BIO ENERGY
Renewing Energy-Restoring Earth

PRISM

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BIOENERGY AND BIOFUEL

RENEWING ENERGY–RESTORING EARTH

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HILTON BOSTON BACK BAY, BOSTON, MASSACHUSETTS, USA

ABSTARCT BOOK

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DAY – 1

Plenary Talk

Regenerative Agroenergy Systems: A Reality-Based Approach to Bioenergy and Biofuels

Dr. Bruce E. Dale

Michigan State University, East Lansing, Michigan USA

Abstract:

In my case, my life's research has focused on fermentation biofuels, specifically in pretreatment of cellulosic biomass to provide sugars for subsequent fermentation to biofuels. Starting about 15years ago, using TCA and LCA, I tried to look comprehensively, honestly and critically at fermentation biofuels generally, and my own research specifically, in the context of larger economic systems and sustainability goals. I eventually concluded that the only fermentation biofuels that might potentially make economic and environmental sense are bioethanol and biogas. Further experience and observation convinced me that fermentation ethanol will probably be viable in only a few locations, notably Brazil and the USA, primarily for systems-level reasons. I explained this reasoning in a previous editorial. If anyone knows of other countries where ethanol is used (or is on track to be used) at 10% of the total light vehicle fleet fuel volume, please let me know. I would be delighted to be proven wrong. Brazil is currently producing large amounts of ethanol from cane sugar and is beginning to produce significant amounts of ethanol from a cellulosic sugar cane residue called 'bagasse'. The USA is likewise producing many billions of gallons annually from corn grain but produces no significant amounts of cellulosic ethanol.

Biogas, in contrast, has potential for much broader applications than ethanol. In fact, the production and use of biogas seem to be accelerating, while ethanol production in the USA has been steady at about 15 billion gallons per year for the past 10years. Likewise in Brazil, the total production of ethanol has been about 30–35 million cubic meters (8–9 billion gallons) per year for the past 10years. Ethanol production simply is not growing significantly. Why? To better understand why, let's examine some points of comparison between ethanol and biogas.

Plenary Talk

Economics of bioproduction and the supply chain design and policy

David Zilberman

Professor, University of California, Berkeley, USA

Abstarct:

The emerging bioeconomy depends on efficient bioproduction systems that convert biological resources—such as crops, residues, algae, and waste streams - into food, feed, fuels, materials, and environmental services. This paper develops an economic framework linking bioproduction technologies with supply chain design and policy, emphasizing how innovation, logistics, and regulation jointly determine the viability of bio-based industries. Building on the concept of innovation and product supply chains, the analysis shows how technological change in production, processing, and distribution interacts with market incentives, transportation costs, and institutional constraints. Effective supply chains must coordinate feedstock production, processing infrastructure, and downstream markets while managing uncertainty, environmental constraints, and scale economies. Public policy plays a critical role through research support, regulatory design, infrastructure investment, and carbon and environmental incentives that shape adoption and investment decisions. The framework highlights how well-designed policies and supply chains can accelerate the transition toward a sustainable circular bioeconomy that expands production, improves resource efficiency, and reduces environmental impacts.

Plenary Talk

The Future of Biorefining: General Perspectives and a Report from the Field

Lee R. Lynd

Co-founder and CTO of Terragia Biofuel Inc, USA

Abstract :

The emergence of biorefineries producing multiple products from renewable biomass feedstocks has long been anticipated as a key component of a sustainable, circular economy. However, with perhaps a few exceptions such biorefineries have been slow to emerge as indicated by both the deployment of cellulosic biofuel deployment and the stock value of industrial biotechnology companies falling short of expectations. The speaker will offer perspectives on understanding this slow emergence and reasons to persist in biorefinery development and deployment. Dimensions considered will include feedstock availability and choice, conversion technology, product demand and choice, and climate stabilization. Consolidated bioprocessing of cellulosic biomass and Terragia, a biofuel startup, will be offered as examples of promising initiatives.

Plenary Talk

Flying the Future: Advances in Aviation Fuels at the Joint BioEnergy Institute (JBEI)

Blake A. Simmons

Division Director, Biological Systems and Engineering Division at Lawrence Berkeley National Laboratory Berkeley, USA

Abstract :

The vision of JBEI (www.jbei.org) is that bioenergy crops can be converted into economically viable, carbon-neutral, biofuels and renewable chemicals currently derived from petroleum, and many other bioproducts that cannot be efficiently produced from petroleum. JBEI's mission is to establish the scientific knowledge and new technologies in feedstock development, deconstruction and separation, and conversion needed to transform the maximum amount of carbon available in bioenergy crops into biofuels and bioproducts. When fully scaled, JBEI's technologies will enable the production of replacements for petroleum derived gasoline, diesel, jet fuel, and bioproducts. In doing so, JBEI will reduce the nation's dependence on fossil fuels, significantly reduce the amount of carbon added to the atmosphere, reduce contamination of the environment, and provide the scientific tools and knowledge required to transform the bioenergy marketplace. Inside JBEI's Emeryville laboratories, researchers use the latest tools in molecular biology, chemical engineering, computational and robotic technologies, and pioneering work in synthetic biology to transform biomass sugars into biofuels and a variety of bioproducts. As we want to maximize the overall carbon conversion efficiency of bioenergy crops, JBEI has focused on two microbial hosts that have been demonstrated to be able to co-metabolize sugars and lignin-derived intermediates, Pseudomonas putida and Rhodosporidum toruloides, and produce a targeted range of sustainable aviation fuels. This presentation highlights the latest advances at JBEI in terms of bioenergy crops, deconstruction technologies, and microbial production of advanced aviation fuels.

Plenary Talk

Biochar from Biomass and Waste: Fundamentals and Applications

Yong Sik Ok

Professor, Korea University, President of the International ESG Association, South Korea

Abstract:

Biochar has traditionally been used as a soil amendment as it enhances carbon sequestration and soil fertility. In addition to agriculture, biochar has recently been used in various industrial sectors, including textiles, construction, waste management, renewable energy generation, and for climate change mitigation. My plenary speech will provide the fundamentals of biochar, such as its basic concepts, production technology and characterization methods, also including comprehensive examples for conference participants. It will also include information on state-of-art biochar application technologies in the fields of agriculture, energy and environmental sciences with step-by-step case studies.

Keynote Talk

Catalytic Biographite Production and Techno-Economic Evaluation for Lithium-ion Battery Applications

Sunkyu Park

Distinguished Professor, University Faculty Scholar in the Department of Forest Biomaterials at North Carolina State University (NCSU),USA

Abstract:

The escalating global demand for graphite, a primary anode material for lithium-ion batteries, has exposed vulnerabilities in the current supply chain, which is heavily reliant on non renewable and geographically concentrated resources. This research presents a comprehensive approach to producing biographite, a reliable, renewable, and sustainable alternative to fossil-based graphite. This next-generation graphitic carbon material is synthesized from biomass pyrolysis products, including biochar and fast pyrolysis bio-oil, under moderate conditions, which contrasts with conventional high-energy non-catalytic graphitization practice.

This innovative process addresses both technical and economic barriers in the production of high- quality anode active materials (AAM). Catalytic graphitization of biomass-derived precursors enables the sustainable fabrication of AAM with electrochemical performance comparable to that of market-available graphite under moderate conditions. The resulting biographite products demonstrate excellent electrochemical properties, delivering a reversible capacity of ~350 mAh g^{-1} along with remarkable initial Coulombic efficiency and cycling stability over 100 cycles. A conceptual process design of a reaction-separation-recovering sequence was also simulated to understand the technical performance at scale. Cost modeling and risk analysis were introduced to predict the prospective market performance of biographite. Integrating AAM production with liquid biofuels demonstrates the most favorable economic metrics, achieving a minimum selling price of $3.3 per kilogram of uncoated AAM with a preliminary profitability margin of 27%. By utilizing integrated biorefineries, biographite can be competitive with commercial graphite at scales higher than 1500 tonnes per day. This study showcases a promising pathway to secure a domestic supply of critical materials for sustainable energy storage.

Keynote Talk

A New Nitrogen Cycle in Biofuel Agriculture

Steven Singer

Program Director at ARPA-E Lawrence Berkeley National Lab, USA

Abstract:

Synthetic nitrogen fertilizer, which uses natural gas as a feedstock, is typically overapplied in present-day farming practices to account for low plant uptake and loss of nitrogen to the environment. Current approaches to managing nitrogen in biofuel crop production are not sufficient due to high cost, a need for new cultivars, and inconsistent performance in field settings. Developing strategies to harness soil and atmospheric sources of nitrogen to lower the application of nitrogen and improve plant uptake will transform biofuel agriculture. ARPA-E has initiated a program, TEOSYNTE, that harnesses the abilities of plants and microbes on farm fields to influence the soil nitrogen cycle and reduce reliance on synthetic fertilizer.

Invited Talk

Staying productive under pressure: systems evaluations of β-carotene production in Yarrowia lipolytica under continuous fermentation

Yinjie J. Tang

Professor Department of Energy, Environmental and Chemical Engineering, Washington University in St. Louis, St. Louis, MO, 63130, USA

Abstract:

The National Security Commission on Emerging Biotechnology (2025) identified executive priorities emphasizing resilience in the bioproduct supply chain. Over the past two decades, synthetic biology has greatly advanced the development of microbial cell factories. However, extensive pathway engineering and cellular modifications can impose unintended metabolic burdens, and suboptimal growth conditions in large bioreactors frequently trigger unanticipated physiological changes. As a result, cellular responses to intra- and extracellular perturbations remain poorly understood. Scaling microbial fermentation from laboratory to industrial production therefore continues to pose major challenges, particularly in maintaining strain stability during continuous operation. In this study, the Tang Lab and collaborators used a β-carotene producing Yarrowia lipolytica strain as a model to investigate key factors contributing to titer loss, focusing on bioreactor modes, carbon sources, oxygen availability, and media composition. Their results show that fermentation strategy and oxygen levels exert the strongest influence on strain stability, with production losses emerging within roughly 18 growth generations. Notably, oil-based carbon sources significantly improved both titer and production longevity relative to glucose-based media. To elucidate the mechanisms underlying titer loss, we integrated multi-omics analyses, cell imaging, 13C metabolic flux analysis, and kinetic modeling, revealing various contributions from metabolic regulation, subpopulation dynamics, and spontaneous mutations. The findings further suggest that strains engineered for maximal production under laboratory conditions may be less robust in industrial environments, where suboptimal yet faster-growing variants gain a competitive advantage under prolonged stress and ultimately dictate continuous industrial fermentation performance. This work has also catalyzed several new NSF and DARPA supported projects in innovative

biomanufacturing, integrating genetic-circuit engineering, AI/ML and large language models, and advanced bioprocess control.

Invited Talk

The potential of a residue-based Sustainable Aviation Fuel (SAF) economy in the US Midwest

Angela Isabella Scafidi[1]*, Audrey Denvir[1], Daniel Lashof[1], Mitch Schirch[2], Sophia Chryssanthacopoulos[2], Andrea Gustafson[2], Tom Cooklin[2], Philip Jordan[2]

[1]World Resources Institute, USA; [2]BW Research Partnership

Abstract:

Corn stover is an abundant resource in the US Midwest that could replace or compensate for enough jet fuel to meet the near-term goal of producing 3-billion-gallons of sustainable aviation fuel (SAF) per year set forth by the US Grand SAF Challenge. Notably, using corn stover would take advantage of the US' most abundant agricultural residue and allow for the expansion of the SAF industry without dedicating additional land for purpose-grown biofuels crops. Our team examined five pathways for corn stover (four technology pathways for SAF production and one carbon dioxide removal (CDR) pathway to compensate for fossil jet emissions), using input/output modeling to understand the impacts of such an industry on the economy in the US Midwest. A regional residue-based SAF and CDR economy that meets the 3-billion-gallon goal could support 150,000 jobs, $11 billion in labor income, $21 billion in gross GDP value, and $6 billion in gross tax revenue each year. Large initial investments (over $60 billion of capital expenditure) and policy support will be required to scale up a residue-based SAF economy. Aviation is a hard-to-abate sector, and while sufficient stover could be sustainably harvested to produce 3 billion gallons of SAF per year, there is not enough stover to reach the US' 2050 goal of producing 35 billion gallons per year. Other support, such as CDR, will be needed to fully decarbonize the aviation sector. A mature residue-based SAF economy in the US Midwest could provide regional growth, support rural communities, and ensure that sustainable aviation fuel is produced in a way that doesn't require additional land use change.

Invited Talk

From Land To Sea: Converting Food Waste Fermentation to Marine Fermentation

Anga Hackula[1*], Stephanie Lansing[1]

Department of Environmental Science and Technology, University of Maryland, College Park, MD 20742, USA

Abstract:

Volatile fatty acids (VFAs) provide a valorization pathway for organic waste streams within the circular bioeconomy. Food waste, one of the largest underutilized organic resources, is primarily landfilled, is a lost opportunity for resource recovery. Dark fermentation provides an approach to convert food waste and other organic materials to VFAs.

A semi-continuous mesophilic (35 °C) system was operated for 365 days at a hydraulic retention time (HRT) of 12 days achieving VFA yields of up to 6.7 g/L. The VFAs consisted of primarily acetate (6.0 g/L), with traces of butyrate (0.5 g/L). Approximately 36% of the soluble chemical oxygen demand was accounted for as VFAs, suggesting alternative metabolites, such as lactic acid. Long-term operation demonstrated stable VFA production from food waste, supporting its viability for terrestrial waste valorization.

Offshore application was explored by adapting for saline dark fermentation processing marine organic matter. Through a gradual salinity and feedstock adjustment approach, this study investigated the transition to a saline dark fermenter with 205 days operating in semi-continuous conditions. Total VFAs peaked at 12.9 g/L with acetate constituting over 70% of products. Traces of butyrate (0.6 g/L) and propionate (0.2 g/L) were also observed. Food waste fermentation was dominated by lactic-acid associated taxa, such as Bifidobacterium and Lactobacillus. A shift to Clostridia-dominated communities were observed at higher salinity when the fermentation chamber had shifted from food waste to marine organic matter.

Overall, this study demonstrates that dark fermentation can be effectively transitioned from land-based food waste systems to saline marine applications, providing acetate-rich VFAs for downstream energy conversion such as energy conversion technologies, such as microbial fuel cells, within both the circular and Blue Economy frameworks.

Invited Talk

Just Add Sea Water: A Biological and Chemical Process for Conversion of Organic Wet-Waste to Fuels, Fertilizers, Epsom Salts, and Esters

Smith Pittman*[1,3], Dr. Danielle Bartholet, PhD[1,3], Shyanne Lambrecht[2], Dr. Drazenka Svedruzic[3], Jin Young Kim[4], William Black[4], Han Li[4], Pat Gilcrease[2], Dr. Susan De Long, PhD[1], Dr. Jason Quinn, PhD.[1] and Dr. Kenneth Reardon, PhD[1]

[1]Colorado State University, Fort Collins, CO, USA, [2]South Dakota School of Mines, Rapid City, SD, USA, [3]National Renewable Energy Laboratory, [4]University of California, Irvine, Irvine, CA, USA

Abstract:

Organic wet-waste, such as manure and food waste, represents a major resource for circular industrial processes but is often landfilled, worsening greenhouse gas emissions and air quality. Traditional anaerobic digestion mitigates these impacts only partially due to the low value of its methane and CO_2 byproducts. This research integrates decades of isolated findings into a

cohesive, industrial-scale process that converts organic wet waste into sustainable aviation fuel (SAF) and high-value chemicals.

The process centers on electrochemically enhanced AD for methanogenesis inhibition, in-situ ammonia and volatile fatty acid (VFA) extraction, and dynamic pH control. To eliminate reliance on purchased acids and bases, seawater is desalinated via bipolar membrane electrodialysis (BMED), generating acid/base solutions enriched with seawater ions. Their reuse in ammonia stripping forms fertilizers, electrolytes, and Epsom salts as valuable byproducts. The ammonia-lean digestate undergoes microbial chain elongation using lactic acid to add two carbons to the VFA in the digestate. Concentrated VFAs are upgraded into hydrocarbons for SAF via ketonization and hydrodeoxygenation or into high-value esters via microbial alcohol conversion, purification, and esterification. Pentyl caproate, the primary ester produced, achieves market values near \$198 kg^{-1}, offsetting fuel costs.

Techno-economic analysis demonstrates that, at commercial scale, ester co-production and seawater BMED integration improve economic viability such that SAF could be distributed at zero cost while maintaining a positive 30-year net present value. Life cycle assessment confirms major reductions in carbon intensity and resource depletion, positioning this system as a viable circular alternative to petrochemical production.

Invited Talk

Trends in Global Mitigation Policies: Potential Impact on Biofuel Demand

Linda Schmid

Multilateral Ethanol Policy Manager. U.S. Grains and BioProducts Council 20 F Street NW, Suite 900, Washington DC 20001

Abstract:

Last November in Belém, Brazil, the 30th UNFCCC Conference of the Parties of 194 country representatives gathered to address global warming. National energy plans were delivered, negotiators tackled divisive issues, and industry held energy forums. Bioethanol was showcased for use on road, in aviation, and maritime. The global demand for innovative adaptation and mitigation technologies was evident in Belém. Stakeholders returned home to unlock carbon markets to mobilize finance, technology, and trade in mitigation goods and services. Major economies submitted 2025 Nationally Determined Contributions (NDCs) to reduce emissions in the form of national plans across energy and economic sectors. For example, Brazil, Canada, and Japan noted where they will seek emission reductions and how they will accelerate their energy transitions. Of the 194 parties who attended, 113 submitted NDCs required under Article 4 of the Paris Agreement as a primary tool to reduce emissions and quantify progress. This growing trend in mitigation policies favors bioethanol deployment. An assessment of national plans indicates their potential to drive innovation, increase biofuel demand, and where policy adjustments are made facilitate cross border flows of bioethanol. For example, carbon mitigation policies drive innovation in decarbonizing products and services such as low-carbon biofuels, alternative-fuel fleets, and carbon capture storage

services. The buildout of carbon market infrastructure, including emissions trading systems, government-togovernment carbon markets, and carbon accounting systems, incentivizes demand for biofuel. As governments work to remove discriminatory life-cycle analysis measures, bioethanol will flow more easily across borders to meet decarbonization demand in export markets.

Invited Talk

Title: Engineering yield traits for *de novo* domestication of biofuels crops

Jennifer C. Fletcher and Liu Hong

University of California, Berkeley, USA

Abstract:

The regulation of stem cell activity in plant shoot and floral meristems is crucial for their continuous growth and production of vegetative biomass, fruits and seeds. Work in our lab and others identified a central intercellular signaling pathway called the CLAVATA-WUSCHEL (CLV-WUS) pathway that forms a negative feedback loop controlling stem cell homeostasis. Naturally occurring mutations in this pathway are associated with historical fruit and seed yield trait increases in key food crops such as corn, rice and tomato. We are leveraging our knowledge of stem cell maintenance mechanisms to increase yield in the emerging oilseed crop pennycress *(Thlaspi arvense)*. Here we report the characterization of three pennycress *CLV*-like loci and show that they regulate stem cell activity, development-related gene regulatory networks, and multiple yield traits. Our research enhances the productivity of pennycress and can accelerate its *de novo* domestication as a cash cover crop for the bioenergy sector.

DAY – 2

Plenary Talk

Foundations for Circular Biomanufacturing: Engineering Energy, Food, Materials and Pharmaceuticals for Life Beyond Earth

Adam Paul Arkin

Department of Bioengineering University of California, USA

Abstract :

The Center for the Utilization of Biological Engineering in Space (CUBES) is helping define the scientific and technological foundations for *circular biomanufacturing*—biological systems that convert limited local resources into the energy, food, materials and medicines needed for long-duration human missions. This effort is grounded in rigorous mission-architecture modelling, techno-economic and risk analysis, and synthetic biology of plants, microbes and nanotechnology-enabled interfaces. Our team has developed plant-based molecular pharming strategies for on-demand therapeutic production in constrained environments ; engineered autotrophic microbes and nanowire-microbe hybrids for CO_2 and N_2 capture with electro-/photo-bio interfaces; advanced bioplastic production pathways from CO_2-fed microbes, including production of benzyl-group enriched polymers for high-performance materials; and created a roadmap and systems-modeling framework that specifies loop-closure, mass/power/volume trade-offs, and TEA for deep-space biomanufacturing. While the work remains at foundational TRL levels, CUBES provides a discipline-defining blueprint for *how* biomanufacturing might enable sustainable life-support in deep space—and, as a sand-box for Earth's circular bioeconomy, to close elemental loops for food, energy, materials and medicines.

Keynote Talk

Reimagining Biomass Conversion: Pathways to Advanced Fuels, Bioproducts, and Energy Materials

Noppadon Sathitsuksanoh

University of Louisville, USA

Abstract

The world is moving toward the energy transition, and biomass offers a renewable, abundant carbon source that can support this shift. However, most current technologies use only portions of biomass or convert them into a narrow set of products, limiting their full potential in a circular bioeconomy. Therefore, we must re-wire carbon flows by transforming every biomass component into fuels, bioproducts, and energy materials for sustainable biorefineries. This talk

will highlight developments in solvent engineering for biomass processing, enabling effective fractionation and selective carbon-stream utilization. We will also discuss the integration of chemical–biological pathways that upgrade biomass into advanced fuels, bioproducts, and energy materials.

Keynote Talk

Biomimetic Compartmentalization of Catalysts for Bioenergy and the Bioeconomy

Cheryl A. Kerfeld

MSU-DOE Plant Research Lab and Department of Biochemistry and Molecular Biology, Michigan
State University and
Environmental Genomics and Systems Biology Division and Molecular Biophysics and Integrated
Bioimaging Division, Berkeley National Laboratory

Abstract

Bacterial microcompartments (BMCs) represent biological modularity as multienzyme-containing proteinaceous organelles. Bioinformatic analyses have revealed the widespread occurrence of functionally diverse BMCs across the Bacterial Kingdom. The generalized structure of BMCs establishes catalyst proximity and spatial control of local reactant and substrate concentrations, sequesters volatile or reactive intermediates, and controls metabolite and gas exchange with the surrounding environment. Accordingly, BMCs can be viewed as a biological paradigm for spatially confined chemistry. Recent advances in programming and assembling BMCs in vivo and in vitropoise this biological architecture to become a platform for spatially confined chemistry. BMC architectures provide a template for combining synthetic chemistry with synthetic biology to resolve mechanisms for spatial control of reaction networks with unprecedented precision. Relative to lipid- bound compartments, the protein-based boundary of the BMC can be precisely structurally designed and the multiple shell constituents can be individually tuned for electron, substrate, product, and potentially gas transport properties. The Center for Catalysis in Biomimetic Confinement, a US Department of Energy Energy Frontier Research Center, is developing BMC shell architectures into a versatile, composable system for applications in catalysis, biomaterials and biomining.

Keynote Talk

Systems Biology Approaches to strain engineering

Aindrila Mukhopadhyay

Lawrence Berkeley National Laboratory, USA

Abstract:

Engineering strains for biomanufacturing poses a complex set of challenges beyond pathway engineering. Enabling the use of multiple carbon sources, tolerance enhancements, high flux to final products and reliable performance at scale are all required for successful bioproduction. In this talk we will review several examples of systems biology efforts, aided by synthetic biology and biosensor development to enable robust production of biofuel and bioproduct targets in both bacterial and fungal strains.

Invited Talk

Genome-engineering of industrial diploid yeast for Lignocellulosic Biofuels

Dr. Amit Ghosh

Indian Institute of Technology Kharagpur, Kharagpur 721302, INDIA

Abstract:

An increasing demand for fossil fuel and a simultaneous need to curb down the CO_2 emissions from fuels have motivated the world to produce biofuels from lignocellulosic raw materials such as agriculture and forestry waste. Saccharomyces cerevisiae is a potential candidate for fermentation; its major drawback includes the inability to utilize the substrates available from the breakdown of plant biomass. One major limitation in using S. cerevisiae for lignocellulosic fermentation is its inability to metabolize and ferment D-xylose. Here, we report for the first time on the metabolic engineering of industrial diploid yeast for co-utilization of glucose and xylose sustainably using lignocellulosic feedstock. Recent advancements of synthetic biology have accelerated the metabolic engineering efforts in yeast to channelize a particular metabolite with higher yield than the wild-type. Simultaneously, we have developed the genome-scale metabolic models (GEMs) of non-conventional yeast to map the complete carbon flux flow obtained by metabolic flux analysis which will assist in their rational metabolic engineering. Therefore, our work is envisioned towards developing advanced microbial cell factories by redirecting carbon flux towards key precursor pool for the production of different targeted biofuels and commercial molecules assisted by the use of modern systems and synthetic biology tools.

Invited Talk

Neutron-Enabled Insights into Biomass Pretreatment for Biofuels

Hugh O’Neill1*, Sai Venkatesh Pingali1, Austin Conte2, Anton Ashner1, Yunqiao Pu1, Mohan

Mood1, Micholas Dean Smith2, Omar Demerdash1, Barbara Evans1, Jermey Smith1,2, Arthur J.

Ragauskas1,2, Brian H. Davison1

1Oak Ridge National Laboratory, Oak Ridge, Tennessee, 2University of Tennessee, Knoxville, Tennessee.

Abstract:

Plant biomass represents a renewable feedstock for fuels, chemicals, and advanced materials, yet its efficient utilization is limited by the complex hierarchical structure of the plant cell wall. Composed primarily of cellulose, lignin, and hemicellulose, the cell wall undergoes significant structural reorganization during chemical and biochemical deconstruction. However, the molecular interactions among these polymers that control biomass structure and recalcitrance are still not well understood. Here, we highlight several examples demonstrating how neutron scattering has enabled new discoveries related to plant cell wall structure and its deconstruction. Firstly, time-resolved neutron scattering was used to study thermochemical pretreatment under industrially relevant conditions, revealing the chronological evolution of biomass structure. These measurements provided new insight into cellulose microfibril reorganization, including increased ordering and coalescence, and showed that lignin aggregation occurs primarily during the initial heat-up phase rather than during cooling, overturning prior assumptions. The second example focuses on transgenic poplar trees with altered cell wall structures that are less recalcitrant than wild-type trees. Significant changes in cellulose microfibril organization were observed and correlated with reduced lignin content, providing molecular-level insight into the origins of decreased recalcitrance and informing future strategies for engineering plant biomass to improve deconstruction. Finally, we demonstrate how neutron scattering can be applied to advanced biomaterials such as transparent wood, revealing the associations between wood and polymer matrices that confer their unique properties. Collectively, these examples illustrate how neutron scattering enhances our understanding of plant cell wall architecture and the processes that drive biomass morphological changes relevant to biofuel and bioproduct production.

Invited Talk

Bio-innovations for a Resilient, Circular Bioeconomy

Mary Blanchard

Wisconsin Energy Institute (WEI) at UW – Madison, USA

Abstract:

The conversion of non-food biomass into biofuels and high-value bioproducts represents a critical pathway toward sustainable energy systems and a circular bioeconomy. The Wisconsin

Energy Institute (WEI) at the University of Wisconsin - Madison is working at the heart of this challenge to accelerate the development of new sustainable biotechnologies to help meet society's ever-growing need for fuels, chemicals, and materials. This talk will showcase advances in plant transformations, pretreatment technologies, and microbial fermentation that have significantly improved the efficiency of breaking down complex biomass from a variety of biomass resources into fermentable sugars and platform chemicals. Innovations in systems biology, the utilization of both purpose-grown and waste organic feedstocks, and the production of a broad range of biobased products, such as bioplastics, biobased chemicals, and biomaterials will also be discussed. Together these breakthroughs offer the potential for a new generation of biorefineries that open new markets, create jobs, and generate new economic opportunities for communities nationwide.

Invited Talk

Biomass Blends for Flexible, Economically Stable, and Scalable Biomanufacturing

Kalyani Ananthakrishnan a , Ramkrishna Singh a,b , Lukas Webb b, Blake A. Simmons a,c ,
Ning Sun a,b ,

Nawa Raj Baral a,c

a Biological Systems and Engineering Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720, United States
b Advanced Biofuels and Bioproducts Process Development Unit, Lawrence Berkeley National
Laboratory, Emeryville, California 94608, United States
c Joint BioEnergy Institute, Lawrence Berkeley National Laboratory, Emeryville, California 94608,
United States

Abstract:

Biorefineries commonly rely on a single biomass feedstock, leaving them vulnerable to supply disruptions caused by price volatility, quality degradation during storage, and inconsistent large- scale availability. Incorporating biomass blends or sequentially using different single feedstocks aligned with their harvesting seasons can alleviate many of the constraints associated with single-feedstock dependence. Realizing this flexibility, however, requires
biomass deconstruction pathways capable of efficiently processing diverse feedstocks and producing cost-effective intermediates for downstream upgrading into fuels, chemicals, or materials. Recent advances in distillable amine-based solvents demonstrate strong potential for deconstructing a wide range of biomass feedstocks under uniform operating conditions, thereby enabling feedstock-flexible biorefineries. In this study, we conduct a comprehensive techno-economic comparison of single feedstocks and biomass blends using 11 herbaceous and 11 woody feedstocks available across the continental United States. Candidate blends for herbaceous and woody biomass were identified using a multi-factor decision matrix that incorporated availability, delivered biomass cost, geographic distribution, sugar-yield

potential, potential coproduct credits, and sugar-production cost. Blending ratios were determined based on the decision-matrix scores and subsequent economic optimization. We also evaluated how variations in delivered biomass cost and feedstock quality influence the optimal economic blending ratio.

Overall, the results highlight that biomass blends can achieve economic performance comparable to single feedstocks and, in many cases, outperform them—particularly when the primary feedstock experiences price surges or quality degradation. The analysis also reveals clear transition points where blends become more advantageous than single biomass feedstock.

Invited Talk

Distillable Amine Solvents Enable Efficient Pretreatment of Diverse Single and Mixed Lignocellulosic Feedstocks

Xueli Chen1, Anagha Krishnamoorthy1, Joseph Palasz1, Nawa Raj Baral1,2, Venkataramana Pidatala1,2, Tyrell Lewis1,3, Yang Tian2,4, Carolina Barcelos1,3, Xinyi Zhou1,3, Xihui Kang1,3, Yinglei Han2,5, Chang Dou1,3, Corinne D. Scown1,2, Eric Sundstrom1,3, Aymerick Eudes2,4, Hemant Choudhary2,5, Ning Sun1,3, and Blake Simmons1,2,*

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5 Department of Bioresource and Environmental Security, Sandia National Laboratories, Livermore, CA 94551, USA

Abstarct:

Developing distillable solvents for efficient biomass pretreatment is central to biorefineries, as they can enhance fermentable sugar yields while enabling low-loss solvent recovery and recycling. Here, we apply distillable amine-based solvents to pretreat a broad range of lignocellulosic feedstocks to improve enzymatic sugar release. Twenty-two feedstocks from diverse regions and biomass categories were characterized for carbohydrate, lignin, and lignin-unit (S/G/H) composition. Five solvents—ethanolamine, ethanolammonium acetate, butylamine, butylammonium acetate, and triethylamine—were evaluated on eight representative feedstocks. Among them, butylamine performed best, offering high sugar release, efficient solvent removal, and a low boiling point that facilitates recovery.

Pretreating poplar with neat butylamine at 140 °C for 3 h produced 90% glucose and 71% xylose, with strong water tolerance up to an 8:1 water:butylamine ratio. Mechanistic studies using XRD, TGA, fluorescence microscopy, elemental analysis, and solid- and solution-state NMR showed that butylamine largely preserves biomass structure while performing targeted ester cleavage, disrupting lignin–carbohydrate cross-links and partially solubilizing lignin.

Extending butylamine pretreatment to all 22 feedstocks yielded consistently high sugar release and solvent recovery, with agricultural residues and blends showing the strongest responses. Scale-up in a 1 L Parr reactor achieved >90% glucose release and >99% solvent removal, and the resulting hydrolysates supported growth of multiple microbial hosts, confirming fermentation compatibility. Techno-economic analysis identified solvent loading and recovery, solid loading, sugar yield, enzyme use, and biomass cost as key factors in achieving sugar prices of $0.45–0.79/kg. Overall, this work demonstrates that butylamine is an effective, recoverable, and scalable pretreatment solvent for diverse lignocellulosic feedstocks, supporting the development of cost-effective, feedstock-flexible biorefineries.

Invited Talk

Valorization of Lignocellulosic Biomass to Produce Biohydrogen

Young Eun Song

Lawrence Berkeley National Laboratory, USA

Abstract:

Biological hydrogen production from lignocellulosic biomass offers a sustainable route to renewable energy generation while simultaneously reducing organic waste. Dark fermentation using Clostridium thermocellum is especially promising because its cellulosome facilitates direct hydrolysis of raw lignocellulose without enzymatic pretreatment. However, commercial deployment remains constrained by inadequate mixing and mass-transfer limitations when handling solids-rich, non-pretreated biomass. Therefore , homogeneous mixing is essential to ensure efficient enzyme dispersion, effective substrate with cell interactions, and rapid removal of hydrogen during continuous operation. To address these challenges, we applied an integrated process-optimization strategy combining Computational Fluid Dynamics (CFD) and experimental evaluation. CFD simulations of high-solids corn stover under multiple impeller configurations guided the development of a customized bioreactor with enhanced flow uniformity. Using the engineered C. thermocellum KJC19-9 strain, capable of co-utilizing cellulose and hemicellulose, we assessed hydrogen production across different biomass loadings. Higher biomass concentrations improved hydrogen yields, while solubilization consistently reached approximately 65% for glucan and 70% for xylan. Particle-size reduction provided only marginal improvements in hydrogen productivity and did not significantly affect overall performance. Collectively, this work presents a scalable and mixing-optimized bioprocess for dark fermentation of raw lignocellulosic biomass, providing a viable pathway toward pilot-scale biohydrogen production.

Invited Talk

Hydrogenases as Enablers of Redox-Driven Biomanufacturing

Justin Panich

Lawrence Berkeley National Laboratory, USA

Abstract:

Hydrogenases offer a scalable route for supplying reducing power to microbial metabolism, enabling biomanufacturing pathways that operate independently of organic electron donors. By catalyzing hydrogen oxidation with high efficiency, these enzymes provide a direct biochemical interface between renewable electricity, molecular hydrogen, and cellular redox networks. Recent progress in microbial engineering has enabled the deployment of hydrogenases to support both C 1 conversion pathways and heterotrophic biomanufacturing pathways. This work evaluates system-level constraints governing hydrogenase-driven metabolism, including redox balancing, electron allocation, and mass transfer limitations. Integration with electrochemical hydrogen generation is considered as a means to couple electrical energy directly to biosynthesis. Remaining challenges related to enzyme stability, oxygen tolerance, and process scalability are discussed in the context of strain engineering and bioreactor design.

Invited Talk

Auto-floating microalgae – An alternative way for cultivating easily harvestable microalgal biomass

Yuansheng Hu 1 *, Hui Pan 2 , Xinmin Zhan 2

1 UCD Dooge Centre for Water Resources Research, School of Civil Engineering, University College Dublin, Ireland; 2 School of Engineering, College of Science & Engineering, University of Galway, Galway, H91 TK33, Ireland

Abstract:

Microalgae-based biofuels have been recognized as one of the most promising third generation biofuels to replace fossil fuels in the future. However, the growth and development of the microalgal biofuel industry remain economically unviable due to several technical challenges associated with large-scale microalgal biomass production. Among these challenges, cost-effective microalgae harvesting is one of the most critical bottlenecks, accounting for 20–30% of total microalgal biomass production costs. To address this issue, we developed a novel process for the selective enrichment of auto-floating microalgae, which can spontaneously float to the water surface under quiescent conditions, thereby enabling easy harvesting. This process is achieved by repeatedly retaining the floating layer and discharging the subnatant in semi-batch photobioreactors. The auto-flotation mechanism is based on in situ gas flotation induced by photosynthetically generated micro-oxygen bubbles, with cell-surface hydrophobicity playing a pivotal role in effective bubble–cell adhesion. This auto-flotation mechanism also results in excellent dewaterability, further facilitating downstream processing. Using a naturally developed mixed microalgal culture as inoculum, the proof of concept was first established with secondary effluent as the culture medium and subsequently validated using aquaculture wastewater under mixed-culture conditions. The enriched auto-floating microalgae achieved an excellent harvesting efficiency of >90% within 30 minutes via auto- flotation. Notably, the auto-floating microalgae exhibited a strong tendency toward granulation, which further enhanced harvesting performance. Overall, easily harvestable auto- floating microalgae provide a potential approach for cost-effective microalgal biomass production.

Invited Talk

Scaling Up the Forest Bioeconomy: From Thermal Deoxygenation to Sustainable Fish Feed

M. Clayton Wheeler

University of Maine, USA

Abstract:

The University of Maine's Forest Bioproducts Research Institute (FBRI) leverages over a decade of expertise in scaling up biomass conversion technologies to transform woody biomass into a diverse portfolio of fuels, food, and chemicals. This talk will highlight FBRI's specialized facilities, including the Biomass to Bioproducts Pilot Plant (B2P2) and the Synthetic Crude Oil Pilot Plant (SynCOPP), which can produce hundreds of kilograms of organic acids and up to 75 kg/day of crude oil in continuous mode.

A centerpiece of this presentation is UMaine's patented Thermal Deoxygenation (TDO) process. This innovative pathway converts sawdust into a platform of levulinic and formic acids via acid hydrolysis, which are then neutralized into organic salts that are pyrolyzed at 450 °C in a process we refer to as TDO. The resulting aromatic-rich biocrude oil contains less than 6 wt% oxygen and can be hydroprocessed into cycloalkane-rich sustainable aviation fuel (SAF). Notably, testing has demonstrated that a 50% blend of UMaine SAF meets ASTM D1655 specifications for commercial jet fuel and satisfies the requirements for military JP-8 fuel. Furthermore, the talk will introduce the new Sustainable Wood to Fuel and Fish Feed (SWF3) project, a transdisciplinary program designed to strengthen the US bioeconomy. This initiative expands FBRI's conversion expertise by integrating continuous hydrothermal liquefaction for SAF production with fermentation technologies. The project aims to upgrade low-quality woody biomass into two high-value streams: jet fuels and single-cell protein for aquaculture fish feed. By co-producing these materials, the SWF3 program seeks to reduce SAF production costs, incentivize sustainable forest management, and enhance nutrition security by providing alternative, sustainable ingredients for the global aquaculture industry.

Invited Talk

From Genes to Gigawatts: Bridging Biological Innovation and Climate Investment in the Bioenergy Transition

Jillian Chase

Azolla Ventures, Cambridge, USA

Abstract:
Bioenergy sits at the intersection of biology, technology, and finance and presents an opportunity to be a significant enabler for decarbonizing hard-to-abate sectors for which electrification alone is insufficient. Yet, despite decades of research, bioenergy remains under-deployed relative to its significant climate potential. This talk explores how advances in life sciences and strategic climate investment can unlock the next generation of sustainable biofuels and bioenergy systems.

Drawing on perspectives from the life sciences and impact investing, we will examine how non-food feedstocks, synthetic biology, and integrated biorefineries are redefining the efficiency and carbon balance of biomass conversion. We will also explore how bioenergy has the potential to be transformed from a low-carbon solution to a source of *negative emissions*. From an investor's standpoint, the presentation highlights emerging risk-management frameworks, life-cycle sustainability metrics, and new financial mechanisms that make bioenergy bankable and scalable.

By linking scientific innovation with climate finance, this session offers a roadmap for accelerating sustainable bioenergy deployment — turning biological ingenuity into gigawatt-hour scale potential.

Invited Talk

Coupling pretreatment and solvent recovery to enable closed-loop biomass deconstruction

Md Maksudur Rahman[1,2,], Hemant Choudhary[1,3], Blake A. Simmons[1,4], John M. Gladden[1,2], Alberto Rodriguez [1,2]

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[3]*Bioresource and Environmental Security, Sandia National Laboratories, 7011 East Avenue Livermore, CA 94550, USA.*
[4] *Biological Systems and Engineering, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA, 94720, USA.*

Abstract:

Efficient solvent recycling is critical to improving the performance and feasibility of lignocellulosic biomass pretreatment processes for biofuel and biochemical production. However, selecting an optimal pretreatment solvent and recovery technique that improves enzymatic saccharification and fermentation while remaining cost-effective and ecologically sound continues to be a significant challenge. This study compares three solvent recovery techniques including small-scale distillation, pressing, and washing with centrifugation using alkanolamines as volatile solvents for pretreatment of sorghum biomass, a bioenergy feedstock. We monitored key process outcomes like solvent recovery efficiency, fermentable sugar yields and biocompatibility of the resulting hydrolysates with microbial conversion hosts like *Rhodosporidium toruloides* and *Pseudomonas putida*. In the distillation approach, vacuum distillation (~80 °C) was performed across varying biomass-to-solvent ratios, with and without water washing. The pressing method involves the use of a mechanical press to extract solvent, followed by water washing and evaporation in successive trials. The third approach involves washing pretreated biomass with water and recovering solvent via centrifugation. Recovered solvents from each method were reused in subsequent pretreatment experiments to determine their effectiveness, functional stability, and microbial toxicity across multiple cycles. Techno-economic analysis (TEA) models were generated based on the obtained solvent recovery efficiency, sugar yield and conversion data to assess energy consumption and the overall process feasibility. This study aims to provide comparative insights into practical solvent recycling strategies for scalable and cost-effective biomass conversion.

Invited Talk

Design-Driven Microbial Engineering for Carbon-Optimized Bioproduction

James Carothers

University of Washington, USA

Abstract:

Biomass-derived feedstocks represent abundant but under-utilized carbon pools for industrial biomanufacturing. This talk presents design-driven microbial engineering frameworks that treat carbon optimization as a first-principles design constraint, enabling conversion of lignocellulosic hydrolysates and one-carbon species into high-value chemicals for sectors including semiconductors, advanced materials, and specialty polymers. Vignettes will highlight non-model microbes engineered through DBTL cycles to generate polymer precursors from lignocellulosic streams; cell-free C1 assimilation achieving >90% conversion to industrial di-acids; and design-scale mapping of regulatory networks to identify leverage points that improve carbon retention and pathway performance. We also showcase genome-integration technologies that unlock new microbial chassis, including production of photoresist precursors from lignin-derived aromatics. Underlying these advances are multi-gene program engineering, CRISPR-enabled genome-wide programming, ML-guided design, and high-throughput single-cell analytics that accelerate discovery and enable predictive, carbon-optimized bioproduction.

E - Poster Presentations

Liquid Chromatography and Mass Spectrometry Analysis of Volatile Alkaline Protic Solvent Pretreated Lignocellulosic Hydrolysate

Emine Akyüz Turumtay[1,2]*, Joseph M. Palasz[1], Levent Sirtas[1,4], Venkataramana Pidatala[1,2], Hemant Choudhary[2,3], John Gladden[1,2,3], Christopher J. Petzold[1,2], Blake A. Simmons[1,2], Paul D. Adams[1,2,4], Edward E.K. Baidoo[1,2]

[1]Lawrence Berkeley National Laboratory, USA;
[2]Joint BioEnergy Institute, USA;
[3]Sandia National Laboratories, USA
[4]University of California, Berkeley, USA

Abstract:

Lignin, a highly abundant and renewable biopolymer, holds significant promise as a source of aromatic compounds for biofuels, plastics, and pharmaceuticals. However, its inherent structural complexity, poor solubility, and propensity for undesirable reactions during fractionation presents challenges for selective component isolation. One promising approach to overcome these limitations is the use of amines, which improve lignin solubility by forming strong hydrogen bonds, making them more effective solvents compared to conventional non-amine organic solvents. Specifically, volatile alkaline protic solvents like butylamine exhibit typical amine reactivity, such as nucleophilic attack on carbonyl groups in lignin polymers, leading to the formation of amides.

To explore the products formed during butylamine pretreatment, which may potentially inhibit microbial growth in a biorefinery setting, we have developed high-throughput liquid chromatography coupled with quadrupole time-of-flight mass spectrometry (LC-QTOF-MS) methods. These techniques enable the detailed analysis of both the amines and the reaction products, offering insights into their role in biorefinery applications.

E - Poster Presentations

Directed evolution of conjugative plasmids

Thien Vu

UC Berkeley/ Lawrence Berkeley National Lab, USA

Abstract:

In bacterial engineering, horizontal gene transfer via conjugation is a critical mechanism for introducing and optimizing genetic constructs. Despite its importance, conjugative efficiency and reliability often limit the speed and scalability of bacterial strain engineering. In this work, we are evolving a diversity of conjugative plasmids for improved conjugation efficiency. We are using eight unique conjugative plasmids that we isolated from randomly-barcoded transposon mutagenesis libraries from a diverse set of bacteria. Over the next few months, we will repeatedly transfer conjugative plasmid carrying selectable markers and barcodes from a donor *E. coli* strain to a recipient strain. Following each cycle, we will isolate and use transconjugants to initiate subsequent rounds of conjugation, thereby directly selecting for plasmid variants with enhanced transfer efficiency. Over evolutionary time, this approach enriches the mobile genetic element encoded traits that improve conjugation. We aim to enhance conjugation by measuring changes in plasmid transfer frequency and characterizing evolved plasmid populations through long-read sequencing. Ultimately, our goal is to leverage directed evolution to develop more efficient and reliable plasmid delivery systems. More broadly, understanding evolutionary processes will allow engineers to predict how introduced genetic traits will perform in important chassis organisms for bioengineering.

E - Poster Presentations

Impact of Pyrolysis Temperature on the Pore Structure and Surface Area of Bamboo-Derived Biochar for Sustainable Applications

Jyun-Hao, Jhu [1], Hung-Lung, Chiang [2*]

[1] *Department of Safety Health and Environmental Engineering, National Yunlin University of Science and Technology, Yunlin, Taiwan*

[2*] *Department of Safety Health and Environmental Engineering, National Yunlin University of Science and Technology, Yunlin, Taiwan*

Abstract:

Biochar made from agricultural and forestry waste is a promising material for sustainable and circular economies. Because of its fast growth rate, bamboo is an excellent biomass source. Previous studies have shown that the pore structure and thermochemical properties of bamboo-derived biochars improve greatly with higher carbonization temperatures (Lu et al., 2026). Building on this, this study explores how pore formation and structural changes in bamboo biochar vary at different pyrolysis temperatures to better optimize its physical properties for environmental uses.

E - Poster Presentations

An unconventional study: replacing all crude oils with fuels from cellulosic biomass (CWF)

Chiara Berretta1,2,3, Tilman Schildhauer1 , Bruce Dale4 , Charles Forsberg3

1 Paul Scherrer Institut; 2 École Polytechnique Fédérale de Lausanne; 3 Massachusetts Institute of Technology; 4 Michigan State University (emeritus)

Abstract:

Cellulosic biomass offers a sustainable alternative to fossil fuels, yet current biomass-to-fuels strategies often sacrifice carbon yield by consuming biomass for (1) process heat; (2) removing oxygen from the cellulosic feedstock as CO2 or supplying H2 to remove oxygen as water. With ~1 billion dry tons of sustainably sourced U.S. biomass yearly, full conversion using current strategies would displace slightly more than 30% of transportation fuel demand. Achieving a complete replacement of crude oil requires massive low-carbon H2 and external heat addition. This doubles the liquid hydrocarbons produced per ton of biomass, making hydrogen the highest cost and enabling higher biomass prices, which in turn significantly increase the cellulosic supply. Because economies of scale favor large biorefineries while un-densified biomass is economically shipped only ~30–70 miles, we assess intermediate "depot" concepts that densify/convert biomass into shippable commodities – (i) pelletization (commercial), (ii) fast pyrolysis (early commercial), (iii) anaerobic digestion (commercial for many feedstocks) and (iv) direct hydrogenation (research phase) – against carbon efficiency, product quality, co-production of refractory carbon for soil amendment, overall energy efficiency, technological maturity, and refinery integration potential. Key trade-offs emerge: pelletization enables lower transport cost but limited carbon return; fast pyrolysis produces up to ~70% bio-oil, biochar containing ~25% of biomass carbon and gases for thermal integration, but needs H2-assisted bio-oil stabilization before long-distance shipping; anaerobic digestion offers recyclable digestate and biogas compatible with Fischer–Tropsch synthesis, but biogas transport requires upgraded biomethane grids; direct hydrogenation produces bio-oils but shifts the H2 supply burden to depots. This study aims to support relevant stakeholders in recognizing the energy and capital intensity of different biomass-to-fuels routes and prioritize those with the greatest implementation potential. As such, it is part of a larger MIT effort to evaluate future transport fuel options (hydrocarbon liquids, ammonia, hydrogen, etc.) in a carbon-constrained world.

DAY – 3

Plenary Talk

Biofuels: a paradigm of present and future

Rafael Luque Alvarez de Sotomayor

Universidad ECOTEC, Km 13.5 Samborondon, Samborondon, EC093202, Ecuador

Abstract:

Biofuels represent a crucial bridge between today's energy needs and tomorrow's sustainable solutions. In this lecture, we will explore how advances in green chemistry, catalytic engineering and biomass/waste valorization are redefining the present landscape of biofuel production while opening new avenues for future developments. Drawing on past and present work in waste-to-fuel technologies, multifunctional catalysts and process intensification, this lecture will discuss scalable and cost-effective strategies that convert diverse biomass and waste resources, including agricultural residues, plastic waste and industrial byproducts—into advanced liquid fuels, energy carriers and biofuels (hydrogen). The talk will highlight current challenges, recent breakthroughs and the emerging paradigm in which circularity, carbon efficiency, and technological innovation converge. By examining both present realities and future opportunities, this presentation offers a comprehensive perspective on the evolving role of biofuels in the global transition toward a low-carbon, resilient future energy society.

Keynote Talk

Intensification Strategies for Anaerobic Digestion

Dr. Elsayed Elbeshbishy

Professor, Civil Engineering Dept., Toronto Metropolitan University, Toronto, Ontario, Canada

Abstract:

The anaerobic digestion (AD) process is an integral part of wastewater treatment plants (WWTPs) with the pivotal role of stabilizing the generated sludge and converting it into biogas contributing to environmental protection and energy recovery. Nonetheless, the AD process is characterized with the slow kinetics of sludge hydrolysis, and the anaerobic microorganisms involved in the methanogenic pathway. As a result, the AD process is reported to be sensitive to the applied conditions (i.e., higher organic loading rate, to have sub-optimal methane yields, and to require large footprints due to its limited volumetric capacity. By addressing these deficiencies, notable efficiency and capacity gains can be realized satisfying the urge for intensifying the sludge handling facilities in WWTPs. Therefore, significant research and

industrial efforts have focused on AD intensification. In this presentation, different intensification strategies will be succussed such as the feedstock pretreatment, bioaugmentation, multi-stage AD, the addition of biochar to promote direct interspecies electron transfer, and the potential of biogas upgrade through enriched hydrogenotrophic methanogenic.

Invited Talk

Application of LC-MS based metabolomics analysis to bioenergy research

Edward Baidoo

Lawrence Berkeley National Laboratory, USA

Abstract:

Over the past decade, metabolomics has garnered a lot of attention due to itsprovision of metabolic information pertaining to both function and phenotype.Additionally, when metabolomics data is integrated with other ‘omics’ data, accurate characterization of metabolic activity can be achieved. In the context of bioenergy research, metabolomics analyses have revealed the metabolic potentialfor biofuel production in host organisms and have been used to assess the impactof engineered metabolic pathways on wider metabolism and host physiology. Inthis talk, I will discuss the application of LC-MS based metabolomics methods toidentify bottlenecks in microbial biofuel production, characterize plant rootexudates, and identify substrates and inhibitors in lignocellulosic hydrolysatesfrom pretreated bioenergy crop biomass.

Invited Talk

Dynamic Two-Phase Anaerobic Digestion Biorefineries: An Investigation of Technical and Economic Feasibility

Rajas Shinde[1*], Paul Crosson[1], Jerry D. Murphy[2,3], David M. Wall[2,3]

[1]*Teagasc Animal and Bioscience Research Department, Animal and Grassland Research and Innovation Centre, Ireland*

[2]*SFI MaREI Centre for Energy, Climate and Marine, Sustainability Institute, University College Cork, Ireland*

[3]*Civil, Structural and Environmental Engineering, School of Engineering and Architecture, University College Cork, Ireland*

Abstract:

Advancements in anaerobic digestion (AD) offer opportunities to use the technology in a biorefinery approach for the simultaneous production of valuable biobased products and bioenergy. This study investigated a two-phase AD system, comprising a leach bed reactor

(LBR) and an upflow anaerobic sludge blanket (UASB) reactor, for the production of volatile fatty acids (VFAs) and biogas using grass silage as feedstock. The LBR-UASB biorefinery achieved yields of approximately 100 kg of VFAs and 300 kWh of biogas per tonne of grass silage dry matter. A demand-driven operational strategy was developed to dynamically align VFA and biogas outputs with varying market demand scenarios. This enabled the biorefinery to operate as a dispatchable renewable energy source during peak electricity demand hours and produce biobased products at other times, thereby maximising the revenue potential. A techno-economic model was developed for a 35,000-tonne/year grass biorefinery producing biopolymers, fibre insulation, and biogas, assessing financial viability at both the biorefinery and farm level. The biorefinery achieved a 20-year net present value (NPV) of –$4 million under baseline conditions, improving to +$3.5 million when targeted subsidies and process improvements were implemented. Demand-driven operation enhanced the economic value of the biogas produced by enabling demand-side management services during peak hours and halving the biorefinery's energy purchase costs. Through combined experimental and techno-economic assessment, this study demonstrated the potential role of AD-biorefineries in supporting farm diversification and circular bioeconomy development. Stakeholder engagement further evaluated the potential for AD-biorefinery value chains and identified emerging pathways for digestate valorisation and biogenic CO_2 utilisation. Future work will assess these pathways using the techno-economic and value chain assessment framework developed within this study.

Invited Talk

Combined Algae Processing: Progress, Potential, and Pathways Forward

Matthew Wiatrowski*, Bruno Klein, and Ryan Davis

Catalytic Carbon Transformation and Scale-up Center, National Laboratory of the Rockies, 15013 Denver West Parkway, Golden, CO 80401, USA

Abstract:

Combined Algae Processing (CAP) is a flexible framework for converting microalgae into fuels and value-added products by fractionating biomass into lipid, carbohydrate, and protein streams and upgrading each fraction through separate conversion steps. Over the past decade, CAP has been evaluated across a range of process configurations, biomass compositions, and coproduct strategies, providing insight into both its potential and its limitations as a bioenergy platform.

This presentation synthesizes CAP's historical progress and emerging opportunities as informed by techno-economic analysis (TEA) and life-cycle assessment (LCA). Results from multiple published analyses are used to illustrate how biomass composition, conversion approach, and choice of coproducts influence minimum fuel selling price and broader system performance metrics. Building on this systems-level perspective, the presentation then

examines recent promising CAP pathways in greater detail, including approaches producing scalable coproducts such as polyurethane and thermoplastic products.

Together, these results highlight key cost drivers and trade-offs in microalgae conversion and identify the conditions under which CAP pathways approach competitive fuel costs and favorable life-cycle performance. The findings help prioritize research directions and deployment strategies most relevant for advancing algae-based fuels and products.

Invited Talk

Green Power for Data Centers Using Napier Grass Based Biogas-Hydrogen Pathway

Dr Ganapathy Arumugam1*, Er. Aravinth Muthusamy2, Dr Sornamuki Arumugam3

1Enhanced Biofuels and Technologies LLC, USA; 2Enhanced Biofuels and Technologies India Pvt Ltd, India

Abstract:

Enhanced Biofuels and Technologies LLC (EBTI) presents a circular bioenergy model converting high-yield Napier hybrid grass into biogas, hydrogen and clean electricity to power data centers with 24/7 renewable baseload. One tonne of EBTI Napier biomass generates 180–250 m3 of biogas, yielding 40–50 kg of green hydrogen and 150–200 kWh of electricity through fuel cells or hydrogen turbines. The system integrates anaerobic digestion, biogas reforming and CO2 capture, enabling near-zero or carbon-negative operation while supporting carbon credit generation. Napier grass yields 450–700 t/ha/year, grows on marginal land without fertilizers or pesticides, and sequesters 30–40 tCO2e per hectare annually. A 1 MW deployment can supply 24,000 kWh/day for a 10,000 sq.ft. data center using biomass from ~30 acres, ensuring Tier-III/IV reliability. With modular units from 100 kW to multi-MW scale, projects can achieve ROI within 2.5–3 years, supported by U.S. IRA hydrogen incentives. This solution offers grid-independent, climatepositive digital infrastructure aligned with ESG, RE100 and net-zero goals.

Invited Talk

Kinetic Modeling of Dilute Alkaline Deacetylation for Scalable Lignocellulosic Bioenergy Systems

Yudong Li[1], Smith Pittman[1], Matan Lieber-Kotz, Xiaowen Chen[1], and David A. Sievers[1]

[1]National Laboratory of the Rockies

Abstract:

Dilute alkaline deacetylation is a critical pretreatment step in lignocellulosic bioenergy conversion that removes inhibitory acetyl groups from Xylan and partially solubilizes lignin, thereby improving downstream refining efficiency. Despite its industrial importance, existing deacetylation models often rely on computationally intensive particle-scale simulations that are impractical for reactor-scale design and optimization. In addition, many high-fidelity physics-based models assume constant sodium hydroxide concentration, despite experimental evidence showing that pH decreases in correlation with biomass solubilization during deacetylation. Together, these assumptions limit predictive accuracy under realistic operating conditions where chemical consumption dynamically alters system behavior.

In this work, a generalized and computationally efficient kinetic framework for alkaline deacetylation is developed and validated using flow-through packed-bed experiments with corn stover under industrially relevant conditions. Validation experiments systematically varied temperature and sodium hydroxide loading, while time-resolved measurements of acetate release, lignin solubilization, and Xylan conversion from black liquor samples enabled direct comparison between predicted and observed chemical behavior. In parallel, the evolution of packed-bed properties was quantified through measurements of bulk density, effective porosity, and pressure gradients, providing experimental inputs for permeability estimation.

The proposed model captures parallel hydroxide-driven reaction pathways through Arrhenius-based kinetics coupled by a shared hydroxide balance, enabling explicit representation of hydroxide depletion and pH evolution. Pressure drop data were interpreted using Darcy's law to link chemical conversion with evolving packed-bed hydrodynamics. Validation results demonstrate strong agreement between experimental and modeled trends.

By explicitly resolving dynamic hydroxide consumption and incorporating self-optimizing kinetic parameters, this work provides a kinetic code that is readily integrable into high-fidelity reactor and process-scale models, supporting improved prediction and design of biomass pretreatment systems and development of generalized lignocellulosic biomass stoichiometry in alkaline pretreatment.

Invited Talk

Harnessing the abiotic-biotic interface for CO2 conversion

Deepika Awasthi

Lawrence Berkeley National Laboratory, USA

Abstract:

Decarbonizing chemical manufacturing requires efficient methods to upgrade CO_2 into functional carbon feedstock. Integrating CO_2 electroreduction with microbial upgrading generates liquid intermediates such as formate, enabling diverse multicarbon biosynthetic pathways while mitigating gas–liquid mass-transfer limitations inherent to direct biological CO_2 conversion. However, most integrated CO_2 electrolysis–bioconversion systems rely on a limited set of microbial hosts, slowing the discovery and optimization of carbon conversion

routes. We have developed a modular eFormate-mediated electrochemical–microbial cascade that establishes a robust abiotic–biotic interface. Using a unified eFormate feedstock, we directly compared 13 formatotrophic strains and identified 10 that convert eFormate into multicarbon products and key metabolic intermediates. This platform extends electrochemical–microbial carbon upgrading to diverse microbial systems and enables systematic identification of CO_2-to-C_n pathways.

Invited Talk

Requirements for Biofuels to Replace Crude Oil: Soil Sustainability, Hydrogen and Cellulosic Biomass

Charles Forsberg[1]* and Bruce E. Dale[2]

[1]Massachusetts Institute of Technology, USA; [2]Michigan State University (retired), USA

Abstract:

We have explored alternative system designs to address what is required to replace global crude oil consumption (100 million barrels/day) with non-fossil drop-in hydrocarbon liquids (gasoline, diesel, jet fuel and chemical feed stocks). There are three top-level requirements. The first requirement is to assure long-term soil sustainability by recycling soil nutrients and refractory carbon. Refractory carbon improves long-term soil properties, water retention and other properties. Processes such as fast pyrolysis and anaerobic digestion can meet this requirement. The second and third requirements are coupled. There is insufficient plant food-related products (grains, sugars and carbohydrates) to replace crude oil. Most biomass is cellulosic (grass, trees, kelp, etc.). The cellulose molecule ($(C_6H_{10}O_5)_n$) contains almost one oxygen atom per carbon atom. A hydrocarbon ($(CH)_2$) contains no oxygen. To convert solid cellulose to a liquid hydrocarbon, the oxygen must be removed. Today the dominant paradigm is to use some of the cellulose carbon in the refining process to remove oxygen as carbon dioxide. The alternative is to use hydrogen and extract oxygen as water. Adding hydrogen doubles the hydrocarbons produced per ton of biomass. Hydrogen becomes the primary cost; thus, one can pay more per ton of biomass and thereby increase cellulosic feed stock supply. This combination can enable replacing all crude oil with cellulosic biomass. If hydrogen costs are less than $2/kg, biofuels can potentially become competitive with crude oil. Converting carbon dioxide into hydrocarbons is uneconomic because the conversion process requires three times as much hydrogen as starting with cellulosic biomass.

Invited Talk

Renewable Energy and Circular Animal Agriculture in the U.S."

Wei Liao

Michigan State University, USA

Abstract:

Animal agriculture plays a vital role in food production but also generates large quantities of organic residues that pose environmental and management challenges. In the United States, approximately 9.35 million dairy cows produce nearly 29 million metric tons of dry manure annually, containing substantial amounts of carbon and plant nutrients. Conventional manur management practices such as lagoon storage and land application can lead to methane emissions, nutrient runoff, odors, and potential groundwater contamination. Transforming these waste streams into valuable resources is therefore essential for improving environmental sustainability while strengthening agricultural productivity. This presentation explores how anaerobic digestion and integrated resource recovery systems can convert animal manure into renewable energy, nutrient fertilizers, and reclaimed water within a circular bioeconomy framework. Through anaerobic digestion, manure is transformed into biogas that can be upgraded to renewable natural gas (RNG) for electricity generation, grid injection, or transportation fuels. Meanwhile, digestate can serve as a platform for recovering nitrogen, phosphorus, potassium, and organic carbon while enabling water reclamation, helping to close nutrient and water cycles in agricultural systems. Beyond waste management, animal agriculture can also emerge as a new renewable energy infrastructure for the United States. By integrating manure-derived bioenergy with crop residues and other agricultural resources, farms can become distributed energy hubs that supply low-carbon energy to support emerging energy demands. Such systems could power rural data centers, enable distributed electric vehicle charging networks, and support new energy-intensive technologies. With sufficient scale, circular bioenergy systems embedded in animal agriculture could generate massive quantities of renewable methane and electricity, contributing not only to rural economic development, but also to powering transformative technologies that may support missions to the Moon and Mars.

Invited Talk

Synergies Across Biofuel Technologies: Insights from Argentine Biorefineries and Prospective Pathways for Integrated Low-Carbon Systems (Online)

Jorge Antonio Hilbert

EEC Argentina

Abstract:

The decarbonization potential of biofuels depends increasingly on the ability to integrate multiple technologies within coherent biorefinery systems. Drawing on operational data from Argentine bioethanol and biogas plants, together with prospective life-cycle assessments for future Sustainable Aviation Fuel (SAF) production, this work examines how technological synergies can dramatically enhance greenhouse gas performance beyond what isolated processes can achieve.

Three full-scale biogas plants integrated into a corn-starch bioethanol facility demonstrate reductions of more than 98% compared with fossil energy, approaching carbon neutrality in

both thermal and electrical supply. These empirical results highlight the transformative effect of coupling waste-to-energy systems with conventional ethanol production. Complementary prospective studies for a new biorefinery in Bahía Blanca show that combining biogas substitution, partial DDGS drying, and biogenic CO_2 capture can reduce emissions by up to 101% for ethanol and exceed international SAF thresholds established by ICAO. The analysis confirms that the greatest improvements arise not from any single technology, but from the interaction between them—energy efficiency, coproduct valorization, carbon capture, and low-emission agricultural supply chains.

These findings position integrated biorefineries as a strategic pathway for Argentina and the region, enabling biofuels to achieve climate performance comparable to or better than net-zero alternatives. The study underscores the need for policy frameworks that recognize system-level synergies and reward configurations that maximize carbon circularity and resource efficiency.

Keywords: integrated biorefineries, bioethanol, biogas, SAF, CO_2 capture, life-cycle assessment, Argentina.

Invited Talk

Lessons from Organizing Biomass Logistics in Africa: Keep it Simple is the Success (Online)

Fabrizio Sibilla

S&C Best, Italy

Invited Talk

Decentralized Supply Chains for Electrobiofuels (Online)

Christopher M. Saffron

Michigan State University, USA

Abstract:

Biomass upgrading depots are small-scale facilities that serve to densify raw feedstocks into transportable and salable commodities with increased energy and economic value. Decentralized systems seek to find the optimum balance of "economies of scale" and "economies of transportation," while creating a venue for value addition to rural communities. Fast pyrolysis is a thermochemical technology that can be deployed in small-scale depots to deconstruct and densify biomass by rapid heating (400-600°C) without oxygen to create bio-oil, biochar, and combustible gas. Bio-oil is a bulk dense and energy dense liquid that is less costly to transport than raw biomass. However, bio-oil is limited as a fuel intermediate because of its poor chemical properties, namely high oxygen content, corrosiveness, and potential to react and form sludge. As a remedy, electrocatalytic hydrogenation and deoxygenation (ECH) has been proposed to partially upgrade bio-oil to create a stable fuel intermediate. ECH works by saturating carbon-carbon and carbon-oxygen double bonds as well as cleaving certain ether linkages on a catalytic cathode. Though ECH is capable of upgrading bio-oil, the economic and environmental costs of doing so must not be prohibitive to its adoption. The economic viability of pyrolysis-ECH depots is a function of capital costs, operating costs, and product values, while environmental impacts depend on natural resource consumption, pollutant emissions, and belowground carbon sequestration. In this regard, a technoeconomic analysis and life cycle assessment of pyrolysis-ECH depots will be described to reveal the tradeoffs between depot capacity and transportation, while also tallying contributions to climate change. Sensitivities to biomass purchase price, moisture content, belowground carbon sequestration, electricity source, and electricity cost will be examined. ECH could be the keystone technology in biomass upgrading depots, leading to regionally produced commodities and revenue generation in rural communities.

Keywords

Biofuels, pyrolysis, electrocatalysis, depots, economics

Invited Talk

Engineering Anaerobic Microbial Systems for Carbon Valorization: From Arrested Anaerobic Digestion to CO_2 Gas Fermentation for Acetate Production (Online)

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Abstract:

Anaerobic microbial systems play a central role in natural carbon cycling and offer promising opportunities for sustainable biochemical production. In this work, we investigate engineered anaerobic microbiomes for carbon valorization through two complementary platforms: arrested anaerobic digestion (AAD) of animal manure and gas fermentation using CO_2 and H_2 as substrates. The first part of the study focuses on arresting methanogenesis during anaerobic digestion of animal manure to redirect carbon flux toward volatile fatty acids (VFAs). Through controlled operation of batch, fed-batch, and continuous reactors under thermophilic conditions, along with pretreatment and bioaugmentation strategies, total VFA concentrations approaching 30 g/L were achieved with yields of approximately 0.6 g VFA per g VS. Microbial community analysis using sequencing and statistical ecology revealed enrichment of Clostridia and other fermentative taxa, indicating a shift toward acidogenic metabolism and suppression of methanogenic pathways. Building on this acidogenic platform, the second part of the work explores the conversion of gaseous carbon streams through microbial gas fermentation. A rumen-derived homoacetogenic consortium was enriched and cultivated in a trickle-bed reactor, enabling efficient reduction of CO_2 using H_2 to produce acetic acid. The system achieved acetate concentrations up to 23 g/L with approximately 99% H_2 and 95% CO_2 conversion efficiency. Functional gene analysis confirmed the presence of the acetyl-CoA synthase (acs) gene, indicating activity of the Wood–Ljungdahl pathway. Reactor performance was further analyzed through stoichiometric and kinetic modeling to evaluate mass transfer limitations, product inhibition, and metabolic flux distribution. Together, these results demonstrate how engineered anaerobic microbiomes can be directed to convert both solid organic waste and gaseous carbon streams into valuable chemical intermediates such as acetate. The integration of microbial community analysis, reactor engineering, and metabolic modeling provides a framework for designing scalable anaerobic bioprocesses for circular carbon utilization and sustainable biochemical production.

Keywords: Arrested anaerobic digestion, homoacetogens, VFA, gas fermentation.

Invited Talk

Hybrid electrochemical-biological approach to upcycle food waste into aviation fuel

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Abstract:

Upcycling of food waste to produce platform chemicals through electrochemical-biological approaches presents significant commercial potential. This study is the first to investigate the impact of mono- and co-culture fermentation on platform chemical production in both conventional and electro-fermentation systems, highlighting a novel synergistic interaction between bacterial species. Co-culture fermentation demonstrated higher product yields, with butyric acid and butanol emerging as the primary products in conventional fermentation, following the order: butanol > ethanol > acetone. In electro-fermentation, co-culture systems predominantly produced C_2 compounds such as acetone and acetic acid, showcasing their potential for targeted chemical production. A constant cathode potential was maintained during electro-fermentation using an external voltage. Notably, at –0.1 V, butanol production was 12 times higher than at –0.2 V. Mono-culture electro-fermentation primarily produced C_2–C_4 compounds such as acetone, butanol, and butyric acid, while co-cultures achieved higher yields of select acids and alcohols. Additionally, waste samples were valorized with up to 60% of the efficiency observed in the control experiments, yielding butanol concentrations of 12 g/L after 72 hours of fermentation. Moreover, lowering the applied voltage may allow for the replacement of the potentiostat with a simpler fixed DC power supply, improving the overall practicality, cost-efficiency, and scalability of the electro-fermentation system.

Invited Talk

Integrated Biorefineries: Maximizing Value from Waste Through Multi-Product Platforms (Online)

Dr Jayant Keskar

Director Enpro Envirotech Pty Ltd Australia and Fitec Bioenergy Australia Pty Ltd.

Abstract:

The transition toward a circular bioeconomy necessitates paradigm shifts in waste management and resource utilization. Integrated biorefineries represent a transformative approach to converting diverse waste streams into multiple value-added products, including biofuels, biogas, carbon dioxide, biochar while simultaneously addressing environmental challenges associated with landfill disposal and greenhouse gas emissions.

This presentation examines the integration of different technologies while implementing valorization strategies to extract maximum economic and environmental value from municipal solid waste, agricultural residues, food waste, and industrial byproducts. Unlike conventional single-product facilities, multi-product biorefineries leverage synergistic conversion technologies—including anaerobic digestion, thermochemical processes, to produce a diversified portfolio of outputs tailored to market demands. Key aspects covered include: 1 Analysis of integrated biorefinery configurations and their comparative advantages over linear

waste-to-energy systems; 2. Process integration strategies that optimize mass and energy flows while minimizing operational costs; (3) production of high-value byproducts such as biochar, alongside traditional biofuels; (4) utilization of organic streams for biogas generation, soil amendments; and (5) demonstrating environmental benefits including carbon footprint reduction, resource recovery, and landfill diversion rates exceeding 90%.

The presentation concludes with recommendations for accelerating biorefinery deployment, including policy frameworks that incentivize waste valorization, public- private partnerships for infrastructure development, and research priorities in process intensification and product innovation. As global waste generation continues to rise and demand for sustainable alternatives to petroleum-based products intensifies, integrated biorefineries offer a compelling solution that addresses waste management, renewable energy production, and green chemistry objectives simultaneously.

Keywords: Integrated biorefinery, waste valorization, circular bioeconomy, value-added products, sustainable technologies, multi-product platforms.

Invited Talk

Green Criminology in Malaysia's Palm Oil Industry: Deforestation, Ecological Footprints, and Corporate Environmental Responsibility (Online)

Intan Salwani Mohamed

University of Technology MARA (UiTM), Malaysia

Abstract:

This research employs the treadmill of production (ToP) and legitimacy theories to examine the relationship between deforestation, ecological footprints, and corporate environmental responsibility (CER) in the context of green criminology within the Malaysian palm oil industry. The study employs a regression analysis to assess the connection between deforestation (total palm oil–planted hectares) and ecological footprint data spanning 2008 to 2018. Additionally, content analysis investigates the CER practices of 40 palm oil companies listed on Bursa Malaysia between 2016 and 2019. Results indicate that an accelerated treadmill is associated with increased environmental harm, with Malaysian palm oil plantation deforestation accounting for 43.7% of the nation's ecological footprint. The CER analysis suggests that the industry prioritizes conservation practices, potentially as a strategic response to mitigate environmental legitimacy risks associated with deforestation. This research contributes novel insights into CER behaviour within the framework of green criminology.

Invited Talk

Sugarcane Biomass Utilization: Technical Potential and Implementation Gaps (Online)

Joaquín Mario Ortiz

National Institute of Agricultural Technology, Argentina

Abstract:

Sugarcane-based agro-industrial systems generate large volumes of biomass and process effluents with recognized potential for electricity generation, biogas production, nutrient recovery and other value-added applications. Despite the maturity of many conversion technologies, industrial utilization often remains significantly below its technical potential.

The sugarcane industry in Tucumán, Argentina—located near the southern boundary of commercial sugarcane cultivation—provides a relevant case to examine biomass deployment under moderate scale and operational constraints. In Argentina's 2024/25 season, total ethanol production exceeded 578 million liters. Using commonly reported production ratios of 10–15 liters of vinasse per liter of ethanol, this corresponds to approximately 6–8 billion liters of vinasse generated in a single season, while virtually none is converted into electricity or biogas at industrial scale.

The presentation reviews current utilization patterns of bagasse, vinasse and harvest residues, and discusses the technical pathways available for upgrading these biomass streams. Emphasis is placed on the conditions that determine whether projects move beyond feasibility assessments, including minimum viable scale, capital intensity, logistics of dispersed biomass, regulatory stability, macroeconomic volatility and internal decision-making structures within agroindustrial firms.

Examples from green harvesting systems, selective biomass recovery and improved residue management illustrate how targeted technical adjustments can significantly alter project economics. However, a substantial share of available biomass remains underutilized. The primary constraints are not technological; they are structural, linked to investment logic, regulatory frameworks and system integration within operating agro industrial environments.

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