which shows the major growth among varieties of bioplastics in bio-based polymers instead of biodegradable ones. According to European Bioplastics's data, the largest demand of bioplastics is bio-PET 30 (30% bio-based PET), which is different from what it was predicted by European Bioplastics a few years ago. Currently the 30% bio-based PET demands are driven by international name brands such as Coca-Cola, the largest users of bioplastics globally and other companies including Nike, Heinz, P&G and Ford, that together with Coca-Cola, have formed the PlantPET Technology Collaborative to drive bio-based PET technology. 30% bio-PET is commercially produced and supplied by PET producers such as Far Eastern New Century ([www.fenc.com.tw](http://www.fenc.com.tw)), one of the top 5 PET producers in the world and the most integrated polyester/PET house owned by Taiwanese conglomerate Far Eastern Group ([www.feg.com.tw](http://www.feg.com.tw)). The next step in the advancement of bio-PET is reaching a 100% renewable resin, which requires the production of bio-based PTA and paraxylene. Virent has developed the BioForming® process that uses proprietary catalytic technology to convert biomass derived feedstocks to aromatic chemicals, including bio-paraxylene. The bio-paraxylene can then be used to produce bio-PTA. The main discussions of this presentation will be the conversions of two components of PET, MEG and PTA, to bio-based sourcing from different feedstocks and processing routes which are the key technologies for the economics and success of 100% bio-PET. Various approaches to bio-PTA or FDCA by using first or second generation feedstocks through biological and/or chemical conversions are covered in the presentation. After Coca-Cola demonstrated the successful 100% bio-PET bottle formation through their collaboration with Virent and FENC announced in ACS Green Chemistry Conference of 2014, they are one step closer to 100% bio-PET bottle production. FENC's, Coca-Cola's, and Virent's presentations tells the journey and looks at the future of a successful story of 100% bio-PET.

### **Ralph Lerner, Virent, Inc.**

Bioplastics market overview and the road toward to 100% bio-PET with a successful story to tell  
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### **Fanny Liao, Far Eastern New Century**

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### **Thomas Mallet, Axens**

#### *Innovative solutions for producing drop-in biobased components for Bio-PET*

As per a recent study performed by European Bioplastics, the global bioplastics production capacity worldwide is set to grow 400% by 2018. In this booming market, Bio-PET will be the most important product of all, driven by an increasing demand from end users (Coca Cola, Danone...). To face this market development, Axens aims to gradually expand its technology portfolio with the objective to provide innovative and profitable solutions for producing drop-in biobased component bio-PET from biomass. End of 2013, Axens launched the commercialization of Atol™, a technology for the most profitable production of polymer grade bio-ethylene by dehydration of 1st and/or 2nd generation renewable ethanol. The technology is the result of a partnership between Axens, Total and IFP Energies Nouvelles (IFPEN). Total developed a high performance catalyst formulation at its research center in Feluy, Belgium; IFPEN scaled-up the catalyst performance within an innovative heat recovery process; and Axens industrialized the catalyst formulation and finalized the process scheme with particular focus on energy efficiency. Atol™ relies on a new type of catalyst, providing high activity and a high selectivity toward ethylene, thus maximizing carbon efficiency and significantly reducing bio ethylene production cost. Axens has been selected to be the licensor of the Futurol Technology™, an innovative technology to produce cellulosic ethanol at competitive cost, in line with 1G bioethanol production costs. Futurol technology has been developed since 2008 by a consortium of 4 R&D partners (IFP Energies Nouvelles, INRA, Lesaffre and ARD), backed by seven industrial and financial partners. Their expertise covers the whole production chain, from biomass cultivation and transformation, through biocatalyst development and selection, to development and industrialization of fuels and petrochemicals production processes. The combination of Futurol and Atol technologies will allow Axens to provide a complete and optimized offer for the production of drop-in polymer grade bio-ethylene from biomass. The next step will be the development of the production of bio aromatics including paraxylene (terephthalic acid precursor) as the last link in the chain for the production of 100% bio-based PET.

## **Session 2: Commercializing Novel Biobased Products from Brand Owner and Producer Perspectives**

**Monday, Jul 20 10:30 am - 12:00 pm Room: 520 CF**

### **Moderator: John Shaw, Itaconix Corporation**

#### ***Commercializing Novel Biobased Products from Brand Owner and Producer Perspectives***

The industry is experiencing a new generation of bio-based products that are working their ways into green and standard detergent formulations. Although common themes exist, the specific value and drivers for using bio-based chemicals vary. Brand owners and ingredient producers will briefly introduce their objectives and efforts they have underway to meet them. After these introductory remarks, the panel will discuss trends and opportunities that they see for future adoption and growth and adoption of bio-based chemicals.

**Chantal Bergeron, Seventh Generation**  
***Transforming commerce- The Case of laureth-6***

**Rick Hanson, Croda**

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**Christian Johnson, BioFiber Solutions International**

***BioProducts: Conception to Commercialization***

We sit at the forefront of an evolution in the Non-Fuel Bio-Products industry. Because the non-fuel bio-product industry is still relatively new, this opens many doors for bioproduct thought leaders to conceive bio-based product ideas that will ultimately succeed in a projected \$273 billion dollar global market in 2020. However, there are many challenges that a bioproduct will face in its development from conception to consumer distribution. At this stage in the bioproduct industry's growth, the federal government continues to serve as one of the primary supporters of bio-based products. Bioproducts have yet to aggressively penetrate the commercial market and in to the hands of the public-facing consumer. With over 2000 products registered within the BioPreferred program by the end of 2014, there still exists room for new bioproducts to enter the market. However, how can a business leader conquer the feat of transforming a bioproduct from an idea to a physical product purchased from the shelf? BioFiber Solutions International (BFSI) will share its story of bringing its products to life in the market. BFSI is unique in that its operations cover the entire supply chain, from conception to manufacture, marketing, sale, and distribution, and that our products are in distribution. Our goal is to educate more entrepreneurs, manufacturers, and decision-makers on how to join forces and place their products in the consumer's hands, while equally encouraging a stronger movement in the development and education of bioproducts. We aim to inform these parties on what federal considerations and policies they, and their manufacturers, must take or understand before leaping from conception towards manufacture. In addition, we will address important considerations for marketing and consumer education. Our objective is that attendees of World Congress will leave the presentation with a clearer road-map for taking their product to the next step in the supply and distribution process, and develop a greater sense of confidence for placing their bioproduct in the consumer's hand.

**Rich Engler, Bergeson & Campbell**

***Leveraging "Green" for Visibility***

The conversation around biobased chemicals often focuses narrowly on whether a product is "green" and if a company can sell its product at a "green premium." This is only part of the story and misses the primary task of biobased chemicals: demonstrating commercial advantage. Although there are some government mandates for biobased content, generally biobased chemicals must compete on price and performance or they will find themselves limited to niche markets. On the other hand, biobased products that are competitive can leverage their "green" status for visibility to garner more market share. There are a number of government and non-governmental programs that provide preference for or recognition of biobased chemicals.

**Session 3: Biology, Catalysts, Electrocatalysis, Oh My: Status Check on "The Many Ways to Make Bioproducts"**

**Monday, Jul 20 2:30 pm - 4:00 pm Room: 520 CF**

**Moderator: Jim Lane, Biofuels Digest**

**Dave Law, Liquid Light**

**Mark Herrema, Newlight Technologies**

**Timothy Cesarek, Enerkem, Inc.**

***Biology, Catalysis, Electrocatalysis, Oh My: Status Check on The Many Ways to Make Bioproducts***

Our 'bio' conference includes both bio-based feedstocks and bio-conversion. Together, there are a lot of ways to skin a cat, to result in more sustainable fuels, chemicals and materials. This session offers an unusual 'tour de horizon,' with leading practitioners of varied approaches offering a brief summary of their technology and stage of market development. This is followed by a deep dive Q&A by the moderator to help identify the best applications for each approach and tradeoffs. Expect this to be lively.

**Jay Kouba, Trelys**

***Gas as a Biotech Building Block***

Trelys is developing a versatile bioconversion platform based on methanogenic archaea, organisms that in nature convert hydrogen and carbon dioxide to biomass and methane. Trelys has developed strains which overproduce the feed amino acids, lysine, threonine and methionine. The presentation will review the broad market potential and attractive economics of methanogen mediated conversion of gas to commercial products.

**Session 4: How to Push the Circular Economy Through CO, CO<sub>2</sub>, and C<sub>1</sub> Utilization**

**Tuesday, Jul 21 2:30 pm - 4:00 pm Room: 520 CF**

**Moderator: Manfred Kircher, CLIB2021**

**Sean Simpson, Lanza Tech**

**Scott Noll, ConcordBlue Energy Inc.**

***How to push the circular economy through CO utilization***

Concerning carbon the bio-economy is a real model of a circular economy by i) recycling CO<sub>2</sub> through photosynthesis and transforming vegetable biomass or ii) by direct conversion of CO into chemicals. While utilization of biomass is broadly applied the use of CO-rich gases is currently on the way to becoming a mature platform technology. Its advantage is at first in the variety of feedstock it can use. The spectrum spans from agro- and forestry-based biomass through after-use consumer products in municipal solid waste, to industrial CO-emission from industrial processes such as steel production and oil refining. Second this technology has the potential to not only produce a quite simple chemical entity like ethanol but also to offer a broader portfolio of molecules of industrial relevance. The underlying technology of gas fermentation uses CO, and where available H<sub>2</sub>, gases as the sole source of carbon and energy for product synthesis. The fermentation process has been proven at a pilot scale in China with steel making gas residues. If solid materials are used these must be gasified to generate the CO-rich gas stream for fermentation. Various gasification technologies have been developed, or are under development internationally, each seeking to address differences in the input materials that can be used as a feedstock. A pilot-scale combination of the two processes is being constructed in the US, and will be operational in 2015. This panel will present the technical state of the art and of commercial implementation of CO gas fermentation. It will discuss pros and cons as well as economical implications of this disruptive technology.

**William Bardosh, TerraVerdae BioWorks**

***Production of High Value Materials***

TerraVerdae BioWorks develops biodegradable bioplastics, biobased chemicals, and bioactives from environmentally sustainable, single carbon (C<sub>1</sub>) feedstocks. TerraVerdae's industrial biorefinery platform combines systems biology, bioprocess engineering, and polymer chemistry capabilities to produce high-value, performance biomaterials. These products have applications in the agriculture/horticulture, personal care, dietary supplement, and associated markets. TerraVerdae's synthetic biology platform and proprietary genetic tools have developed biobased products and challenging proteins for companies and institutes worldwide.

**Dirk den Ouden, Photanol**

***Turning CO<sub>2</sub> into high-value chemicals - enabled by bacteria, powered by the sun***

Photanol has developed a breakthrough technology that turns CO<sub>2</sub> from an issue into an asset. Our platform can convert CO<sub>2</sub> directly into valuable products, powered by the sun. We use cyanobacteria that live on CO<sub>2</sub> and sunlight. Our microbiologists engineer these bacteria by introducing properties (genes/enzymes) of other organisms (such as fermentative bacteria, yeasts and plants) to have them produce and excrete valuable compounds by design. They now divert their energy use from growing and multiplying toward making the desired product in a very efficient way. This production technology can

produce an almost infinite number of chemicals for use in fuels, plastics, food, personal care products, etc. Not made from fossil resources, not made from crops, but from CO<sub>2</sub> and energy provided by the sun. This platform offers our partners a way to avoid dependence on fossil resources, to avoid using crops, to obtain a more economically attractive route to an existing product or to get access to new products. Photanol has proof of concept on a wide range of products and operates a pilot plant to prove reliable production under relevant conditions. In this session we will share an update on the achievements to date and the roadmap to commercial production.

**Session 5: Market Opportunities for Biobased Monomers and Materials**  
**Wednesday, Jul 22 8:30 am - 10:00 am Room: 520 CF**

**Moderator: James Wynn, MBI International**  
***Cellulosic Succinic Acid: A Reality!***

The production of bio-succinic acid via fermentation is one of the most developed in the recent crop of biobased chemical technologies. Several technologies have emerged and are in various stages of scale-up and commercialization. All current technologies use glucose as the primary feedstock. With an increased focus on sustainability (and concerns over competition with food availability) a technology to make succinic acid from non-food sugars would be game-changing. MBI has developed two separate but compatible technologies: the AFEX biomass pretreatment technology and the A. succinogenes-based succinic acid technology, which when combined allow the efficient and scalable production of cellulosic bio-succinic acid. Hydrolysis of AFEX-treated corn stover pellets at >20% (w/w) solids loading was demonstrated in a 3800L conventional fermenter, producing a sugar stream containing >100 g/L of highly fermentable sugar. AFEX sugars have been used to produce succinic acid without any detoxification, showing that the combination of the AFEX pretreatment and the A. succinogenes fermentation system represent a scalable technology for the production of cellulosic bio-succinic acid. The distinctive features of the two technologies and how they interplay to efficiently produce cellulosic bio-succinic acid will be described, with a focus on the advantages of the AFEX-derived pellets as a biorefinery feedstock and the simultaneous C5-C6 utilization by the succinic acid production technology.

**Markus Piepenbrink, BASF SE**

***Renewables-based Chemicals - from raw material opportunities to increased performance***

BASF will give an overview and some specific insights on its activities in the biochemicals arena. This includes technology screening, R&D activities, market development and examples for products targeting opportunities from raw materials diversification to performance increase. This embraces not only renewables-specific innovation, but also the correlation to conventional chemical business (markets, regional aspects, supply chain integration, etc.) as well as industrial applications.

**Cesar Granda, Earth Energy Renewables, LLC**

***Production of Highly Pure Organic Chemicals from Anaerobic Digestion***

Unlike pure culture fermentations, anaerobic digestion (AD) is an extremely robust and versatile process for bio-conversion of organic materials. AD employs natural consortia of microorganisms that adapt very efficiently to most organic feedstocks and operating conditions. Unlike other fermentation processes, AD requires no aseptic conditions, no genetically engineered organisms, and no extraneous enzymes. As a result, AD is also the most inexpensive bio-conversion process in the market. However, conventional AD produces relatively low-value methane as its main product. Methane is the final product in the AD conversion stages. In AD, acidogenic bacteria break down organic materials into simpler molecules (e.g., free sugars, amino acids, glycerol) and then they convert these simpler molecules into short- and medium-chain fatty acids (e.g., propionic, butyric, caproic acids). These fatty acids are then, in turn, converted to methane and CO<sub>2</sub> by methanogenic organisms. These fatty acids are, therefore, produced in higher yields (>2.5X) than methane and also, once recovered, they demand considerably higher prices (>15X) than methane, thus drastically improving AD economics and value proposition. In addition, these fatty acids enjoy a very rich chemistry; therefore, they may be converted into other high-value chemicals such as esters (e.g., methyl or ethyl propionate, methyl or ethyl butyrate), primary alcohols (e.g., propanol, butanol, hexanol) and even olefins (e.g., propylene, butylene) and fuels (e.g., gasoline, jet fuel). Earth Energy Renewables (EER) is commercializing its patented technology for efficiently inhibiting methane in AD to selectively produce the fatty acids and the subsequent recovery of these valuable fatty acids. EER has successfully demonstrated in its pilot facility that it is able to readily produce these fatty acids in high yields and with remarkable high purity without the need for expensive purification.

techniques. The recovered fatty acids are of excellent quality for the chemical market or to be used as feedstocks for the production of other valuable organic chemicals. The high value of these organic chemicals and the efficiency of its technology allow EER to quickly achieve profitability at small scales, with low investment and risk. This strategy allows EER to proceed with a series of small, but profitable, stair-step increases in scale to decrease engineering and financial risk as the company continues to scale up to larger facilities in the future.

**Marcel van Berkel, GFBiochemicals**  
***Bringing Biobased Levulinic Acid to Market***

Global demand continues to grow for sustainable biobased products. Levulinic acid has significant potential to replace petroleum-based products in both the chemical and biofuel sectors. It can bridge gaps between market segments while enabling new market applications. GFBiochemicals is the first company to produce levulinic acid directly from biomass at full commercial scale. With its own IP portfolio and a commercial-scale plant in Caserta, Italy, GFBiochemicals' breakthrough process is bringing sustainable levulinic acid to market. Levulinic acid has already been recognized by the US Department of Energy as one of the 'top ten' promising biobased building block chemicals. Of this list, levulinic acid and ethanol were the only two substances with applications in both chemicals and fuels. This presentation will demonstrate the full potential of levulinic acid and GFBiochemicals' plans for wider commercialization. In chemicals, levulinic acid offers one of the largest families of value-added derivatives and with it a range of applications throughout the value chain, such as pharmaceuticals, agrochemicals, non-toxic plasticizers and safer solvents in coatings. In biofuels, levulinic acid derivatives can be used to produce biodiesel and renewable jet fuel.

**Philip Goodier, Plaxica Limited**  
***Plaxica Versalac: Transforming the cost base of lactic acid and bio-propylene glycol manufacture***

Nearly all processes to convert biomass to green chemicals rely upon the conversion of cellulose to fermentable sugar. The operating cost of these processes is dominated by two factors: the energy and / or enzyme required to hydrolyse the strong cellulose molecule to clean fermentable sugar and the capital cost of the biomass processing unit. Plaxica is taking a radically different approach in two areas: Firstly, we focus on the hemicellulose content of biomass. This is easier to extract and hydrolyse than cellulose, leading to a large reduction in operating costs. Hemicellulose-rich by-product streams already exist in a number of existing industrial processes – for example in the pulp industry – so the capital for the biomass to hemicellulose step has already been spent. Secondly, we use a low cost chemical process to convert sugars to lactic acid – with a particular focus on the C5/C6 sugar streams from the hydrolysis of hemicellulose. Our chemical process is tolerant of the impurities present in biomass. Lactic acid is a valuable C3 platform chemical. Its conversion to polylactic acid green polymers is well known – our process transforms the cost and performance of PLA. Plaxica's lactic acid can also be used to produce green propylene glycol at a lower cost than the existing petrochemical route.

**Session 6: Renewable Chemicals for the Production of Thermoplastics and Thermosets**  
**Wednesday, Jul 22 10:30 am - 12:00 pm Room: 520 CF**

**Moderator: Matt Engler, Verdezyne**  
***Commercialization of Renewable Nylon Intermediates***

Verdezyne is developing a platform of bio-processes for cost-advantaged production of renewable nylon intermediates, including adipic acid, sebacic acid and dodecanedioic acid (DDDA). DDDA, the first product to be commercialized, is used to manufacture nylon 6,12 for engineered plastics requiring special properties such as high chemical, moisture and abrasion resistance. This paper will discuss the path to commercialization for the first of Verdezyne's proprietary yeast-based fermentation technologies, which offer both feedstock flexibility and cost advantages. Other platform targets will be briefly discussed, including the next launch, adipic acid, used in the manufacture of nylon 6,6 and thermoplastic polyurethanes. The development and commercial introduction of these bio-based products provides the world with cost-effective, renewably sourced, and greener alternatives to the current environmentally unsustainable petrochemical processes used to make these ingredients.

**Patrick Gruber, Gevo**  
***Low Cost Alcohols Converted to Chemicals, Materials, and Fuels***

Alcohols such as ethanol and isobutanol can be made at low cost by fermentation from renewable resources. Agricultural based feedstocks are extremely complex. Production of ethanol and isobutanol serves to simplify the production process in that the complexity is removed, and simple, clean alcohols can be used for conventional chemistry. Ethanol can serve as a raw material to make: acetone, propylene, n-butanol, diesel fuel, and hydrogen. Isobutanol can be used to make polyester, PMMA, jet fuel, isocatane and other chemical products. The products produced from ethanol and isobutanol can be competitive with the petrochemical equivalents. This presentation will give an overview of the processes and economics to make competitive biobased chemicals and materials from low cost alcohols.

### **Deepak Dugar, Visolis**

#### ***Bio-based high performance polymers***

Visolis is developing bio-based processes for production of carbon-negative, high-performance polymers to replace petroleum based processes with total addressable markets over \$10 billion. The shift in the production of ethylene from naphtha to natural gas liquids (which does not produce C4-C6 by-products) has led to supply shocks and rising C4-C6 chemicals prices. Furthermore, these processes remain extremely energy intensive and reliant on fossil sources. Our process enables cost competitive production of bio-based elastomers, unsaturated polyester resins, super adsorbent polymers, and other products using a variety of feedstocks like agri-residues, dextrose, glycerol and syn-gas. The high-yield process is a platform technology based on engineered microbes coupled with efficient processing. Furthermore, flexibility in the production process allows for rapid changes in the product mix in response to volatile market conditions reducing commercial risk much like a modern refinery. The Visolis process would reduce the production cost of various products by 30-50% relative to the petroleum-based equivalent, while reducing process greenhouse gas emissions by 70%. As a bio-based process, our technology uses the photosynthetic capability of plants to fix CO<sub>2</sub> into structural materials that can sequester carbon for decades. Resin applications alone represent a carbon sink potential of over 200 million tons CO<sub>2</sub>e, equivalent to planting 2 billion trees.

### **Paul Caswell, Cathay Industrial Biotech, Ltd.**

#### ***Cathay Industrial Biotech Ltd***

Cathay provides technological and commercial leadership in industrial biotechnology. Cathay is the first pure-play industrial biotechnology company to successfully deliver commercial-scale products for over 10 years. Cathay's biotech technology platform includes an integrated genetic engineering to commercial construction and development process that has moved it to a leadership position in the production of LCDAs, which are used in nylons, adhesives and corrosion control lubricants. Cathay's LCDAs are sold in over 15 countries, providing exceptional value to customers. In 2014 Cathay launched Terryll® PA56 made from the new monomer, pentane diamine. Terryll® is a 47% renewable polyamide and the first odd/even nylon providing improved properties for use in textiles.

### **Tom Boussie, Rennovia**

#### ***Bio-Based Monomers for 100% Renewable Nylon***

Rennovia is developing scalable, chemical-catalytic conversion processes for the production of high-value chemical products from renewable raw materials. Employing advanced catalysts and industrial chemical manufacturing technologies, Rennovia is focused on the production of drop-in products from widely-available carbohydrate feedstocks. Rennovia's current large-volume product targets include adipic acid (AA) and hexamethylenediamine (HMD), both monomers for nylon-6,6 production. Nylon-6,6 is a 5.3 B lb/yr, \$7 B global market. Rennovia's renewable AA technology has been piloted for three years and is currently being scaled up with development partner Johnson Matthey Process Technologies. The process technology for bio-based HMD is currently in pilot phase at Rennovia, moving to an integrated mini-plant in 2016. Both processes are operating close to target commercial metrics and have projected production costs significantly advantaged over current petrochemical processes.

## **Track 7: Advanced Biofuels and Biorefinery Platforms**



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Advanced Biofuels

**Session 1: Biofuels and Federal Regulation. The Roadmap to Regulatory Approval  
Monday, Jul 20 8:30 am - 10:00 am Room: 520 BE**

**Moderator: Adam Gustafson, Boyden Gray & Associates**

***Biofuels and Federal Regulation: The Current State of Play***

A federal court in Washington D.C. is expected to rule soon on a challenge by ethanol producers to EPA's rule governing approval of new high-octane certification fuels for new vehicles. This presentation will address the Court's decision and the auto industry's demand for high-octane fuel like a mid-level ethanol blend to power the next generation of engines needed to meet increasingly stringent fuel efficiency standards. Boyden Gray & Associates recently filed a case on behalf of the States of Kansas and Nebraska, the Urban Air Initiative, and the Energy Future Coalition challenging anti-ethanol bias in EPA's latest vehicular emissions model—MOVES2014, which States must now use in their State Implementation Plans for National Ambient Air Quality Standards. This presentation will address the flaws in EPA's model and the underlying EPA's fuel effects study and the process of challenging "arbitrary and capricious" agency action in court.

**David Glass, D. Glass Associates, Inc.**

***The Emerging Roadmap to Gain Regulatory Approvals for Uses of Genetically Modified Algae for Biofuel or Bio-Based Chemical Production***

In spite of some initial uncertainty, a road map is emerging for how industrial uses of genetically modified algae and cyanobacteria for biofuel and bioproduct production will be regulated. This presentation will give an overview of the U.S. regulatory landscape that such projects might face, and the scientific issues underlying these regulations. In the United States, industrial biotechnology activities using genetically modified organisms might be covered either by regulations of the U.S. Environmental Protection Agency or the biotechnology rule of the U.S. Department of Agriculture, and there has been a difference of opinion over the years within the algae community about which agency is better qualified to have jurisdiction. Many observers have felt that EPA's biotechnology rule under the Toxic Substances Control Act (TSCA) offered a clearer legal and definitional basis for coverage of modified microalgae than the USDA rule. In fact, in recent years, EPA has indeed reviewed and allowed several proposed uses of modified algae or cyanobacteria, including at least four Microbial Commercial Activity Notices (MCANs) for proposed commercial applications and a series of TSCA Experimental Release Applications (TERAs) for the first outdoor field tests of modified algae in open ponds. While this might not rule out the applicability of the USDA regulations to some future proposal, EPA's actions establish that it considers algae and cyanobacteria to fall within the purview of the TSCA regulations. The regulatory regimes of EPA and USDA will be discussed, along with an analysis of their applicability to uses of modified microalgae or cyanobacteria. Strategies to comply with these regulations and to address environmental impact issues will be presented. The presentation will also cover corresponding regulations in countries outside the U.S., and contrast their regulatory approaches to those of the U.S. agencies. David J. Glass, Ph.D. is an independent consultant specializing in renewable fuels and industrial biotechnology regulatory affairs, with over 25 years experience with U.S. biotechnology regulations, and extensive familiarity with international biotechnology and renewable fuel regulations. He formerly served as director of regulatory affairs for Joule Unlimited Technologies.

**Boyden Gray, Boyden Gray & Associates**

***Biofuels and Federal Regulation: The Current State of Play***

A federal court in Washington D.C. is expected to rule soon on a challenge by ethanol producers to EPA's rule governing approval of new high-octane certification fuels for new vehicles. This presentation will address the Court's decision and the auto industry's demand for high-octane fuel like a mid-level ethanol blend to power the next generation of engines needed to meet increasingly stringent fuel efficiency standards. Boyden Gray & Associates recently filed a case on behalf of the States of Kansas and Nebraska, the Urban Air Initiative, and the Energy Future Coalition challenging anti-ethanol bias in EPA's latest vehicular emissions model—MOVES2014, which States must now use in their State Implementation Plans for National Ambient Air Quality Standards. This presentation will address the flaws in EPA's model and the underlying EPA's fuel effects study and the process of challenging "arbitrary and capricious" agency action in court.

**Richard Engler, Bergeson & Campbell**

***TSCA and the Regulation of Biofuels***

Biofuels and biofuel products are chemical products. As such, in addition to the regulatory requirements under the Clean Air Act (CAA) Renewable Fuel Standard or fuel additive registrations, all biofuel and

biofuel products are regulated under the Toxic Substances Control Act (TSCA), the federal chemical control framework that addresses chemical substances that are not defined under TSCA as food, drug, or pesticide related. Toward that end, we invite attendees to ask themselves – Has your company followed the appropriate TSCA approval procedures for your biofuel or biofuel products? How would your company fare if the U.S. Environmental Protection Agency (EPA) conducted a TSCA audit on your biofuel manufacturing facility?

- Have you verified the identity of your product with a TSCA nomenclature expert? Is that verified identity listed on the TSCA Inventory of Chemical Substances?
- Did your company conduct any research and development (R&D) work on a new biofuel or biobased chemical product? Did you follow all procedures and maintain all applicable paperwork required for chemical R&D work?
- Does your company's biofuel or biobased chemical manufacturing process involve the formation of chemical intermediates? Have you verified and documented that those chemical intermediates comply with TSCA?
- Does your company use recycled waste products as feedstock? Have you verified and documented that the recycled waste products comply with TSCA?

All of these issues, and more, must be addressed BEFORE commercial manufacture begins. Otherwise, EPA could consider your company to be non-compliance with TSCA which could result in fines that quickly escalate to \$100,000+ and perhaps more importantly, a devastating reputational impact. This presentation will highlight the critical aspects of regulatory approval for chemicals under TSCA and hints on how to navigate the TSCA process.

**Heather Shearer, Biotechnology Section, Environment Canada**

***New Substances Notification: a Federal Regulatory Perspective on Organisms used in the Bioeconomy***

In Canada, production organisms, such as organisms used in fermentation, CO<sub>2</sub> capture, and biofuels production, as well as the new substances they produce, may be subject to federal regulations administered by authorities including Environment Canada, Health Canada, the Canadian Food Inspection Agency, and the Department of Fisheries and Oceans. The manufacture or import of certain animate products of biotechnology (but not ones used in fertilizers, feeds, veterinary biologics or pesticides), including genetically modified organisms and certain naturally-occurring microbes, are regulated under the Canadian Environmental Protection Act, 1999 (CEPA 1999). Under current regulations, these products of biotechnology are subject to notification in order that a science-based risk assessment may be conducted. The purpose of the risk assessment is to manage any potential harm to the environment or human health. This presentation will provide a description of the New Substances Notification Regulations (Organisms), and the notification process under the current regulatory framework, including an overview of the data requirements to be met in a successful notification process. Furthermore, an indication of how other regulatory authorities in Canada may be triggered under specific circumstances will be provided, with a particular emphasis on the biofuels industry.

**Session 2: Taking Innovative Technology from Laboratory to Commercialization**

**Monday, Jul 20 10:30 am - 12:00 pm Room: 520 BE**

**Moderator: David Bressler, University of Alberta**

**Tim Brown, Renmatix**

**Ray Miller, Verdezyne**

***Taking Innovative Technology from the Laboratory to Commercialization: An Industrial Perspective***

Design of a new and efficient biotechnological method is the first of many steps towards commercialization. This panel will discuss various aspects of the commercialization process that occur on the industrial side, once a viable technology has been developed in the lab, as well as other economic factors that must be considered. Topics to be discussed include scale-up from the laboratory to pilot plant, policy implications, feedstock supplies, downstream applications, and the shift from biofuels to bio-based chemicals. The following group of panelists will provide a "lessons learned" platform with engaging discussions that will benefit attendees having experience with this process, as well as those who are interested to learn what it entails. David C. Bressler, the moderator for this panel, from the University of Alberta, the Biorefining Conversions Network, and Forge Hydrocarbons, has experience and insight to talk about scaling up technologies developed in the laboratory to the pilot plant scale. David will describe

several facets of the process including intellectual property protection, technical requirements of scale-up, and funding procurement. Mike Hartmann, the Executive Vice-President of BioAmber, Inc. will outline the various stages of the company, from development to growth, and the challenges facing the industry at each of these stages, including the importance of public policy. Insights into their effects on growth and competitiveness will be discussed. Tim Brown is the Chief Strategy Officer and Vice-President of Finance at Renmatix and has a great deal of expertise in strategic planning, corporate finance, as well as sustainable technology, and product development. Using North American sugar sources as an example, he will examine the issues surrounding securing feedstock supplies such as treatment, location and building relationships. This will be connected to a discussion on downstream end users of products and demand driven commercialization of technology. Ray W. Miller worked for many years at DuPont carrying out business development in Industrial Biosciences and is currently the Chief Business Officer of Verdezyne, Inc. Ray will discuss the use of biotechnological processes for the production of drop-in chemicals, which are typically produced by the petrochemical industry. The principles behind these cost-effective renewable processes will be outlined, as well as the strategic partnerships that are necessary for commercialization. This group of panelists will describe various parts of the commercialization process from an industrial perspective and give insight from their personal experiences. The aim of the panel is to address the efforts and considerations that must be made outside of the laboratory in order to successfully market a technology.

### **Martin Mitchell, Clariant**

#### ***Cellulosic Ethanol: commercialization and application in biofuels and biochemicals***

More and more economies are looking at possibilities to substitute fossil resources by renewable ones, both to secure energy supply and to increase sustainability. The transport sector in particular will continue to be largely dependent on liquid energy sources and advanced biofuels are the preferred way to efficiently reach renewable substitution goals in the short to medium term. But also the chemical and materials industries see an increased call for more sustainability and renewables in their products. Lignocelluloses show a huge potential as a new feedstock for the production of advanced biofuels and biobased chemicals globally. The key technical hurdle in the past has been how to access the sugars bound in the lignocellulosic material. In recent years technological breakthrough has been achieved through a variety of technologies, in particular enzymatic conversion. The matter now is to validate production processes and optimize the efficiency for large scale competitive production, in particular through high process yields combined with low OPEX and CAPEX. Clariant's sunliquid® technology overcomes these challenges through a thorough and entirely integrated process design and innovative technology features offering a one-stop shop solution flexible to be used to convert different feedstock and adopt to various plant concepts. The production cost can compete with those of first-generation bioethanol and the greenhouse gas savings of the sunliquid® ethanol are 95% compared to fossil fuels. Realisation on an industrial scale is no longer merely a dream. Since July 2012 Clariant has successfully been operating a demonstration plant in Straubing, Germany, with an annual capacity of 1,000 tons (1.25 million litres, 330,000 gallons), converting approximately 4,500 tons of lignocellulosic feedstock per year. After focussing on wheat straw for the first months of operation, in May 2013, first runs with corn stover and sugarcane residues also showed good results and validated the technology further. This was a new milestone reached by the project, confirming that the technology can be implemented worldwide. The results obtained in the demonstration plant have been incorporated into the recently finished sunliquid® Process Design Package. It thus delivers the technological blueprint for commercial facilities between 50 and 150 kt (20 - 60 million gallons) of ethanol production per year. In addition, a fleet test by Clariant, Haltermann and Mercedes-Benz brings cellulosic ethanol onto the road as an E20 blend for the first time. All three companies contribute with their expertise to the project. sunliquid® 20 is a premium-grade petrol containing 20% cellulosic ethanol, produced at Clariant's sunliquid demonstration plant in Straubing, Germany. The fuel is tested in Mercedes-Benz series vehicles and shows excellent performance and sustainability results: an increase in fuel demand and 50% reduction in particle emission. In addition to the application in the transport sector, the technology offers a platform for the biobased chemicals sector. E.g. cellulosic ethanol can be converted into bio-MEG for the production of biobased chemicals. In addition, sunliquid® offers access to low cost cellulosic sugars for further conversion.

### **Session 3: The Aviation Biofuels Opportunities**

**Monday, Jul 20 2:30 pm - 4:00 pm Room: 520 BE**

**Moderator: Luuk A.M.vanderWielen, TU Delft  
Ignaas Caryn, KLM-AirFrance**

**Olivier Rolland, TOTAL – New Energies**  
**Telma Teixeira Franco, UNICAMP**  
**Maria Fiskerud, SKyNRG**

### ***The Aviation Biofuels Opportunities***

The aviation sector has worldwide agreed to reduce their GHG-footprint in 2050 to 50% of that in 2005, and to grow carbon neutral from 2020 onwards. This is a huge ambition from a sector that still grows 4-5% annually of which roughly half of the growth can be compensated by improved aircraft technology, operations and infrastructure, but the other half has to come from use of aviation biofuels. The global scenario is roughly a doubling of fuels consumption towards 2050, of which the majority has to be sustainable biofuels with GHG-savings of 80+%. Today's aviation biofuels are mostly based on hydrotreated used cooking oils and other oil residues, but the required scale and net GHG-savings require availability of biorenewable and lignocellulosic biofuels. These are emerging. This development represents a huge opportunity for the biobased industries, a very attractive and significant investment possibility and a significant challenge for all stakeholders involved. Most scenarios indicate that this development can only be successful with joint efforts of all stakeholders involved: aviation and fuels industries, agro-sector investors, governments and technology providers. Several countries have produced national strategy documents to cope with this opportunity. The proposed session brings together industry and academic leaders from the aviation sector to address bottlenecks to reach this global goal, discuss options to solve those, and map the path forward. The session will discuss impacts from logistics and scale, feedstock-technology combinations, biorefinery and cascading, and integrated development in industry clusters. The format is an interactive panel discussion on provocative propositions, and the stage is set by pitches of the panelists.

**Session 4: Utilizing Feedstocks and Wastestreams in Biofuels and Biorefinery Platforms**  
**Tuesday, Jul 21 2:30 pm - 4:00 pm Room: 520 BE**

**Moderator: Fatma Mechmech, Polytechnique Montreal**

### ***Use of alfalfa juice as nitrogen source for butanol production by Clostridium Acetobutylicum.***

Biobutanol is produced from a wide range of lignocellulosic feedstock as a carbon source through a biochemical route called Acetone-Butanol-Ethanol (ABE) fermentation using *Clostridium* species. Given the fact that these types of raw materials are rich in carbohydrates and poor in nitrogen the fermentation medium should be always supplemented with expensive nourishing elements, especially nitrogen sources, necessary for the growth and the metabolism of *Clostridia* strain. Agricultural residues can be a promising alternative. Indeed, green plants (grass, clover or alfalfa) are used worldwide for the production of pellets fodder to feed livestock. The drying process to produce the pellets is often preceded by a pressing step generating large volumes of plant juice which are considered as "difficult" waste streams causing environmental problems. Its richness in nitrogen, protein and vitamins makes this juice an excellent supplement of fermentation medium. The objective of this study is to enhance butanol production by developing a newly ABE fermentation medium based on the substitution or the supplementation of expensive nutrients by alfalfa juice. Three different cuts (June, July and August) of early-bloom Canadian alfalfa have been pressed, analyzed and compared. Based on the composition of the juice extracted from each sample in terms of C:N ratio and nutrient content, the most suitable juice has been selected to be used in fermentation. To investigate the effect of nitrogen supplementation on *Clostridium* growth and butanol production, the fermentation experiments were firstly carried out using a synthetic standard medium in the presence of 60 g/L of xylose as a carbon source and the addition of yeast extract concentrations. Alfalfa juice was then used to replace yeast extract in the medium or to supplement it at different proportions 10, 25 or 50% v/v. The results showed that the best C/N ratio, enhancing the butanol production is comprised between 25 and 35. When replacing the yeast extract by the alfalfa juice at a nitrogen concentration of 0.9 g/L the butanol production was about 3.49 g/L value equal to that obtained with a standard synthetic medium. And finally, the supplementation of medium with alfalfa juice at 10%v/v enhanced butanol production to achieve a concentration of 5.62 g/L.

**Antonio Marzocchella, University di Napoli**

### ***Butanol Production by fermentation of fruit wastes***

The continuous interest in chemicals and fuels production from renewable resources has renewed the attention to the production of butanol by the biotechnological route. However, the Acetone-Butanol-Ethanol (ABE) fermentation route - despite widely adopted during the first half of the last century - is still open to investigation. *Clostridia* - saccharolytic butyric acid-producing bacteria - are able to produce ABE

adopting a wide spectrum of carbohydrates. However, the cost and the availability of the fermentation feedstocks are still a key issue for the economic success of the butanol production processes. Industrial and food waste(water) streams are particularly interesting as renewable substrates because they are abundant and un-competitive with food sources. In particular, agro-industrial wastes - peels, seeds, and pulps - are about 50% of the raw processed fruit and their disposal is an economical-environmental critical issue for the industries (Mamma et al. 2008; Oberoi et al. 2010). However, the high fraction of sugars of the fruit peels makes them a promising interesting feedstock for the production of chemicals such as butanol (Sánchez-Orozco et al. 2012). This contribution reports on the feasibility of bio-butanol production by fermentation of fruit peels. Apple and pear peel extracts were tested as substrate for the fermentation. The anaerobic solventogenic bacterium *Clostridium acetobutylicum* DSM 792 was adopted for the fermentation processes. Batch tests were carried out under a wide interval of peels to water mass ratio. The conversion process was characterized in terms of metabolites and cell production, sugars conversion, specific velocity of butanol production and of sugar consumption, butanol and cell yields. The continuous conversion in a biofilm reactor was successful carried out. Mamma et al. (2008). *Bioresour. Technol.* 99(7), 2373-2383. Oberoi et al. (2010). *J. Agric. Food Chem.* 58(6), 3422-3429. Sánchez-Orozco et al. (2012). *Energies* 5(8), 3051-3063

**Richard Smith, The University of Nottingham**

***Bioproduct Generation from Artemisia Annua L and the Waste Streams Generated During the Production of Artemisinin***

*Artemisia annua* L. (*A. annua*) is an annual herb grown in many tropical and subtropical countries such as Madagascar, India and Kenya. It is cultivated by farmers in these regions to extract artemisinin, a vital active ingredient used in the treatment of Malaria. With increasing competition from synthetic producers, the cost of farming the herb is becoming overwhelming for the farmers. This study looks at increasing the value of *A. annua* by investigating the ability to extract artemisinin and other marketable phytochemicals; from the biomass and the waste streams generated during artemisinin production in a biorefinery. The first section of this work looked at the potential for *A. annua* leaf and the waste streams to be used as a biofuel source. Proximate analysis showed that for all the samples the volatile matter was the highest with leaf averaging at around 60% volatile matter in comparison to the waste stream samples which had an average of 94%. Ultimate analysis showed that the processed and non-processed leaves all had similar carbon, hydrogen and nitrogen compositions with around 45% carbon content at a co-efficient of variance of 0.01. The calorific values of the *A. annua* waste streams were reasonably high at a heating value of 44 MJ/kg/dry basis. In comparison, the processed and non-processed leaves averaged at a high heating value of 18MJ/kg/dry basis. The results showed that *Artemisia annua* L waste streams and processed leaves have the potential to be used to generate useful bioproducts. Kinetic studies were also carried out on the samples using the Direct Arrhenius method to analyze the data and the results were compared to other biomass sources. The samples were screened for the presence of several chemical products. The GC-MS results showed that artemisinic acid, arteannuin b, phtyol, artemisinin as well as other phytochemicals were present in both the leaf samples and the waste streams. Artemisinin, artemisinic acid, hexacosanol, octacosanol, dihydroartemisinic acid and ferulic acid, were chosen to be studied and quantified in the biomass samples and the waste streams.

**Mohd Badri Dawood Abbasi, Malaysian Biotechnology Corporation**

***Advanced Biogas as Alternative Feedstock for Non-Fossil based replacement products***

The bio-based products are currently facing a challenging period due to downward trends of global oil prices impacts. One of the key drivers for this bio-based products have been the high oil prices which makes fossil-based replacement products are economically feasible and offer good margin to the companies producing bio-based products. The main feedstock for these bio-based products is renewable raw materials to substitute fossil based raw materials. In view of the latest development in the downwards trends of global oil prices, the fossil-based replacement products are vulnerable to the global oil prices and thus make the investment in the bio-based products economically unattractive. Alternatively, Industry players have begun realizing the underlying potentials within the biogas industry and rethinking to move beyond electricity. The application of advanced biogas will unlock the huge economics potentials within. The biogas market reached USD19.8 billion in global revenue in 2013 and is estimated to hit USD33 billion by year 2022 due to acceleration of infrastructure for natural gas, tightening environmental regulations, and significant potential to meet growing demand within the energy and chemical markets. With the continuous emission of over 1.5 billion cubic meter biogas (biomethane) from the palm oil industry every year and another 2 billion cubic meter of biogas from sewage treatment plants and municipal solid waste industry, there is large opportunity for Malaysia to position as the commercial hub for Asia's biogas

industry. Global players are continuously exploring and the production of diverse products like biochemicals, oleochemicals, feed additives, biohydrogen, compressed biogas and bio-dimethyl ether. BiotechCorp as the promoter of biogas initiative in Malaysia will highlight the potential of biogas industry in Malaysia and what it can offer to the industry players as well as the issues and challenges that need to rectify.

**Session 5: How the Forest Industry in Growing the Biobased Economy**  
**Wednesday, Jul 22 8:30 am - 10:00 am Room: 520 BE**

**Moderator: Paul Lansbergen, FPAC**  
**Jean-François Lévasseur, National Resources Canada**  
**Gurminder Minhas, Performance BioFilaments, Inc**

***How the Forest Industry is Growing Bio-Product Business***

The Canadian forest products industry is transforming and diversifying into new bioproduct markets. Ultimately, the industry wants to maximize the value from its fibre resources and byproduct streams. The existing pulp and paper mills are already biorefineries but can be more so with the addition of new product lines. These new bioproducts require the adoption of innovative technology, not all of which is commercialized. The industry is working hard with partners to explore these opportunities, adopt new technology, and enter new markets. The Canadian government is supporting this transformation with an important funding program, Investments in Forest Industry Transformation (IFIT), to reduce the risk in adopting unproven technologies. The proposed panel would highlight progress to-date, trends, and opportunities ahead. This panel will be of interest to all players along the supply chain who are interested in the production or use of sustainable wood fibre feedstocks.

**Gilles Amsallem, Biomethodes**

***Bootstrapping the bio-refinery revolution: integrating flexible bio-refineries within the existing wood industry value chain***

Bio-refinery technologies have been developed to produce biofuels and/or chemicals intermediates from ligno-cellulosic material (wood, straw...). One of the major hurdles currently faced by this industry is the lack of a proper supply chain sourcing of the raw materials for the bio-refinery. Cellulosic ethanol plants are only recently emerging in great part due to the complexity of setting up the infrastructure to collect the existing corn stover, as well as store it on site. This complexity has led to significant delays, as well as unanticipated cost of the biomass. Furthermore, cellulosic ethanol producers have experienced great loss due to the difficulty of storing vast amounts of biomass (all major cellulosic ethanol plants have suffered from fire of their biomass stockpile). The good news is that there is a ligno-cellulosic material that is readily available and already part of a significant supply chain: wood. By properly leveraging the complete value of the biomass, it is possible to size the bio-refinery industrial so that it can be nested within the existing wood supply chain. This presentation will provide an overview of two such projects being developed by Biométhodes: integration of a bio-refinery within a hard wood floor processing plant, and integration of a bio-refinery into a pulp and paper plant.

**Session 6: Canadian Biorefineries in a Global Context**  
**Wednesday, Jul 22 10:30 am - 12:00 pm Room: 520 BE**

**Moderator: Jack Saddler University of British Columbia**  
**Hung Lee, University of Guelph**  
**Warren Mabee, Queen's University**  
**Tom Browne, FPInnovations**  
**Andrew Richard, Comet Biorefining**

***Canadian Biorefineries in a Global Context***

The NSERC Bioconversion Network is an NSERC Strategic Network, now in its final year of operation, focused on developing renewable fuels and chemicals from lignocellulosic biomass. The bioconversion process offers us a pathway to generate fuel ethanol and biochemicals for the Canadian marketplace, but is currently limited by various scientific and technical barriers. In Canada, our unique opportunity is the availability of vast quantities of cellulosic material found in our forests. Members of the Bioconversion Network have worked in the areas of environmentally-sustainable technology development related to

pretreatment, enzymatic hydrolysis and fermentation, with the goal of supporting bioconversion applications in Canada. The proposed panel highlights some key outputs of the Network outputs in the context of industrial development and international trends. One key consideration is the need to plan feedstock supply chains in a manner that minimizes costs and environmental impacts; a methodology to assess these costs and impacts will be discussed and optimal biorefinery sites will be identified across Canada. The importance of pretreatment to obtain sugars from lignocellulose at a reasonable cost was another theme within the Network, and the panel will explore the industrial potential of deploying effective pretreatment technologies and creating commodity intermediate products such as sugars to support the emerging Canadian biorefinery sector, and indeed the larger North American bioeconomy. Similarly, the ability of new fermentation technologies to handle multiple sugar streams delivered by more effective enzymatic hydrolysis remains a ripe area of research; the panel will explore the current status of fermentation within the bioconversion platform and discuss a range of potential products associated with this platform. Finally, the international forces that affect the emerging biorefinery sector will be discussed, including changes to the price of oil and willingness of governments to subsidize renewable technologies as assessed by the International Energy Agency.

## **Track 8: Growing Global Biobased Markets**



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### **Session 1: Quebec's perspectives in the Context of a Growing Global Bio-economy Monday, Jul 20 8:30 am - 10:00 am Room: 520 AC**

**Moderator: Patrice Mangin, University of Quebec at Trois-Rivières**

**Marie-Helene Labrie, Enerkem Inc.**

**Kevin MacDonald, Buckman North America**

**Gurminder Minhas, Performance BioFilaments Inc.**

#### ***Quebec's perspectives in the context of a growing global bio-economy***

For economic and environmental reasons, a noticeable global trend is emerging that progressively integrates developing bioprocesses and sustainable bio-products for the emergent industrial bio-economy. The two main drivers propelling the growth of bio-based industry are the climate protection, mainly reducing the carbon footprint and greenhouse gases emission, energy security and the shift from fossil-based to renewable feed-stocks. The potential for global growth of bio-based industries in the coming decade is very promising. Many countries are investing to expand national bio-based economies for domestic and international markets. Various sources confirm that bio-based chemicals are expected to benefit from the largest part of growth. The sector alone reached a market value of \$3.6B in 2011 projected to reach \$12.2B by 2021. Most of the growth will concern bio-based specialty chemicals such as adhesives, surfactants, solvents and biopolymers. By example, global production of bioplastics is expected to quintuple by 2016 while the industrial enzyme market will generate sales value of \$7.4 B in 2015 and will experience a 6.5% annual growth beyond 2015 according to Industrial Biotechnology (2014). About the global biofuels markets, there are expected to increase from \$82.7B in 2011 to \$185.3B by 2021. Besides, the demand for biomass for cogeneration of heat and electricity will more than double. The Canadian Quebec province possesses many assets to boost the development of its bio-economy. The diversity and abundance of its bio-ressources are huge. By example, Quebec annual harvesting potential of forest residues biomass is estimated at 14.86 million wet metric tons per year notwithstanding a 6.56 MT for crown/foilage. In Quebec, forest biomass allocation ensures long term supply security due to the new Quebec forestry regime that promotes investment, development, and integration of forest biomass valorization technologies to existing infrastructures. Furthermore, Quebec benefits from world-class industry-oriented research facilities with advanced technology infrastructures covering most of biomass processing and bio-based molecules extraction methods. The research focuses more and more on sustainable development and waste conversion into valuable products. Quebec also benefits from a critical mass of highly qualified personnel leading various projects, many integrated within Canadian research networks in key sectors of bio-economy as green chemistry, molecular biology, biomaterials, bioenergy, environmental technologies, etc. and emergent disciplines such as algae biology, algae farming or algae biomass refining, and synthetic biology. The panel main goal is to share with WCIB participants the perspectives of Quebec in this world-scale bio-economy. The bio-based products and energy actually produced by major players in Quebec will be presented. Panel participants will discuss about how the bio-

economy will increase Quebec competitiveness, innovation, and economic wealth/prosperity through sustainable, smart and inclusive economic growth and jobs; thus satisfying the needs of a growing population whilst protecting the environment through clever resources exploitation. Panel participants will also discuss how Quebec could distinguish itself from other parts of the diversification including hydroelectricity and natural gases in view of establishing a world class bio-economy.

## **Session 2: Growing the Biobased Economy - A Value Chain Approach**

**Monday, Jul 20 10:30 am - 12:00 pm Room: 520 AC**

**Moderator: Kathryn Sheridan, Sustainability Consult**  
**Stefano Facco, Novamont SpA**  
**Jo Kockelkoren, Reverdia**  
**Catherine Tredway, WhiteCloud Innovations**

### ***Growing the biobased economy - A value chain approach***

In the last ten years, biobased companies have developed technology to a point where many biobased chemicals and plastics are commercially-viable. What is needed now is more intense commercialization, to move renewable chemicals from a fringe sector to a real competitor to petroleum-based chemicals. Working across the value chain is key to this commercial development. Put simply, unless a value chain approach is taken, the bio-based economy will not be successful. This panel will include Reverdia, Novamont and WhiteCloud Innovations. Each company will present its role in the value chain, how the companies interact with each other and how a successful end product depends on the solid coordination of different players in a partnership approach. The speakers will also elaborate on the synergies needed to grow the biobased industry. Company Descriptions Reverdia, powered by DSM + Roquette, produces Biosuccinium™ sustainable succinic acid with proprietary green technology to enable customers to produce bio-based, high-quality performance materials with a substantially-improved environmental footprint. Reverdia, with strong expertise in fermentation, recovery and plant scale-up, is an innovation leader using its proprietary low pH yeast technology rather than bacteria to produce biobased succinic acid. Novamont is an Italian industrial company whose roots lie in the Montedison School of Materials Science and which was set up in 1989 with a view to implementing the ambitious project of some research workers from the large industrial chemistry group: to integrate chemistry, agriculture and the environment. Ever since it was set up, Novamont has significantly contributed to the creation of a new sustainable industrial policy promoting a new model of development and encouraging the transition from a product-based economy to a system-based economy, through the use of renewable resources for the production of bioplastics for specific applications with a low environmental impact. WhiteCloud Innovations is a Toronto-based company that has designed an alternative construction material to address the traditional problems of the wood-panel industry (particleboard, plywood, MDF, OSB). These products are notorious for their use of formaldehyde, a known human carcinogen. Additionally, these products often swell due to water exposure, mold and have limited resistance to flammability. Working with industry professionals and leading green chemists, WhiteCloud has developed Organic Composite Board (OCB) to be formaldehyde free with built in anti-microbials, flame and smoke retardants, and water resistance - a material that is more efficient both mechanically and environmentally.

### **Joachim Schulze, Thyssen Krupp Industrial Solutions AG** ***ThyssenKrupp Industrial Solutions***

ThyssenKrupp Industrial Solutions (TKIS) is working since more than 8 years in the field of Industrial Biotechnology. It is the Goal and Mission of TKIS to bridge the gap for BioTech organizations between laboratory and industrial operation by providing its scale-up experience, multi-purpose facility and engineering services. The anticipated growth for the Industrial Biotechnology did not yet take off as challenges have been underestimated; time- and moneywise. The current low oil price and the diverse effects of shale gas do not help either, as there is no green premium effect seen. Many companies died in recent years as they could not bridge the gap between lab and industrial scale – the so-called valley of death. One challenge is the complex value chain for (Bio)Chemicals with barriers between the Agro Industry and the Chemical Industry. Another barrier is the introduction to the market especially if new products are involved (e.g. Biopolymers). This requires a complex partnering along the value chain which TKIS can offer as partner for BioTech entities. The Scale-Up of the process and the production of ton-size samples for application tests and seeding the market is the other big challenge as it requires substantial investment in Piloting and CMO's. TKIS has the possibility with its multi-purpose facility to Scale-Up the

process and to produce the required product in larger quantities. Based on the production information TKIS can design and build industrial facilities worldwide including the provision of complete process wraps.

**Session 3: Biobased Development in Brazil - Beyond Ethanol**  
**Monday, Jul 20 2:30 pm - 4:00 pm Room: 520 AC**

**Moderator: Mariana Doria, Brazilian Chemical Industry Association**  
**Jose Bomtempo, Federal University of Rio de Janeiro**  
**Gabriel Lourenco Gomes, Brazilian Development Bank**  
**Bernardo Silva, Brazilian Industrial Biotechnology Association**  
**Flavia Alves, Federal University of Rio de Janeiro**

***Biobased Development in Brazil - Beyond Ethanol***

Aiming to contribute to the Brazilian industrial development, the study to assess diversification alternatives for the Brazilian chemical industry was sponsored by the Brazilian Development Bank (BNDES), and was executed by Bain Co and Gas Energy. It identified chemical segments with local market opportunities and production resources, and evaluated the integration of existing industrial chains in Brazil with new technologies. The study contributed to design public policies to promote the Brazilian chemical sector. Specifically, one particular report of this study focuses only on renewable chemicals. The objective of this panel is to present investment opportunities and perspectives for the biobased industry in Brazil. The first two presentations will highlight the investment opportunities in Brazil on renewable chemicals, revealing quantitative data on the Brazilian market. Secondly, the following presenters will show the industry perspective, with the contribution of the Brazilian Chemical Industry Association and the Brazilian Industrial Biotechnology Association. Finally, the panelists will discuss the short and medium term scenario in Brazil to establish these investments.

**Session 4: Getting Multiple Stakeholders to Buy In: Innovation, Partnerships and Commercialization**  
**Tuesday, Jul 21 2:30 pm - 4:00 pm Room: 520 AC**

**Moderator: David Bressler, University of Alberta**  
**Doug Cameron, First Green Partners, LLC**  
**David Dodds, Dodds & Associates, LLC**  
**Christophe Luguel, Industries & Agro-Resources Competitiveness Cluster**

***Getting Multiple Stakeholders to Buy In: Innovation, Partnerships and Commercialization***

The industrial biotechnology sector is providing innovative, renewable and cost effective alternatives to petroleum-based mainstream processes. In order to develop these technologies toward commercialization, support from investors, funding agencies, and government are necessary. This panel will outline the roles of these partners and use examples from their own experiences to examine how these relationships and communication are key to success. Professor David Bressler, the moderator for this panel, is from the University of Alberta (Edmonton, AB, Canada), and is also the Executive Director of the Biorefining Conversions Network (BCN) and Chief Technical Officer of Forge Hydrocarbons, a company that arose from research developed in his academic laboratory. Given his experience with the various stages of the commercialization process, Professor Bressler will talk about the importance of building a regional bioeconomy through networking and connecting the various participants such as universities, government, and industries. Dr. Peter Riddles has been involved with biotechnology and agriculture research for many years and is now a board member for many scientific bodies, including CSIRO, California Technology Council, and the Alberta Research and Innovation Authority, as well as the director of ViciBio Pty Ltd. Peter will address the interplay between innovation systems and policy, and how they affect emerging biotechnologies. He will review the role of the various players (i.e. universities, government, funding agencies, investors, etc.) that are involved during the commercialization process and how each contributes at various stages. Dr. Doug Cameron, Co-President and Director of First Green Partners will examine the role of investors during the commercialization process. Doug has experience in various facets of the biotechnology sector, including academia, industrial commercialization, and raising venture capital. Doug will discuss strategic investments from partnering companies and venture capitalists, as well as the importance of these relationships and partnerships as a technology is commercialized. Dr. David Dodds has more than 25 years of expertise building and running interdisciplinary teams in biotechnology and chemical process development, which have led to commercialized technologies. David established Dodds &

Associates in 2002, and advises startups and established organizations. As a member of this panel, David will draw from his own experiences to examine how to merge scientific disciplines efficaciously and promote communication amongst academic labs and businesses. The overall aim of this panel is to discuss the commercialization process in the context of funding agencies and investors, and the relationships that are required for success. The panelists will draw from their expertise to examine how to productively commercialize technology in the bioindustry.

**Mario Pennisi, Life Sciences Queensland Ltd**

***Building a global Bio-Economy through Partnerships***

The world is getting smaller with our ability to communicate instantly and to travel the globe efficiently. That and the fact that Innovation is a global activity indicates that any new sector such as the BioEconomy will be global in its development. Hence countries should be reaching out to create international partnerships with others with a focus on similar aspects of the Bio Economy. The session will look at the connectivity of four countries with a focus on Biomass utilization from agriculture and forestry in their countries, but also recognize the need for a global connectivity to likeminded organizations. The Bio-based Delta in The Netherlands, Life Sciences Queensland, Australia, and Michigan Biotechnology Institute, United States of America have MOU's signed with Bioindustrial Innovation Canada. The MOU's have a focus on developing research and business partnerships for the development of biomass opportunities to bio-based chemicals; biomaterials; aromatics; lignin development and other areas of opportunity. The MOU's are in the early days of development of all the logistics, but are moving forward. The speakers will discuss their strengths as local groups and how the global outreach will add strength to their development of biomass to build their bio economy. If you have an interest in biomass and how it will be developed internationally to help build the Bio economy, than you will definitely have an interest in this session and the development of global partnerships.

**Session 5: Driving the Bioeconomy: The Economic State of the Biobased Products Industry  
Wednesday, Jul 22 8:30 am - 10:00 am Room: 520 AC**

**Moderator: Marie Wheat, United States Department of Agriculture**

**Janet Gardner, Amyris**

**Jesse Daystar, Duke University**

**Jeff Grove, ASTM International**

***Driving the Bioeconomy: The Economic State of the Biobased Products Industry***

Around the world, over \$400B worth of conventional manufacturing products are produced each year using biomass. We know the biobased products industry is creating jobs, generating new business opportunities, and working to meet the growing demand for more sustainable products, but how many jobs, what is the state-by-state economic impact, how are companies succeeding in the global marketplace, and what are their business strategies to expand their market share and grow the new bioeconomy? These questions and more will be examined in this session surrounding the outcome of a brand new economic study required by Congress in the 2014 Farm Bill and undertaken by the USDA BioPreferred® program. The study, the first of its kind, highlights significant long-term prospects for growth in the biobased products industry and the industrial sectors impacted. It examines the current state of play of the global bioeconomy and the specific economic impacts of biobased companies across the United States. Industry drivers will be discussed, for example, with companies from over 40 countries currently participate in the BioPreferred program it is now one of the top drivers in in the growing global demand for biobased products. Mandatory requirements for U.S. federal agencies to purchase biobased products, USDA voluntary biobased product certification and labeling, and focus areas for the USDA BioPreferred Program – including biobased intermediates and complex products – will be discussed. Learn about ASTM's standards for testing biobased content and recent international efforts at standards harmonization supporting this growing industry. As the technical underpinning of biobased products, standards play a critical role in removing barriers to trade and expanding markets for U.S. goods and services. A global industry representative will also speak to their real world experience in growing the biobased industry in their particular sector and give voice to how the economic data from the new study reflects what is truly happening in the industry, as well as discussing the opportunities to further boost the bioeconomy.

**Session 6: PublicPrivate Partnerships on Bioeconomy. Common Approaches, Differences, Grounds for Common Action in the EU and in the US**

**Wednesday, Jul 22 10:30 am - 12:00 pm Room: 520 AC**

**Moderator: Barend Verachtert, Bio-based Industries Joint Undertaking  
Marcel Wubbolts, DSM  
Stefano Facco, Novamont**

***PublicPrivate Partnerships on Bioeconomy. Common approaches, differences, grounds for common action in the EU and in the US***

In the EU a public private partnership named Biobased Industries Joint Undertaking has been launched. EU focusses on advanced biorefineries, utilizing residues from agriculture, forestry and EU producers and industries global market leaders, e.g. in enzyme technology (64% of all companies operate from within the EU); About 10% of EU chemicals today produced from renewable biomass, expected to rise to 30% in 2030 globally. Several EU industrial sectors concerned: chemical, textile, pulp and paper, sugar, starch, woodworking, biotechnology. EU producers and industries global market leaders, e.g. in enzyme technology (64% of all companies operate from within the EU); About 10% of EU chemicals today produced from renewable biomass, expected to rise to 30% in 2030 globally. Several EU industrial sectors concerned: chemical, textile, pulp and paper, sugar, starch, woodworking, biotechnology. The Biobased economy concept made simple: Making everyday products from biomass and waste, with biorefineries at the centre of it all. The concept is to build on the principle of smart and efficient use of resources. It will focus on: Unlocking the potential of residues and side-streams and waste (e.g. forest residues, agricultural lignocellulosic residues or dedicated crops), and optimising the utilisation of existing feedstock (forest and agricultural biomass) The PPP Bio-Based Industries JTI is needed as a catalyzer for the creation of new value chains, Cross-sectorial collaboration along value chains of previously unrelated sectors and industries, Pooling of resources, De-risking investments at higher TRL levels, Develop the necessary range of conversion processes for integrated biorefineries, Demonstrate and deploy advanced large-scale biorefineries, Facilitate and promote the uptake of bio-based products Similar experiences can be analysed in the US from a different approach: biopreferred policy. Is there common lessons to promote Biobased value chains? What are the differences (GMOs, Biofuels, public and private support? Is there a need for a common approach at global level?

**Roger Kilburn, IBioIC**

***Seeing the wood for the trees: Building a biobased industry in Scotland and the UK***

In late 2013 Scottish Enterprise and Chemical Sciences Scotland published the "National Plan for Industrial Biotechnology" which presents the challenge of increasing the uptake of Industrial Biotechnology within Scotland as a whole, but also delivering an industry with combined revenues of £900M by 2025. This talk will present the considered strategy that will deliver this vision, discuss the range of companies currently engaged in IB, and the requirements/potential for growth in each industry sector. It will also detail the case for construction of one or more bio-refineries within Scotland, seek to explain issues of feedstock supply and other perceived obstacles that may need to be overcome prior to their construction. Scotland has some interesting environmental and geodemographic properties which make a number of feedstocks economically viable for exploitation. A biorefinery roadmap will be published in February 2015 detailing the feasibility of forestry, domestic waste, co-products from the whisky industry and seaweed, as the starting point for the growth of a new industry. This presentation will describe some of these opportunities and the work currently ongoing in their development. Finally the talk will introduce the Industrial Biotechnology Innovation Centre, an initiative backed by the Scottish Government and set up, in part, to enable the delivery of the "Plan". Its operational model is to facilitate, instigate and fund collaborative projects in IB involving academics and companies, both large and small, across Scotland and further afield. Within its first year the centre has 14 university partners, is building 2 open access equipment centres, has well over 500 industry contacts and has created unique Master's and Doctoral training programmes to equip the next generation of industrial biotechnologists with the skills necessary for the industry to succeed. Industrial Biotechnology in the UK may never achieve the scale of that seen in the Americas, largely due to pressures of land use, climate and current political appetite but irrespective of that, the impact it can have on Chemical Sciences, Life Sciences and Renewable energy within the UK will be substantial.

**Oskar Slotboom, Avantium**

***Competitive routes towards Bio-based Products***

Significant effort is ongoing to develop bio-based alternatives to existing petro-based materials, driven by the call for sustainability and enhanced by public policies and subsidies. Often a bio-based route to a basic chemical building block such as Paraxylene or Ethene is pursued. Converting such a 'drop in' into end material such as PET or MEG/Polyethylene respectively simply uses the same chemical route and assets as the petro-alternative. At the same time, this route is oftentimes inherently carbon- and oxygen- and energy-inefficient. In addition, the resulting bio-material is identical to the petro-alternative, so that any additional costs have to be justified as a 'green premium' by the end user. For example in the currently used four-step synthesis of Bio-MEG (as used in PET bottles) following the same route as petro-MEG synthesis via Ethylene Oxide, a theoretical maximum yield (by weight) of 67% can be achieved. Also all oxygen is first completely removed, after which it is re-introduced in two chemical steps. Using a single-step hydrogenolysis from glucose to MEG, a theoretical maximum of 100% carbon- and oxygen use can be achieved leading to 100% weight yield. Similarly, in the synthesis of bio-PTA a theoretical maximum 460 kg of PTA from 1000 kg of glucose can be achieved ( $C_8H_{10}O_4$  from  $2 \times C_6H_{12}O_6$ ). Alternatively, a maximum of 870 kg of Bio-FDCA that can be polymerized to PEF (Poly Ethylene Furanoate) can be produced from 1000 kg of glucose ( $C_6H_4O_5$  from  $C_6H_{12}O_6$ ). At the same time PEF has performance benefits over PET that are relevant in many application areas, such as high Tg and modulus and increased gas barrier ( $O_2$ ,  $CO_2$  and  $H_2O$ ), which is important in food and beverage packaging. For new materials, the investments in process development, material and application development, and manufacturing technology and capacity are higher and implementation of such processes and materials may therefore take more time to overcome the hurdles commonly encountered in the field. However, these new processes and materials that are engineered to make use of the functionalities of the bio-feedstock will have high potential in the long term and will be critical to broad implementation of bio-based chemicals. The performance benefits of new materials may help market introduction as that requires a competitive cost level with petro-based alternatives. As the leader in FDCA and PEF technology, Avantium has now reached results in its process development that allow for mid-term manufacturing costs to be in range with historical PET prices in the US. In addition, Avantium is developing a process to produce Bio-MEG from starch or glucose at a projected cost below the current petro-MEG price using its one step hydrogenolysis process.