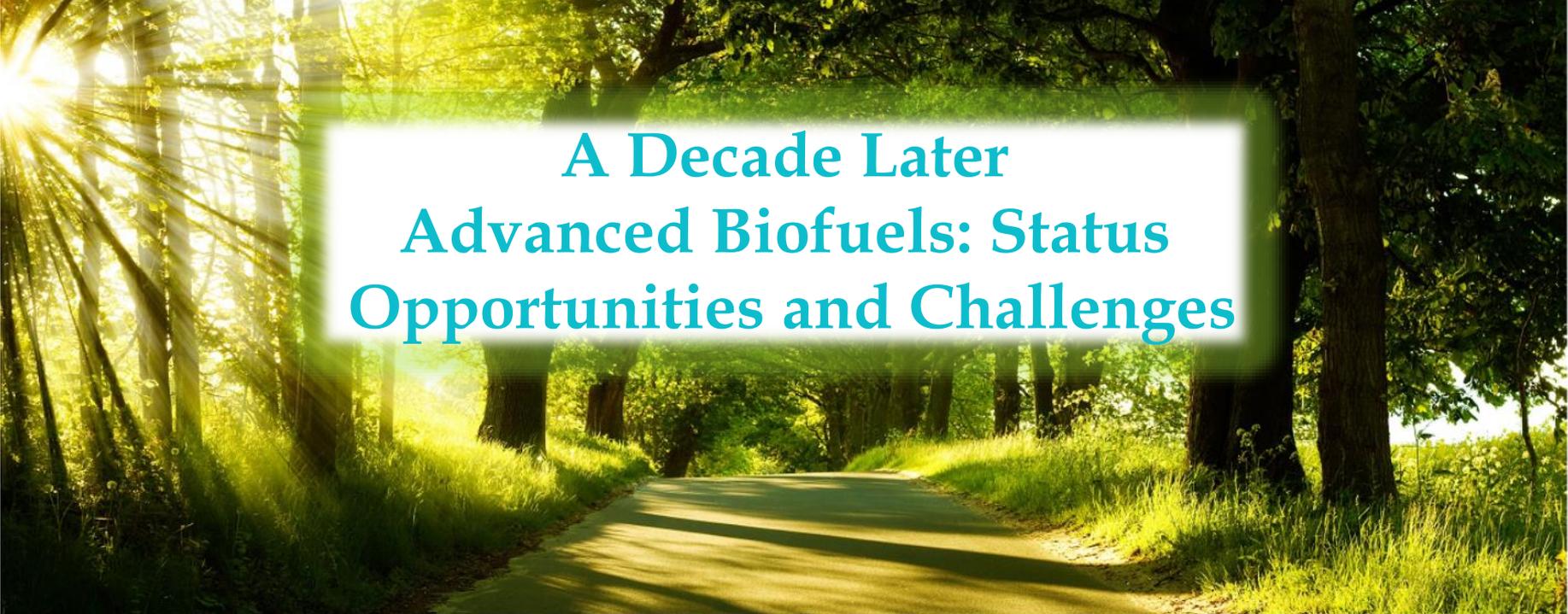


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The background of the slide is a photograph of a dirt path winding through a lush green forest. Sunlight filters through the trees on the left, creating a bright, hazy atmosphere. The path is flanked by tall grass and dense foliage.

A Decade Later Advanced Biofuels: Status Opportunities and Challenges

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Status of Advanced Biofuels

- There are over 2,000 biomass to fuel facilities representing 1,461 companies in 90 countries.
- First-generation biofuels will continue to dominate the market but will lose market share
- Advanced biofuel capacity is expected to double by 2020 to 9.6 billion gallons per year.
- Biodiesel begins to fade from their 65% market share as low-carbon and high-performance drop-in biofuels such as renewable diesel increase

North America Activity 2ND Half 2017

- EPA approved sorghum oil as a feedstock to produce RIN credit
- Ryze Renewables received a USDA guaranteed loan for \$112 million for a biorefinery in Storey County, Nevada to open in 2019.
- Proton Power announced a partnership to build a 40 million gallons per year in West Virginia. Construction of the \$80 million plant is expected to start in 2018.

North America Activity 2ND Half 2017

- SynSel Energy, Inc. announced that they have secured up to \$600M in construction funding to build two \$300M biorefineries.
- In a setback, DuPont announced they would sell their cellulosic ethanol plant in Iowa.
- Poet-DSM's Project LIBERTY plant in Emmetsburg, Iowa as the only currently operating cellulosic ethanol plant. They reported a pretreatment process that has increased uptime to 80%

European Activity 2ND HALF 2017

- Clariant announced plans to build a cellulosic ethanol plant in Romania based on its Sunliquid process.
- There are rumblings of similar projects in Slovakia and other countries.
- There was also significant activity in northern Europe.
 - St1 announced it was continuing to target production of renewable diesel at its refinery in Gothenburg, Sweden in 2020.
 - Silva Green Fuel AS is building a demonstration generation biofuel plant in Hurum, Norway.
 - CRI/Criterion Catalyst Company has announced licensing there IH2 hydroprocessing technology for use Biozin Holding's sawmill in Åmli, Norway.

Activity in the Rest of the World

- In South America, Brazil's Senate approved a national biofuels policy, *RenovaBio*, to increase the use of biofuels.
- Enerkem and Sinobioway Group Sign a C\$125M Agreement to Accelerate Enerkem's Global Expansion and Create a Joint Venture to Build over 100 Biofuel Facilities in China
- Continued activity in Australia, New Zealand and Africa

Opportunity-Mixed Waste to Energy

- There is growing interest in waste-to-energy projects that replace landfilling and incineration.
- The economics of processes that use these wastes are rapidly improving due to high landfilling tipping fees
- The recycling of wastes is more appealing than converting purpose-grown agricultural products.
- Waste-to-energy projects provide greenhouse gas reductions while solving solid waste disposal problems.

Opportunity- Waste for Fuel

- Velocys saw shares jump 40% after British Airways deal -Velocys plans to take hundreds of thousands of tonnes of post-recycled waste and convert it fuel
- Canada's Enerkem Inc., received U.S. EPA approval to collect RIN's for cellulosic ethanol produced at its Edmonton, Alberta municipal solid waste conversion plant.
- Abengoa announced it was selected by Fulcrum BioEnergy to construct the first plant in the U.S. that will produce biofuels from municipal solid waste (MSW) gasification. The Nevada plant will produce 10 million gallons of aviation fuel.

Opportunity- Waste for Fuel

- Recently Japan's SEKISUI CHEMICAL CO., LTD. and LanzaTech announced a joint breakthrough in the conversion of municipal solid waste to ethanol.
- Meridian Waste Solutions Inc. announced the award of a \$3 million grant from the USDA to support the commercialization of lignin conversion and refining technologies

Opportunity- High Value Co-Products

- Many developers of advanced biofuels have pivoted to higher value products
- Processes that use fermentation to produce sugar-derived building blocks like succinic and adipic acid have been commercialized.
- Processes that produce traditional chemical building blocks like olefins and aromatics are also being developed Clariant, Allenotech and many others are moving forward.

Wastes from Higher Value Products

- Processes that convert feedstock and by-product wastes from ethanol and other fermentation processes are a major opportunity.
- These include methods for monetarizing carbon in aqueous wastes and residual lignin removed from the biomass.
- There is a growing effort to develop new processes for converting CO₂ to methanol, dimethyl ether, polyurethanes or other chemical products. Approaches to this conversion range from a chemical conversion to microbial conversion technology.

Challenges for Advanced Biofuels

- Process integration
 - Infrastructure for feed and products
 - Need for multiple unit operations to work together
- High cost of production
- Time to market
- Advances in other technologies
 - Electric cars, solar energy
- Stakeholder involvement
 - Public perception
 - Government

Opportunities for Lowering Costs

- Improved feedstock crops, biological synthetic methods and process integration to reduce or convert wastes.
- Developing an efficient infrastructure that improves the logistics of collecting and handling low density solid material scattered over a wide area is key.
- Reducing the complexity of the process would lower CAPEX and reduce the risk of process interruptions.
- Valorizing by-products

Questions About Sustainability

- Greenhouse gas reductions achievable by biofuels have been questioned.
- There are continued concerns the impact of indirect land use.
- There are studies suggesting that replacing or harvesting forests and natural areas results in a negative CO₂ balance.
- The switch to diesel powered vehicles has been questioned. The use of natural gas and methanol are increasingly viewed as better alternatives.
- There is also an increased perception that electric vehicles using solar and wind derived power will replace liquid fueled vehicles in the coming decades.

Uncertainty of Government Commitment

- Uncertainty of future economic incentives.
 - A standoff between biomass producers and regulation proponents preserved the U.S. renewable fuel standards (RFS) targets at current levels until 2019 with no assurances beyond this time.
 - Trump administration is proposing an 82% cut of fund
 - EU is very concerned about sustainability of liquid biofuels as well as the high costs. Recently they have capped the price differential between liquid biofuels and commercial fuels.

Governments With High Interest in Biofuels

- Countries with economies that are major importers of oil or have significant untapped biomass resources are much more motivated to produce biofuels
- India and Brazil announced significant increases in alternative fuel targets.
- In November 2016, the EU established new mandates equiring them to blend 6.8% of advanced fuels by 2030.
- Strong mandates continue in California where the renewable quotas are now taking effect and in the Northeast where mandatory biodiesel additions to heating have been implemented.

Public Perception

- Several economic studies from the Pacific Northwest, Northern Europe and India came to similar conclusion that the public is willing to pay a no more than a 5-10% premium for biofuels.
- Other environmental issues like solid waste recycling, water pollution control and electric vehicles have higher favorability with the public.



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- Technology Evaluation
- Technical Due Diligence
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- Pretreatment
- Conversion
- Product Separation and Upgrading
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