



BETO Program Overview

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BETO Steering Committee

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- James Dooley: Forest Concepts
- Kelly Ibsen: Lynx Engineering, LLC
- Steve Kelley: NC State
- Robert Mantz: Army Research Office
- Bob Miller: Air Products (ret.)
- George Parks: ConocoPhillips (ret.)
- Mark Yancey: Neatech, LLC



Bio-Oil Focus Areas

- Fast Pyrolysis and Upgrading
 - Short residence times (seconds)
 - Upgrade condensate to a liquid
 - Upgrade of vapors prior to condensation
- Hydrothermal Liquefaction: Particularly high-Moisture Feedstocks Like Algae
 - Moderate temperatures, higher pressures, no solvent followed by upgrading
- Hydropyrolysis
- Pyrolysis with H₂ or other H-donors.



Bio-Oils Platform Strengths

- Excellent Progress
- *Rapidly* Advancing State-of-the-Art
- Good Balance of TRLs
 - Fundamental work (ex. corrosion)
 - Bench-scale (catalytic upgrading)
 - 10-100 gal/day facilities
 - Early-stage pilot plants and demos
- Potential Breakthrough Technologies (ex. Hydropyrolysis)
- Labs-Industry Synergy



Bio-Oils Platform Gaps

- Consistent TEA tool for all projects
- Awareness of Refinery Product Requirements
- Some New-Starts Rated Low
 - Poor execution
 - No commercial viability
- Labs Not Always Leveraged by Industry



Bio-Oil Action Items

- TEA
 - Modular, spreadsheet-based
 - Required for all projects (when data available)
 - Expand to other platforms
- Understand Refinery Requirements
 - Partners for demo projects
 - Easily accessible tech capability
 - Tech consultants? Advisory board?
- Better “New-Start”/“Incubator” Projects
 - Clear performance & success criteria with economics



Gasification Platform

- Biomass to Syngas (CO & H₂)/Conversion to Fuels
- Portfolio
 - Gas conditioning (2)
 - Biochem (2)
 - Modeling (2)
 - Advanced concept
 - CDP (5)
 - Modeling (2)
 - Fundamentals
 - Hydrothermal
 - CRADAs (2)



Gasification Strengths

- Balanced Portfolio
- Successes
 - Hot gas conditioning
 - Conversion to alcohols
 - Synergies (GTI char morphology & Enerkem)



Gasification Gaps

- Lack of Industrial Benchmarking
- Awareness of Refinery Product Requirements
- No Dedicated Process Development Unit
- Continuity Assurance When Partners Drop Out
- CDP Projects Often do Not Advance State-of-the-Art
- Pathways to Hydrocarbons



Gasification Action Items

- Set Tech Milestones & TEA Metrics
- Require Applicants to Quantify Benefits
- Promote Interaction with Fuel Industry
- Capture Corporate Memory
- Address Biomass Feeding Issues
- Exploit Nanotech for Fuel Synthesis
- Look for Synergies with Cheap Natural Gas
- Seek Biochem Routes That Don't Require Extensive Syngas Clean-Up



Feedstocks Platform

- Identify and Develop Efficient, Sustainable, Renewable, Biological Materials For the Production of Clean Energy.
- Design and Develop Advanced Equipment and Systems to Reduce Cost, Improve Biomass Quality, and Increase Productivity Throughout the Biomass Logistics Chain.



Feedstocks Strengths

- High Impacts:
 - Range of stakeholders (High-Tonnage Logistics, Regional Feedstock Partnership).
 - Data from past programs
 - Sustainable production and logistics systems
- Innovations:
 - Wide range of barriers/variety of approaches.
 - Success in high-tonnage projects from merging projects.
- Synergies:
 - Build on the legacy of earlier projects.
 - Leverage USDA systems and expertise



Feedstock Gaps

- Regional Variations
- Densification and ash removal or mitigation.
- Uncertainty measures for TEA
- Storage losses
- Data analytics
- RFPs should require submission the KDF and Biomass Resource Library.
- BETO should fund a variety of project maturities from concept discovery to system integration



Feedstock Recommendations

- Require/Encourage Submission to KDF and Biomass Resource Library.
- Fund a variety of project maturities from concept discovery to system integration



Biochem Platform

- Biological Processes That Convert Biomass to Biofuels, Chemicals, and Power
 - Processes
 - Biorefinery integration



Biochem Platform Strengths

- Diversity: Technologies, TRL, Scale
- Cellulosic Ethanol Success
 - Innovative & diverse portfolio
- Focused to Drive Process Economics
- Technology Licensing
- Derisking for Industry & Investors
- Innovative Seed Projects
- Synergy
 - Lessons learned
 - Leverage to other areas



Biochem Platform Gaps

- Hydrocarbon Focus-Related
 - Lignin utilization
 - Hydrolyzate clean-up
 - High value product FOA needed
 - Separations
 - Reactor design
 - High quality strain/catalyst optimization
- Key Concerns
 - Leveraging cellulosic EtOH findings
 - Internal gap analysis
 - Defining barriers and programmatic milestones



Biochem Recommendations

- More Transparent Collaboration with Other Offices (ARPA-E, Office of Science, etc.)
- Graded Metrics Depending on Project TRL/Stage
 - Smart milestones
- End Product/Final Fuel Specificity
 - More than C_x or greater or C_{15}



Algae Focus Areas

- TEA and LCA modeling
- Measurement System Development and Utilization
- Algae Biology—productivity and Yield Improvement. Non-GM, GM.
- Cultivation Improvement.
- Process Development Engineering –Harvest, Pre-processing, Extraction, Fuel Conversion.
- Co-products and Recycle.
- Assessments—Resources and Risks.



Algae Challenges

- \$18.60/Gallon Fuel Cost
- ~5X Improvement in Productivity and Yield Necessary
- CapEx & OpEx Reductions Needed
- Strain Selection and Development Don't Approach 5x Increase
- Need New Innovative Approaches to Increasing Productivity and Yield



Algae Gaps

- Foundational Understanding of Algal Ecology & Physiology
- No Facility to Assess Outdoor Biotic and Abiotic Stresses for GM Strains
- Underutilization of TEA & LCA
- Going from Flask to Pond
- Leveraging Lessons Learned
- Harvest Cost
- Pond Liner Costs



Algae Recommendations

- Reassess MYPP 2022 Projection
 - Comprehensive review of program and strategy
 - Reviewer Proposed Target: 50 g/m²/day at 50% fuel yield (open pond)
- TEA—More & Better
 - Project screening, direction, & monitoring
 - Good comparisons with commercial baselines



Analysis & Sustainability

- Analytical tools, data, and methodologies
 - Support Decision Making
 - Guide Research
 - Demonstrate Progress Toward Goals.



Analysis & Sustainability Strengths

- Shift from Reactive to Proactive
- Articulation of Analysis Framework
 - Beyond costs & GHG emissions
- Project Breadth & Alignment
 - Energy/water/land nexus
 - Energy security
 - International Standardization
- Data Collection
- High Impact Projects



A&S Gaps

- Better Dissemination Plan
- Lack of Consistent Guidelines for Approach & Metrics
- More Complex is NOT Always Better
- More Validation, “Ground Truthing”
- Analysis of Policy Drivers
- Sustainability Metrics
- Additional Collaboration Opportunities
 - MOUs, FOAs with EPA, USDA, NSF, etc.

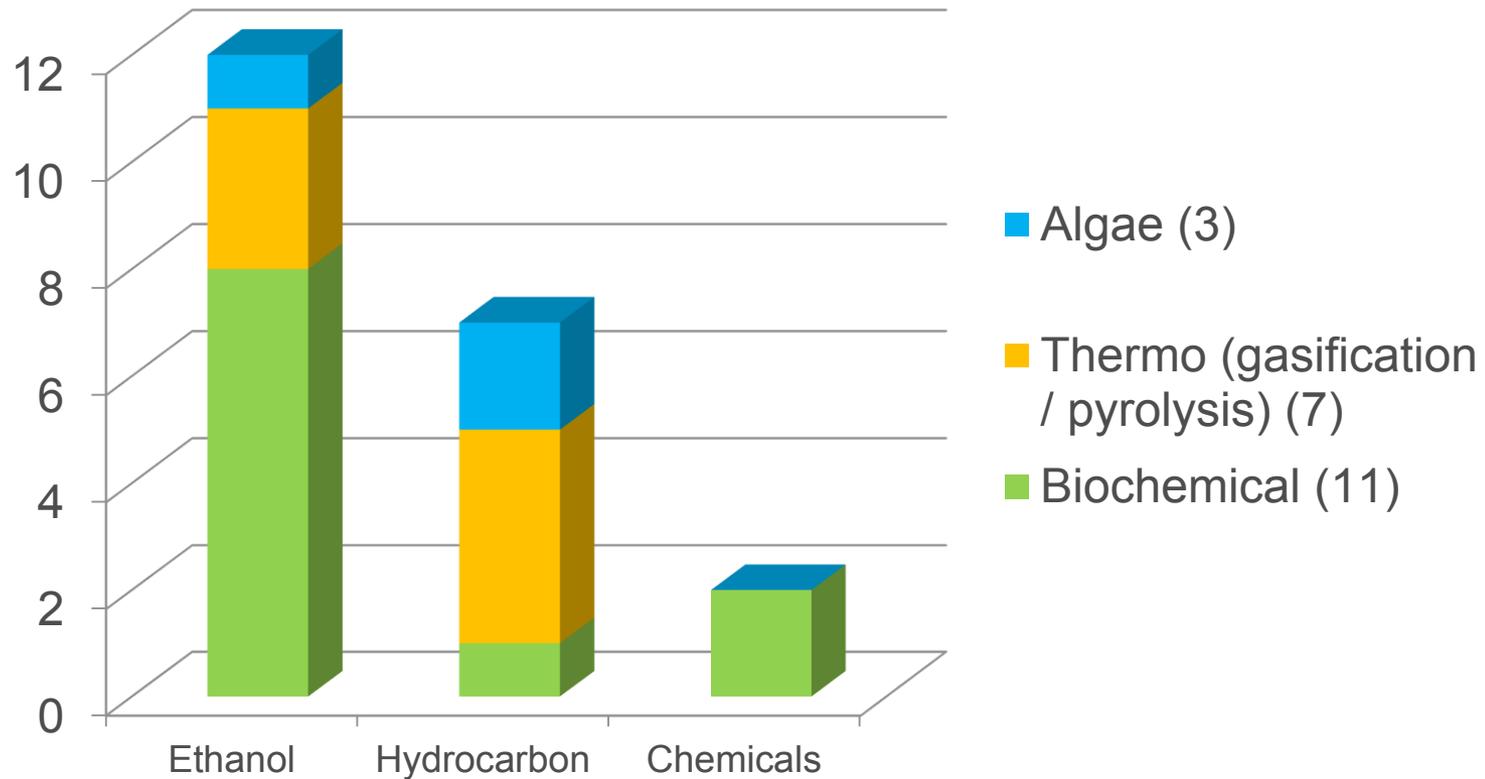


A&S Recommendations

- Improve TEA-LCA Integration
- Pursue Quality DATA!!
- Improve Project Integration



Integrated Biomass Refineries



- 9 Commercial: 6 EtOH, 2 Chem, 1 HC
- 2 Chemical: Succinic Acid & Sugars
- 4 Financing Delay, 6 Under Construction, 10 Commissioning/Start up, 1 Finished



IBR Strengths

- Steel in the Ground
- Significant Capacity for Advanced Biofuels
- Variety of Technologies, TRLs Well Balanced
- Grant Program Leveraged Private Investment
- Proof of Concept Impacts Risk Reduction/
Quantification and Lowers the Financing
Hurdles



IBR Strengths

- Breakthroughs Through Hard Work and Perseverance.
 - POET, Abengoa, INEOS developing commercial sized feedstock supplies
 - Haldor Topsoe making a drop-in gasoline
 - Solazyme advancing the sugars to hydrocarbon fuels pathway
 - Algenol using algae to make ethanol & hydrocarbons



IBR Gaps

- Value Added Purpose for Lignin
- High-Value Co-Products
- Fuels Qualification/Registration
- Ethanol Blend Wall
- Inconsistent and Unpredictable Policy Landscape and Priorities



IBR Recommendations

- Keep it up!
- Biomass to Syngas at the Right Scale
- Facilitate Progression Through TRLs
- Complement Grants with Other Assistance to Address Risk
- Clearly Communicate BETO Message to Public
 - Foreign oil dependence
 - Domestic, sustainable feedstocks
 - Industrial development, jobs
 - Reduce carbon emissions



Across the Program ...

- Analysis: TEA & LCA
 - All projects at all stages
 - Spreadsheets for early stages
 - Rigor for pilot plants and demos
 - Data for validation
- Replacing the Whole Barrel
 - The right direction
 - Need fuels expertise
 - Making the right molecules
 - Fuel qualification/registration
- Regional Impacts of Feedstock Quality



Across the Program ...

- Maintaining the Project Pipeline
 - Incubator→Pilot→Demo→IBR
- Data Sharing Across the Portfolio
- Algae—50/50 Challenge
 - Productivity: 10g/m²/day to 50
 - Fuel Yield: 10g/g algae to 50
- Gasification
 - Prep & feeding
 - Syngas cleanup
 - Novel hydrocarbon pathways



Other Items

- Review Process Vastly Improved
 - IBR Review Structure
 - Reviewer Training/Vetting
- TMs to be Commended
- Responsiveness of Congressionally Directed Projects
- Expertise to Address HC Fuel issues
- Address Process for Down Selects



Questions?

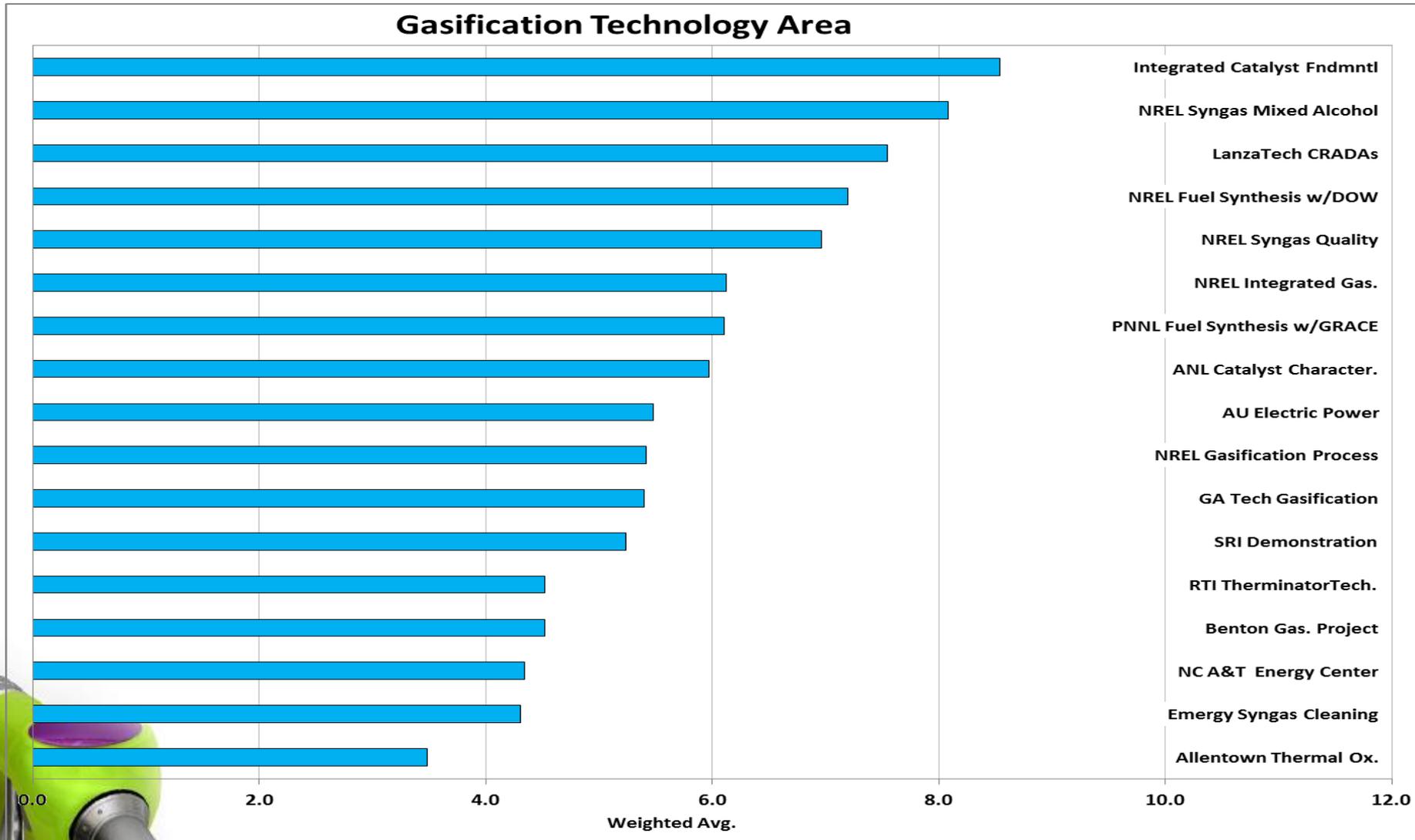


Backup Slides

- Platform Scores

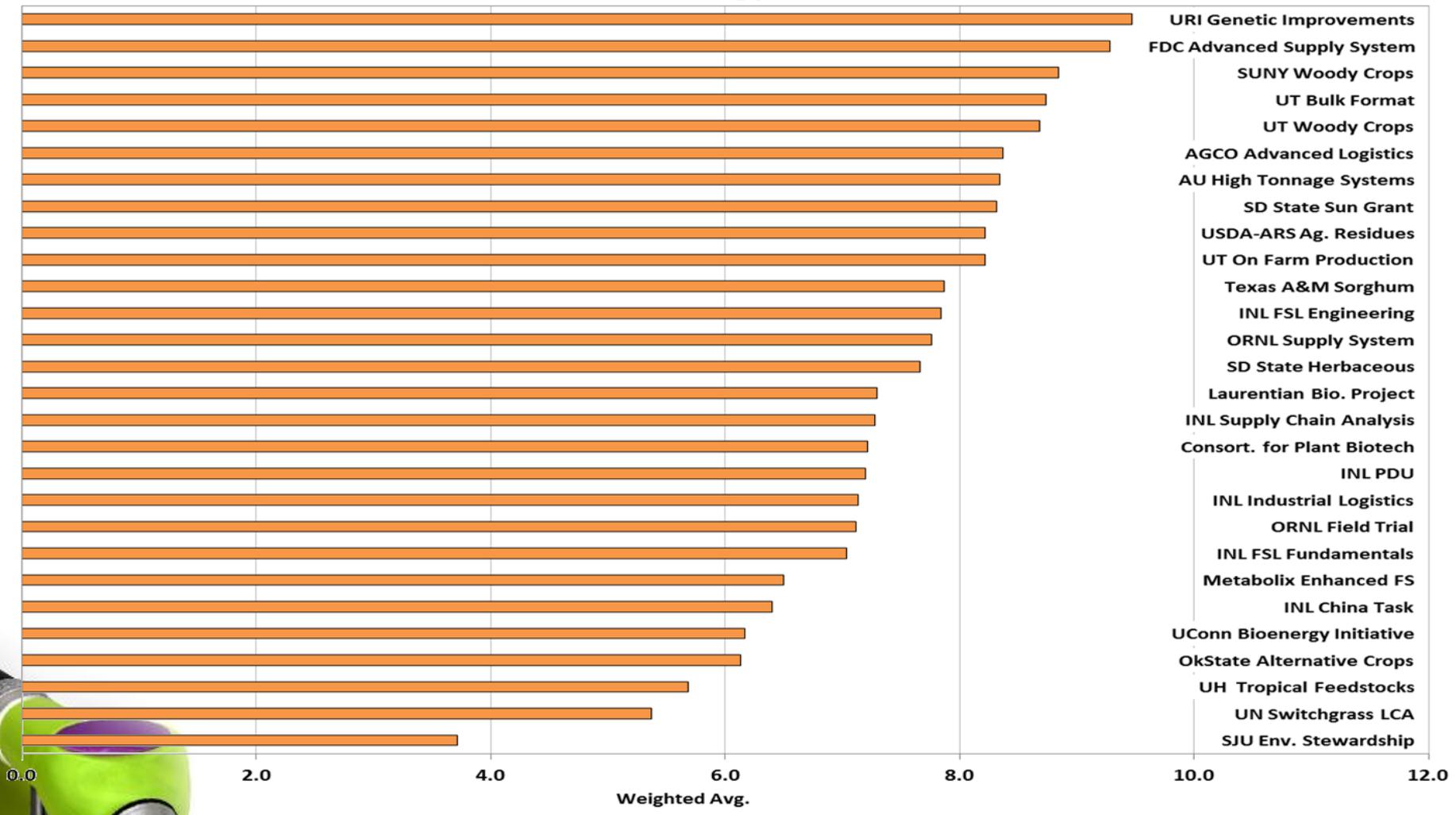


Gasification Project Scores



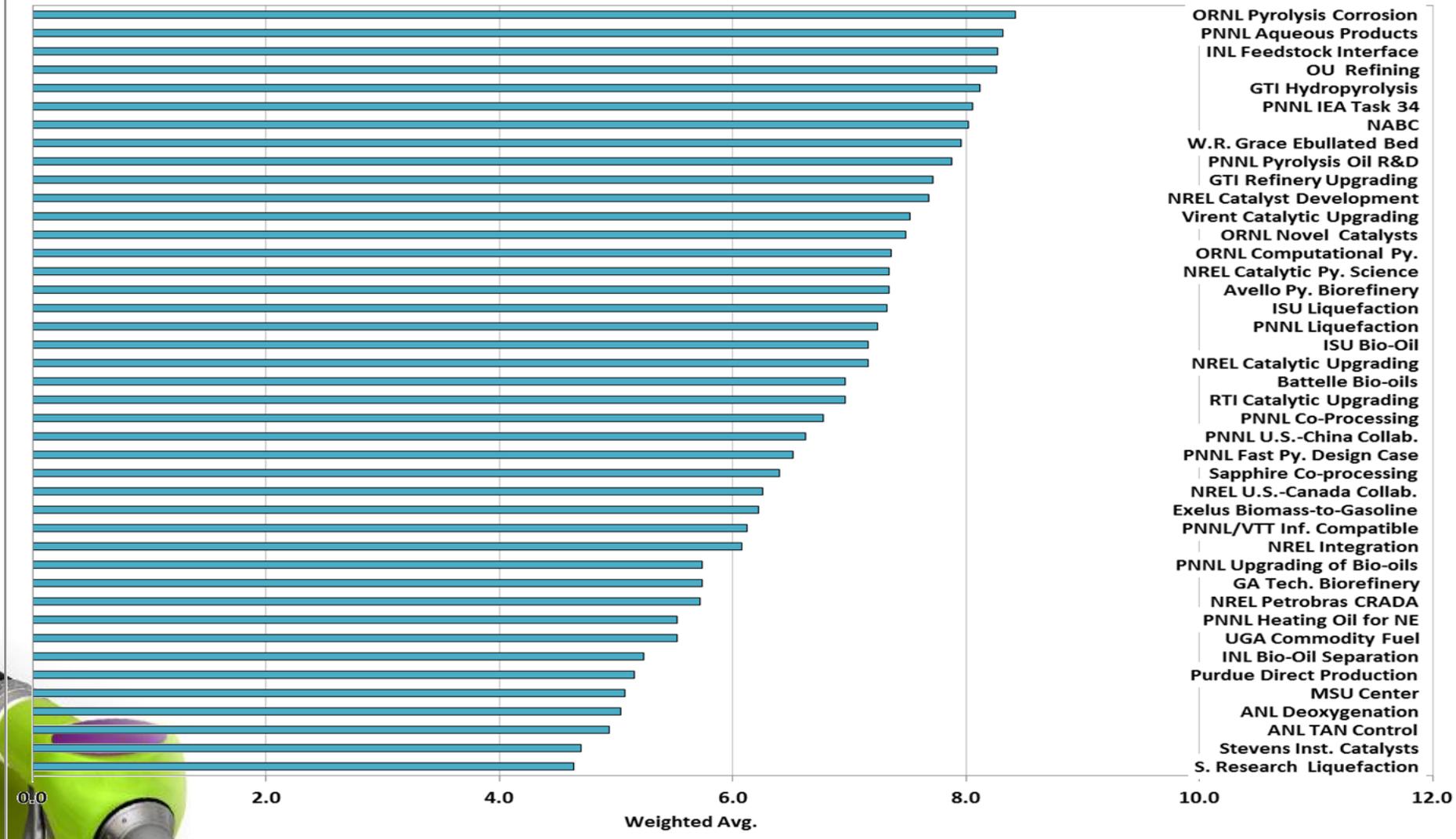
Feedstocks Project Scores

Feedstocks Technology Area



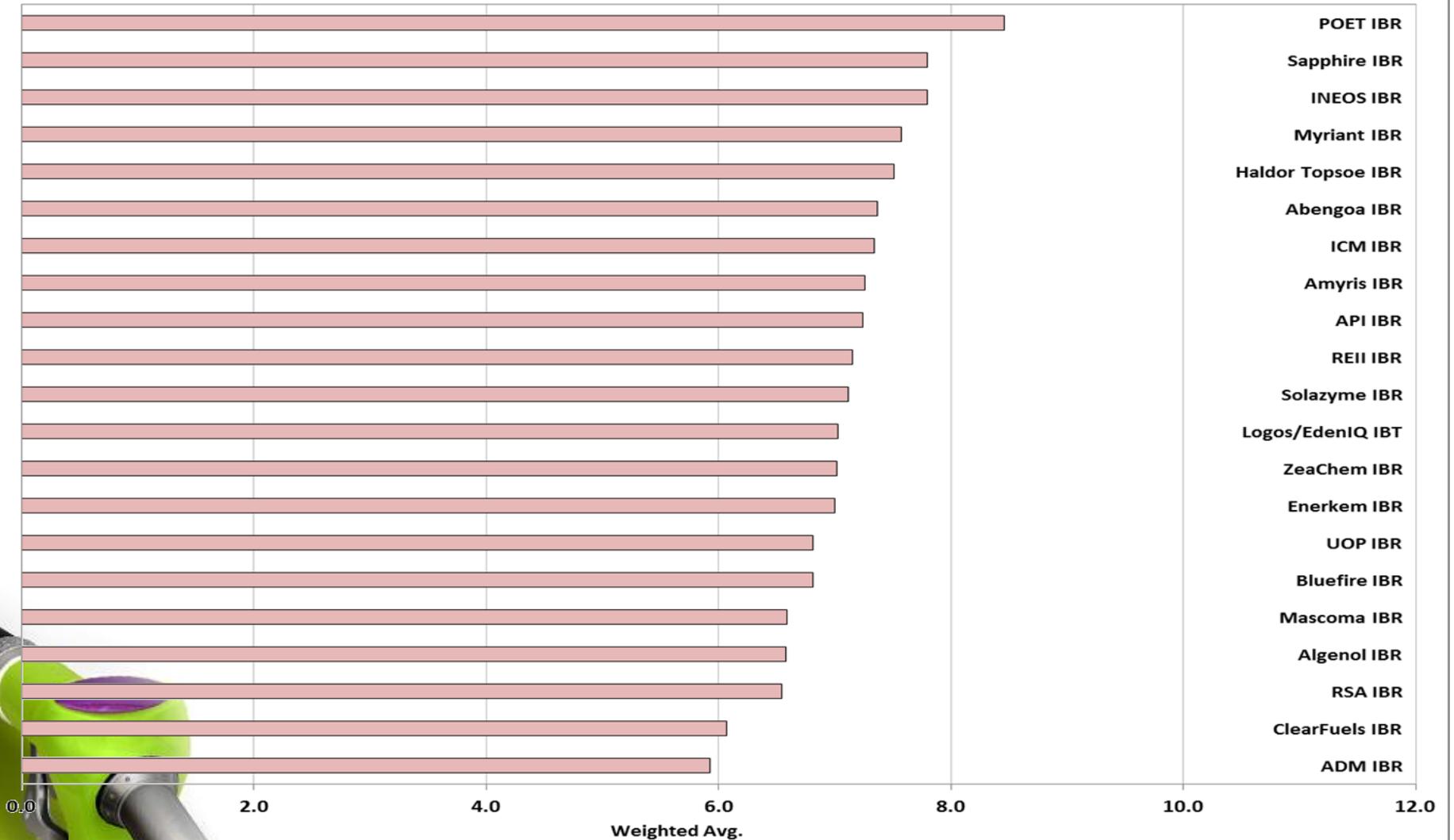
Bio-Oils Project Scores

Bio-Oils Technology Area



IBR Project Scores

Integrated Biorefinery Technology Area



Algae Project Scores

Algae Technology Area

Productivity,
Yield,
TEA, LCA,
Measurement

Resource and
Risk assessments,
Process
engineering

- UCSD Transcriptomic Consortium for Algal Comm.
- ASU Testbed
- NREL Residues for Power
- NAABB
- NREL Algal Biofuels TEA
- Caltech Nutrient Rec.
- ANL GREET for Algae LCA
- SNL Pond Crash Forensics
- PNNL Whole Algae HTL
- SABC
- NREL Algae Compositional
- PNNL Algae Int. Assessment
- PNNL Microalgae Analysis
- INL Algae Int. Assessment
- PNNL Climate Sim. Algae
- SNL Major Nutrient Rec.
- ANL Hydrocyclone Sep.
- BNL Microalgal Oil
- U. of Toledo Nutrient Rec.
- Cornell Consortium
- LANL Lipid Hyper-Accum.
- LANL Risk Assessment
- SRNL Risk Assessment
- INL Microalgae Harvesting
- Sapphire Value Added
- ORNL Sustainable Algae
- Rowan U. Algae to Ethanol

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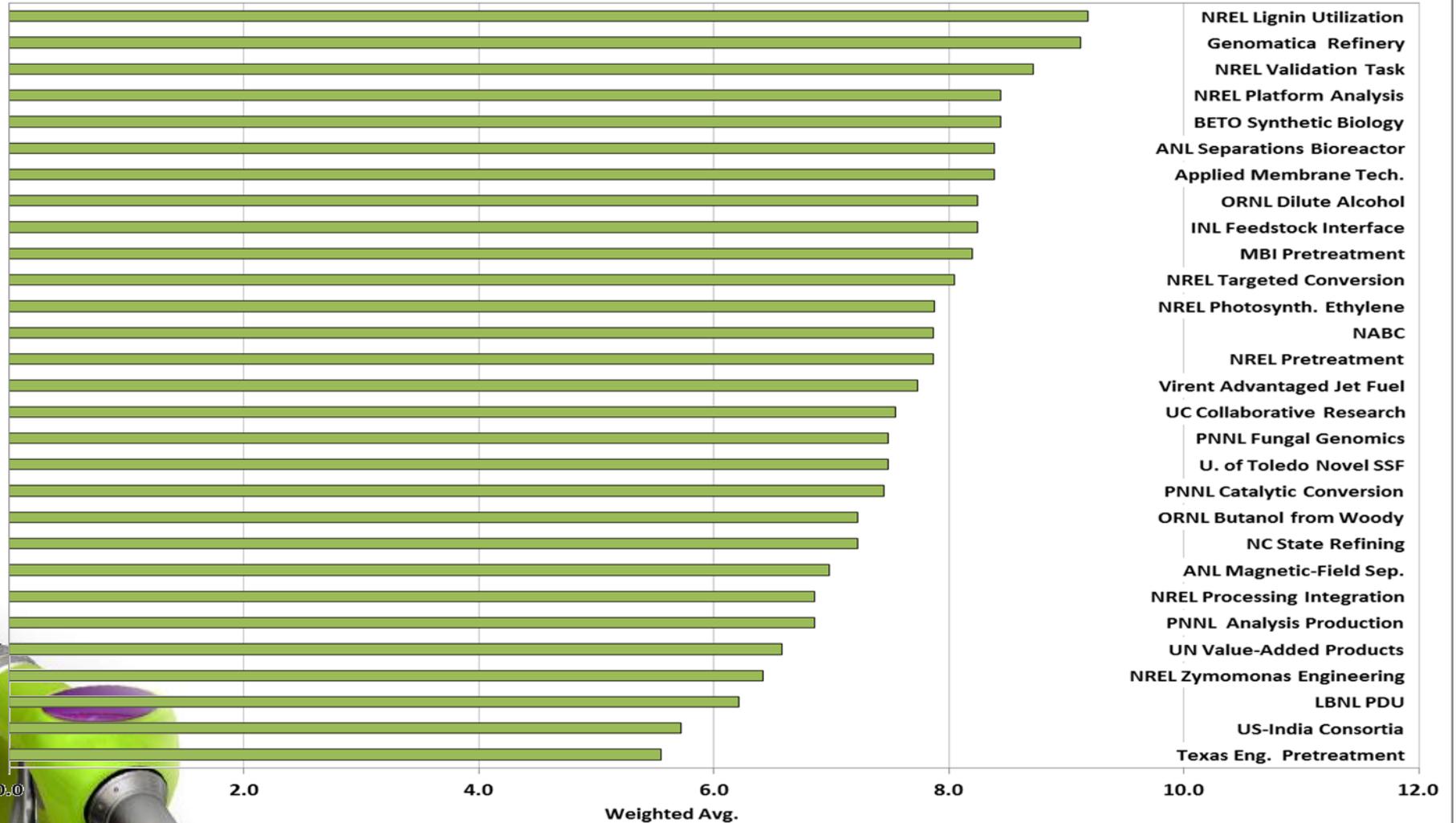
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Weighted Avg.

Biochem Project Scores

Biochemical Conversion Technology Area



A&S Project Scores

Analysis and Sustainability Technology Area

