Bioenergy Technologies Office

2017 Program Management Review

Thermochemical Conversion

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Peer Review Process

– **Thermochemical Conversion Reviewers;**

NAME	AFFILIATION
Shawn Freitas*	ThermoChem Recovery International
Lorenz (Larry) Bauer	LBJ Chemical Consulting
Timothy Brandvold	Abbott Molecular
Jeffrey J. Scheibel	J.J. Scheibel LLC
Neils Udengaard	Haldor Topsoe (Retired)

Review Panel Approach

– **Methodology**
  - 33 projects reviewed both as a group and individually
  - Standardized forms for individual notes/comments
  - Panel team pre and post presentation review discussions
  - Meetings to discuss draft summary document
  - Compiled and aligned review comments for summary

Project Scores

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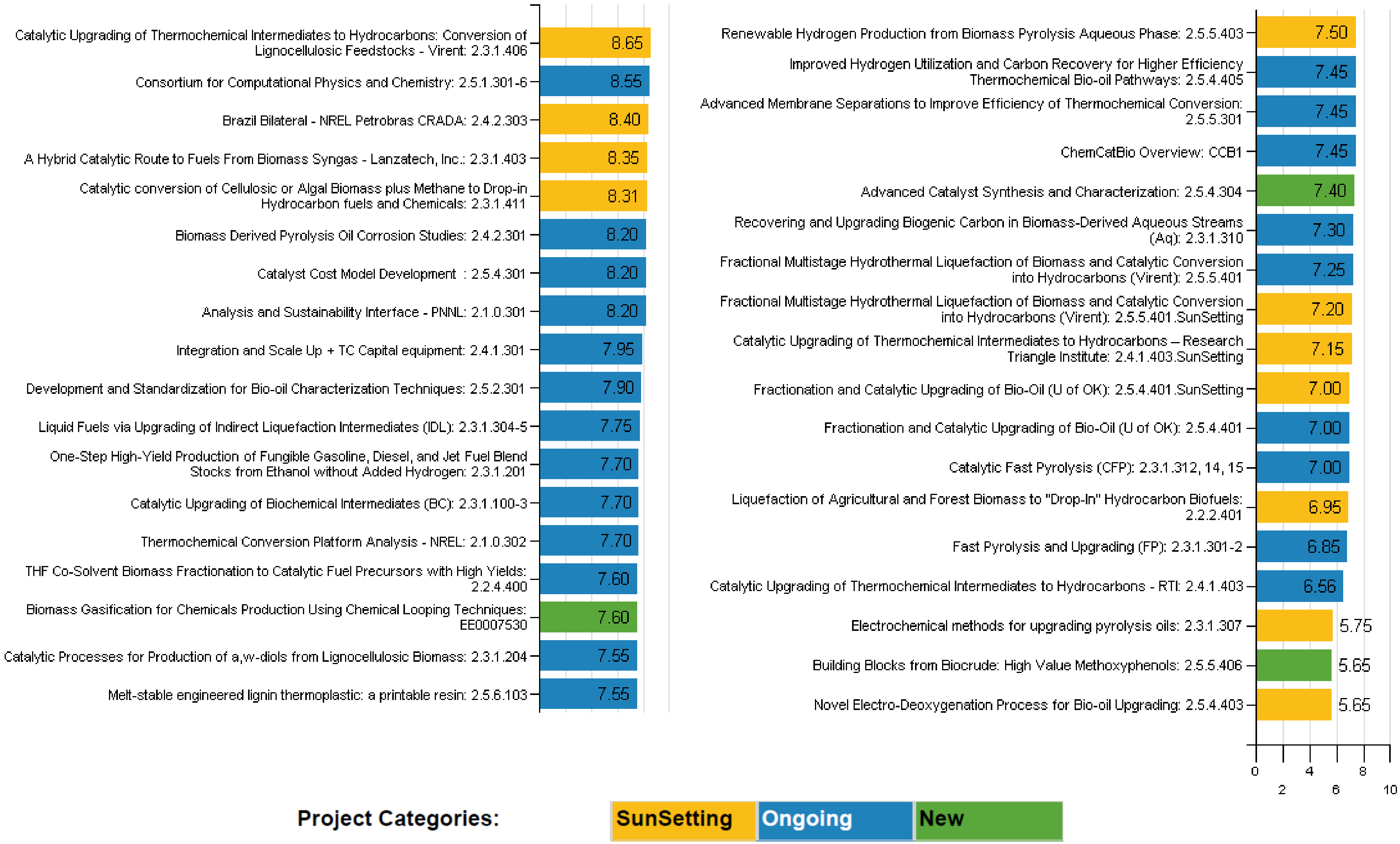

Project Scores

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- **Data Summary**
  - Average scores ranged from 5.65 to 8.65 (Scale 0-10)
  - Median of 7.55

- **Top Performing Projects;**
  - Virent Energy Systems, Inc. – Catalytic Upgrading of Thermochemical Intermediates to Hydrocarbons: Conversion of Lignocellulosic Feedstocks
  - ORNL, ANL, PNNL, NREL, NETL – Consortium for Computational Physics and Chemistry
  - NREL – Brazil Bilateral – NREL Petrobras CRADA
  - LanzaTech, Inc. – A Hybrid Catalytic Route to Fuels From Biomass Syngas
  - Gas Technology Institute – Catalytic conversion of Cellulosic or Algal Biomass plus Methane to Drop-in Hydrocarbon Fuels and Chemicals

Overall Impressions: Impact

- **Advancing the State of the Art**
  - Liquefaction and gasification projects were generally ranked highly
  - Fast pyrolysis requires new directions and further breakthroughs to support commercialization
  - Torrefaction, slow pyrolysis, advanced cook-stoves, and pellet heating should be added to the thermochemical portfolio
- **Relevance of BETO Focus for Investment/Finance**
  - Current portfolio focused on areas requiring major capital investments for commercialization. Creates numerous issues, limiting options/adoption
  - Thermochemical conversions that efficiently generate lower volumes of higher value fuels/chemicals should be prioritized
- **High/Low Impact Directions**
  - Utilization of existing commercial facilities or commercially relevant reactors to prove a conversion or catalysis step
  - Generation of finished products that can be used in existing engines and processes
  - Solvent and hydrothermal liquefaction technologies

Overall Impressions: Innovation

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– **Current Thermochemical Innovations**
  - Leveraging functionality and reactivity of biomass thermochemical products for targeted synthesis of useful chemicals and fuels
  - Co-reactants and alternative hydrogen donors to avoid traditional hydrotreating
  - Improved solvent recycling and in-situ solvent generation technologies for liquefaction processes

– **Necessary Future Innovations**
  - Improvements related to chemical separations and narrowing product distribution are needed
  - Singular focus on up-front carbon efficiency associated with solid to liquid/gas conversions must be revised
  - Integration of up-front biomass feedstock separations to make downstream refining of thermochemical products less process intensive should be pursued

Overall Impressions: Synergies

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- **Current Synergies**
  - Numerous synergies between projects in the portfolio as a function of the consortium approach have reduced redundancies, improved standardization, and accelerated the rate of discovery and progress. Not suitable for every project, but current consortiums working well.
  - Public dissemination of the various models, standards, and studies associated with consortiums must grow beyond published papers and presentations and into open-source and web-based education where interested parties can learn how to utilize these resources. Improved dissemination to this broader audience will lead to new synergies.

- **Necessary Future Synergies**
  - All biomass comminution steps and biomass chemical separations that benefit biochemical conversions will also benefit thermochemical conversions
  - There are numerous opportunities for thermochemical conversions after biochemical conversions as a way of improving overall process efficiency and economics

Overall Impressions: Focus

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- **Areas Requiring Additional Focus**
  - Consider focusing on fuels and fuel infrastructure instead of replacing the barrel or new bio-sources of common hydrocarbons. Biomass chemistries are less likely to efficiently/economically contribute to commodity fuel supplies like diesel and gasoline, and more likely to contribute to high performance and specialty areas like jet fuels, fuel additives, and solvents
  - Leveraging thermochemical know-how to improve and advance biomass based heating technologies would be constructive

- **Areas to Consider Reduced Focus**
  - Use of hydrogen as the primary oxygen removal/stabilization tool for whole-biomass pyrolysis liquids does not show potential for commercial adoption. Focus on this area should be reduced and pyrolysis of biomass components (cellulose, lignin, hemis, etc) should be increased.
  - Biomass pyrolysis liquids are not oils or hydrocarbons. Their potential use as an upstream crude-oil blendstock input should be reduced and focus on downstream finished product blendstocks should be increased.

Overall Impressions: Commercialization

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- **Current Funding Philosophy**
  - Current relationship between ARPA-E and BETO looks to be complementary
  - BETO should continue to invest at the TRL levels that it has in the past and should also continue to enable growth in areas that help to realize its strategic fuels objectives associated with the bioeconomy

- **Enabling Commercialization**
  - To increase number of commercial successes using an unconventional chemical feedstock like biomass, BETO should consider how to enable/support technology developments that pose less investment risk (fundamentally different than trying to de-risk new technologies)
  - Consider focusing on product value & value proposition, then let market forces decide how large or small market will become instead of struggling to carve out minor presence in huge commodity gasoline/diesel markets
  - Renewed focus on valorization of waste and product streams at existing industrial facilities involved in biochemical, biomass, and microbial conversions

Overall Recommendations

- **Utilize world-class fast pyrolysis capabilities to advance the state of the art for pyrolysis and liquefaction of biomass components such as various forms of lignin, cellulose, hemicellulose, and extractives.**

- **Create complementary relationships between BETO catalysis projects/consortiums and DOE fuel and engine researchers. Leverage extensive abilities in both thermochemical conversion and downstream chemical synthesis with thermochemical products to find new and better routes for generating turbine and engine fuel components/additives.**

- **Shift thermochemical project portfolio to include more technologies designed to function at both smaller scales and also as retrofits to existing industrial facilities involved in biochemical, biomass, and microbial conversions (i.e. ethanol, biogas, wastewater, pulp & paper, food processing, etc).**