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DOE Bioenergy Technologies Office (BETO)
2015 Project Peer Review

High-Yield Hybrid Cellulosic Ethanol Process Using High-Impact Feedstock

March 24, 2015
Demonstration and Market Transformation Program

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Goal Statement

- Goals of IBR Project:
  - Mitigate risks so that a 1st Commercial Plant can be financed, constructed, and made operational
  - Demonstrate integrated operations with high-impact feedstocks to support deployment in follow-on commercial facilities throughout the United States

Quad Chart Overview

Timeline

- Budget Periods
  - BP-1: 1/28/10 – 9/30/11
  - BP-2: 10/1/11 – 9/30/14
  - BP-3: 4/13/15 – 6/30/15
- Recent Major Milestones
  - Mechanical Completion: Dec 2012
  - Commissioning/Start-up: Feb 2013
- Percent complete: 96%

Barriers

- Im-C: High Risk of Large Capital Investments
- It-B: Risk of First-of-a-Kind Technology
- It-C: Technical Risk of Scaling and Fully Integrating Biomass Conversion Technologies

Budget

~$MM	Total Costs FY 10 –FY 12	FY 13 Costs	FY 14 Costs	Total (FY 15-End)
DOE Funded	20.914	2.456	0.560	1.070
Project Cost Share	5.228	0.613	0.140	0.268

Project Participants

- Feedstock: GreenWood Resources
- EPCM: Burns & McDonnell
- Key Vendors: Andritz, BASF
- Start-up, Commissioning & Operations: ZeaChem Inc., Pacific Ethanol Management Services

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1 - Tomorrow's Fuels & Chemicals Today

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We Create High Margin and Sustainable Alternatives to Petroleum-Based Fuels and Chemicals in Use, *Today*.

Poplar Harvesting
Boardman, OR

250K GPY IBR Facility
Boardman, OR

Fuels and Chemicals

1 - Company History

2002	2006	2008	2012	
Founded	**Lab**	**Core Pilot**	**IBR Facility**	**1st Commercial**
				
➢ Lakewood, CO ➢ Company headquarters	➢ Menlo Park, CA ➢ 5 GPY ➢ Proved out technology at bench scale	➢ Golden, CO ➢ 50K GPY ➢ 10,000x scale-up of technology	➢ Boardman, OR ➢ 250K GPY ➢ Demonstration of integrated process at scale	➢ Boardman, OR ➢ 25MM+ GPY ➢ Key development milestones completed ➢ Co-location further mitigates risk
	Series A - $6MM	**Series B - $45MM**	**Series C - $25MM**	**Loan Guarantee - $232.5MM**
	MDV MOHR DAVIDOW VENTURES FIRELAKE CAPITAL MANAGEMENT	prairiegold venture partners GLOBESPAN CAPITAL PARTNERS	BIRCHMERE VENTURES ITOCHU MACQUARIE	USDA Silicon Valley Bank A Member of SVB Financial Group

Successfully Developed Technology From Lab To Pilot/Demo Scale & Raised 3 Rounds Of Financing

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1 - Flexible Technology and Diversified Markets

Poplar

Agricultural Residues

Eucalyptus

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Proprietary Technology and Processes

2 Carbon: $485 billion Market

Acetic Acid — Ethyl Acetate — Ethanol

3 Carbon: $595 billion Market

Propionic Acid — Ethyl Propionate — Propanol

C2 Platform End Markets

Ethanol

Acetic Acid / Ethylene Vinyl Acetate

Cellulose Acetate

Ethyl Acetate

Ethylene

Ethylene Glycol

Vinyl Acetate Monomer

C3 Platform End Markets

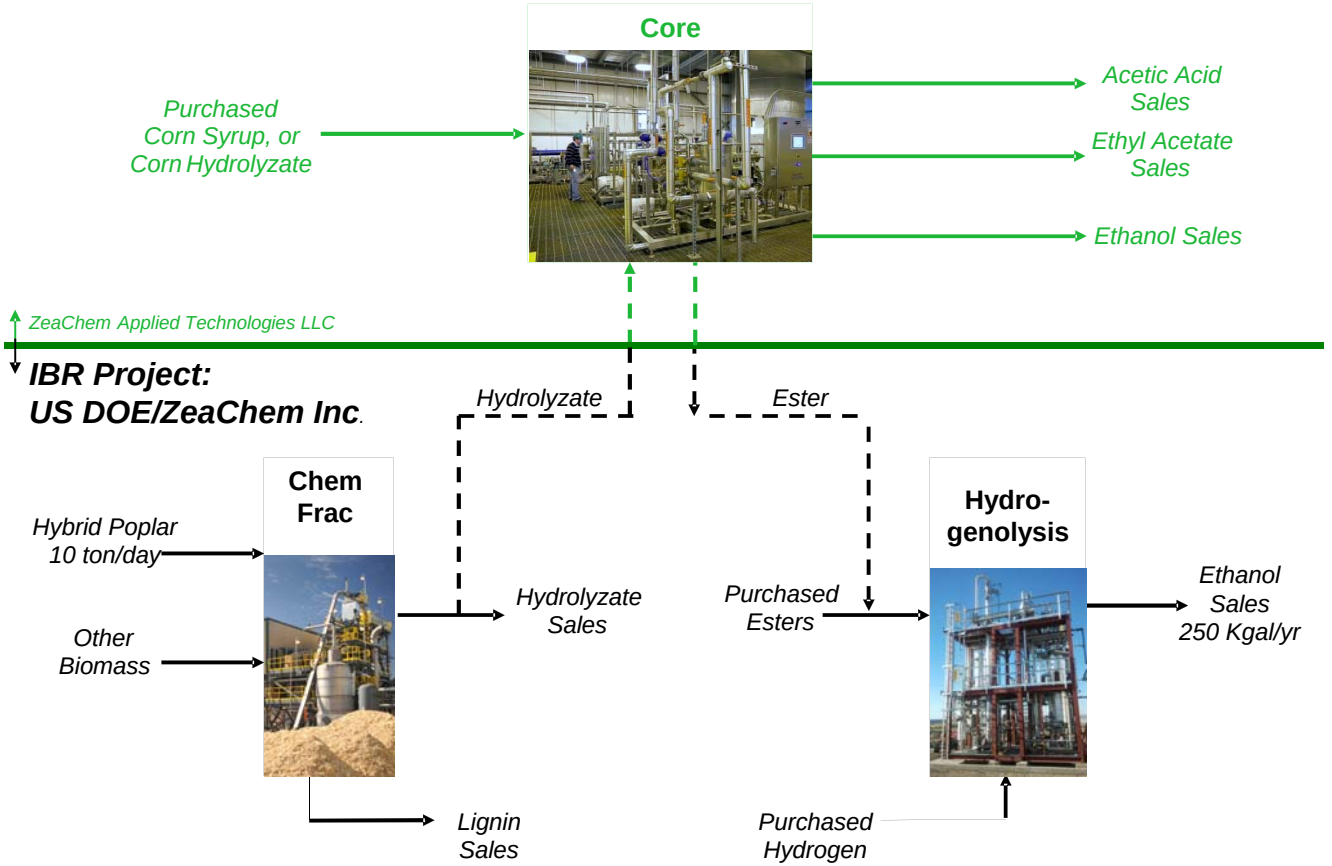
Acrylics

Polypropylene

Propylene

Propionic Acid

1 - Project Description



IBR Project: 10 ton/day Chem Frac unit + 250 Kgal/yr Hydrogenolysis unit

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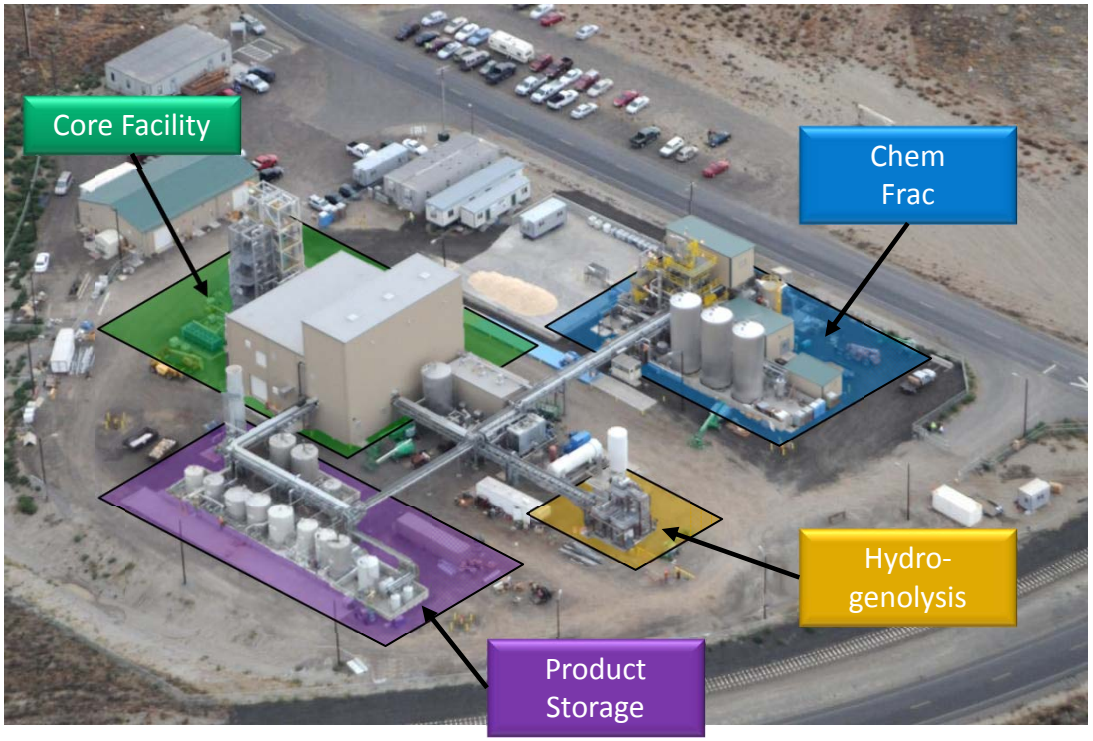
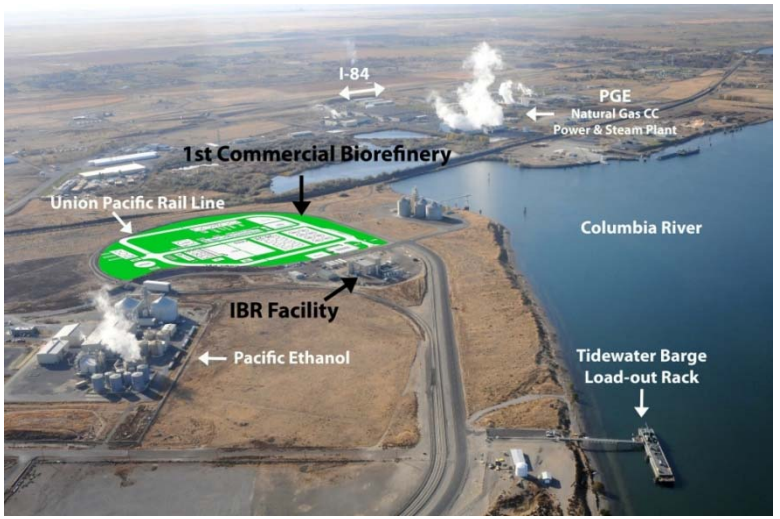
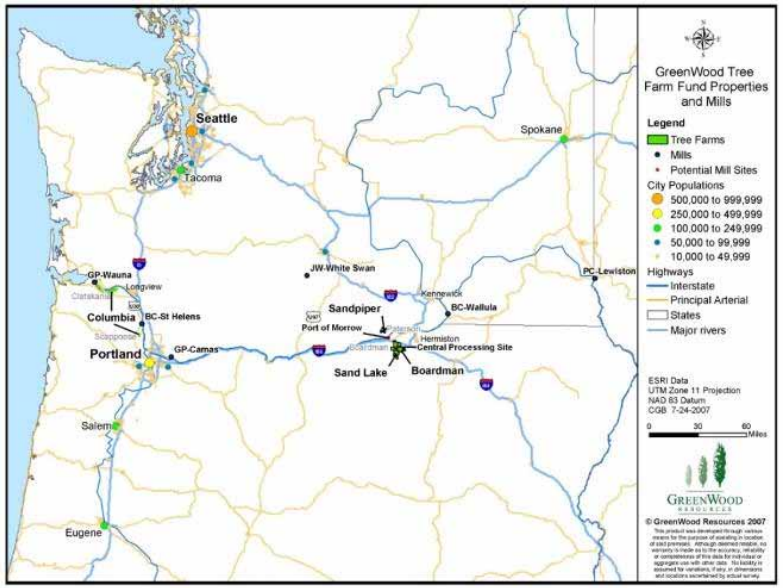
1 - Overview of Boardman, OR Site







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1 – Hydrolysis

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1 – Fermentation

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1- Acetic Acid Purification & Esterification

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1 – Hydrogenation

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2 – Approach: Project Management

- Written Project Management Plan
  - Section A. Project Information
  - Section B. Financial Description of Project
  - Section C. Project Plan with tasks, subtasks, milestones, deliverables, Go/No Go decision points and including performance requirements and metrics
- Additional project tools
  - Work Breakdown Structure (WBS)
  - Risk Management Plan (RMP)
  - Earned Value Management System (EVMS)
- Next Go/No-Go Decision: CD-4 to enter BP-3
  - Completed Independent Engineer's Performance Test demarking end of BP-2
  - BP-3 is when system performance tests are conducted

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2 - Feedstock – Hybrid Poplar

- Dedicated sustainable energy crop
  - High impact feedstock
  - “Bankable” projects
  - Geographic diversity, “Grow where we go”

- Hybrid Poplar Benefits
  - Perennial crop, low inputs, high yield
  - “Store on the stump”
  - Efficient harvesting

- GreenWood Resources
  - Agreements in place for IBR Facility and 1st Commercial Plant
  - Forest Stewardship Council Certified
  - USDA Biomass Crop Assistance Program

GreenWood Trial Plots

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3 – Progress: CD-3/Entering BP-3

- ✓ BP-1: Project Planning
  - ✓ NEPA Determination
  - ✓ Vendor Trials
  - ✓ Schedule A Design
  - ✓ Budget Control Cost Estimate (±10%)
- ✓ BP-2: EPC
  - ✓ Detailed Design
  - ✓ Procurement
  - ✓ Construction
  - ✓ Commissioning
  - ✓ Start-up
  - ✓ First cellulosic EtOH produced February 2013
  - ✓ Independent Engineer's Test
- ❑ BP-3: Performance Trials

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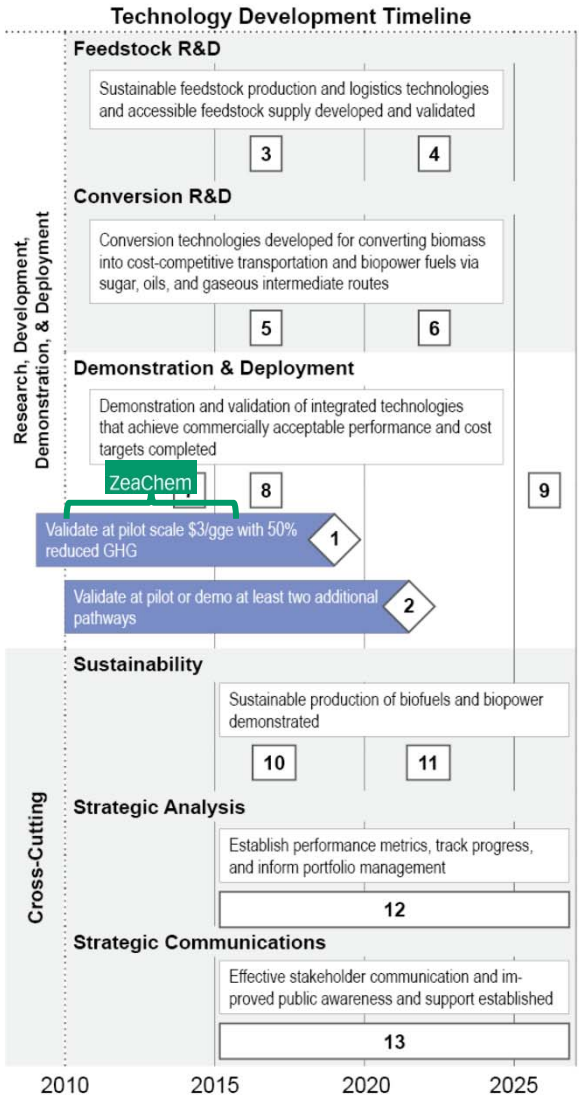
4 – Relevance: BETO Mission and Goals

- Mission: Develop and transform our renewable biomass resources into commercially viable, high-performance biofuels, bioproducts, and biopower through targeted research development, demonstration, and deployment supported through public and private partnerships

  – Goal 1: Enable sustainable, nationwide production of advanced biofuels that are compatible with today's transportation infrastructure and can displace a share of petroleum-derived fuels to reduce U.S. dependence on oil

  – Goal 2: Encourage the creation of a new domestic bioenergy and bioproduct industry



From: US DOE Biomass Multi-Year Program Plan, Nov. 2014

4 – Relevance: BETO Integrated Biorefinery WBS

WBS Element	Description	Barrier(s) Addressed
Analysis and Sustainability	Verify progress of projects toward objectives, assess development of overall technologies across the "Valley of Death," and develop strategies to focus on the most promising areas. - Verification of technology deployment, including independent Engineer evaluations of each project. - Assess progress of biorefineries though TEA. - Deploy models and planning processes to assess the impact of D&D projects on overall bioindustry development.	Im-A: Inadequate Supply Chain Infrastructure Im-B: Agricultural Sector-Wide Paradigm Shift Im-D: Lack of Industry Standards and Regulations It-B: Risk of First-of-a-Kind Technology It-D: Engineering Modeling Tools St-C: Sustainability Data across Supply Chain St-D: Implementing Science-Based Indicators and Methodology for Evaluating and Improving Sustainability St-F: Systems Approach to Bioenergy Sustainability
Technology Interface	Maintain a R&D feedback loop on new technologies ready for piloting and in identifying additional barriers and research needs at larger scale. - Monitor progress of emerging technologies within R&D areas, incubators, and outside sources. - Identify additional barriers and research needs at larger scale through biorefinery projects.	Ft-D: Sustainable Harvesting Mm-A: Lack of Understanding of Environmental/Energy Tradeoffs It-A: End-to-End Process Integration
Feedstocks	Deploy technologies to provide a secure, reliable, affordable, high-quality, and sustainable cellulosic and algal biomass feedstock supply for the U.S. bioenergy industry. - Demonstrate pioneer-scale terrestrial feedstock supply systems. - Demonstrate algal feedstock supply systems to validate technology performance.	Ft-A: Terrestrial Feedstock Availability and Cost Ft-E: Terrestrial Feedstock Quality and Monitoring Im-A: Inadequate Supply Chain Infrastructure Im-B: Agricultural Sector-Wide Paradigm Shift Im-E: Cost of Production It-A: End-to-End Process Integration It-B: Risk of First-of-a-Kind Technology It-D: Engineering Modeling Tools
Integrated Biorefineries	Demonstrate and validate IBR technologies at pilot, demo, and pioneer scale. - Pilots integrate unit operations from feedstock-in through product-out at ≥ 1 dry tonne per day. - Demonstrations prove all recycle streams and heat integration and develop equipment specifications for larger-scale facilities. - Pioneers, or first-of-a-kind plants, prove economical production at commercial volumes on a continuous basis along with a reliable feedstock supply and production distribution system.	Ft-E: Terrestrial Feedstock Quality and Monitoring Ft-F: Biomass Storage Systems Im-A: Inadequate Supply Chain Infrastructure Im-B: Agricultural Sector-Wide Paradigm Shift Im-C: High Risk of Large Capital Investments Im-D: Lack of Industry Standards and Regulations Im-E: Cost of Production Im-F: Offtake Agreements It-A: End-to-End Process Integration It-B: Risk of First-of-a-Kind Technology It-C. Technical Risk of Scaling and Fully Integrating Biomass Conversion Technologies It-D: Engineering Modeling Tools
Infrastructure and End Use	Enable higher rates of renewable fuel usage and define the needs for biofuels infrastructure and market use through 2030. - Address barriers to renewable fuel use in new, existing, and future automobile engines and other areas, such as replacing home heating oil.	Im-D: Lack of Industry Standards and Regulations Im-G: Uncertain Pace of Biofuel Availability Im-H Availability of Biofuels Distribution Infrastructure Im-I. Lack of Acceptance and Awareness of Biofuels as a Viable Alternative It-E. Codes, Standards, and Approval for Use It-F. Engines Not Optimized for Biofuel

From: US DOE Biomass Multi-Year Program Plan, Nov. 2014

4 – Relevance: Project Goals and Alignment

- Goals of IBR Project:
  - Mitigate risks so that a 1st Commercial Plant can be financed, constructed, and made operational
  - Demonstrate integrated operations with high-impact feedstocks to support deployment in follow-on commercial facilities

- IBR Project critical step towards 1st Commercial Plant
  - 22 MMGal/yr cellulosic ethanol
  - Project development underway
  - Anticipated 2016/17 start-up
    - Timing gated by performance tests at IBR Facility

- Success of 1st Commercial Plant will lead to additional follow-on plants in further support of EISA 2007 goals

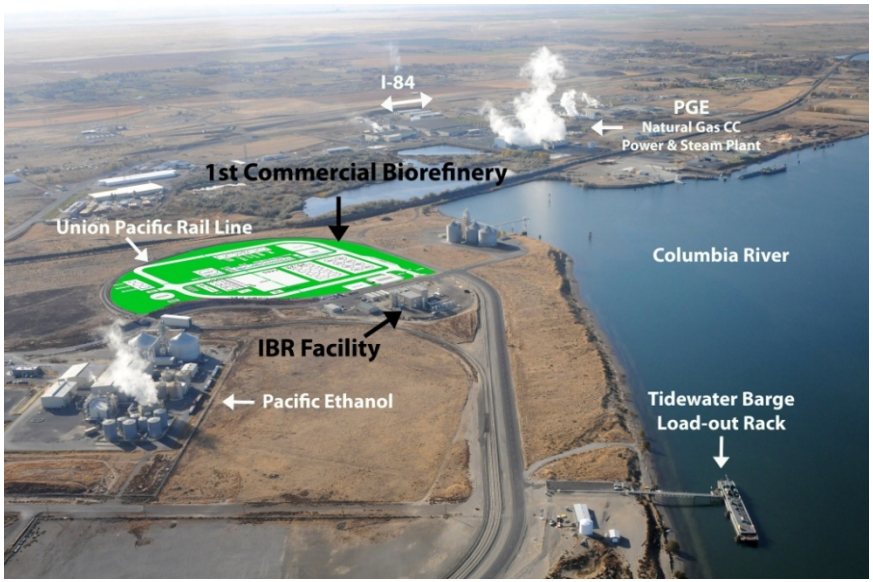
5 - Future Work

- Go/No-Go: Critical Decision (CD-4) for entry into Budget Period 3

- Budget Period 3
  - Performance Test Runs
  - Technical and Financial Reports
  - Project Close-out

Summary

- Successfully built and operated
  - 10 ton/day Chem Frac unit
  - 250 Kgal/yr Hydrogenolysis unit
  - First cellulosic ethanol produced in February 2013
- Project is well aligned with BETO's Multi-Year Program Plan
- Future work under IBR Project:
  - ✓ BP-1: Complete
  - ✓ BP-2: Complete
  - BP-3: Performance Tests
- ZeaChem is on-track for deployment of 1st Commercial Plant



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Acknowledgment and Disclaimer

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