Strategic Analysis Support WBS (4.1.1.30)

March 9, 2021

Data, Model and Analysis

Ling Tao, Eric Tan, Yimin Zhang and Avantika Singh

National Renewable Energy Laboratory (NREL)

Project Overview

Objective: Develop and apply an array of analysis tools to support the strategic direction of BETO

Goal and Context:

- **Evaluate emerging areas of interest** (USDRIVE tech team, jet fuel, WTE, lower cost targets, bio-based chemical market assessment).

- **Utilize analyses beyond traditional** biorefinery focused **TEA/LCAs** to identify both technical (sustainable design) and non-technical barriers (value proposition) and outline mitigation strategies and R&D needs.

Project Overview

Objective: Provide strategic support to BETO, coordinate analytical efforts across EERE offices, inform external and internal collaborations

Goal and Context:

- **Estimate social-economic effects on bioeconomy** (number of jobs) for biorefinery deployment.
- **Develop defensible methodologies, analyses, and tools** to understand the impact of expanding the bioeconomy (economy analysis tools including **refinery blending tools**).

1. Management: Task Structure

Integrate multiple dimensions of strategic support for BETO and for external and internal stakeholders

Input from:
BETO
Stakeholders
Collaborators

Outputs Inform

	Outputs Inform
Strategic Support (Ling Tao)	BETO Conversion team BETO/VTO/FCTO and ATB Support Engagement with stakeholders to review approach & results
Strategic TEA (Ling Tao)	Supports GREET, BSM, JEDI Engagement with CAAFI, FAA, Universities BETO Conversion team
Sustainable Process Design (Eric Tan)	Methodology implementation for stakeholder (industry) BETO Conversion team
Refinery Optimization (Avantika Singh)	Assess impacts of biomass-derived blendstocks with petroleum-derived blendstocks, Co-Optima, BSM
Jobs Analysis and Model Development (Yimin Zhang)	Tool development for stakeholder (e.g., local governments, biofuel developers) Inform BETO of potential socio-economic benefits

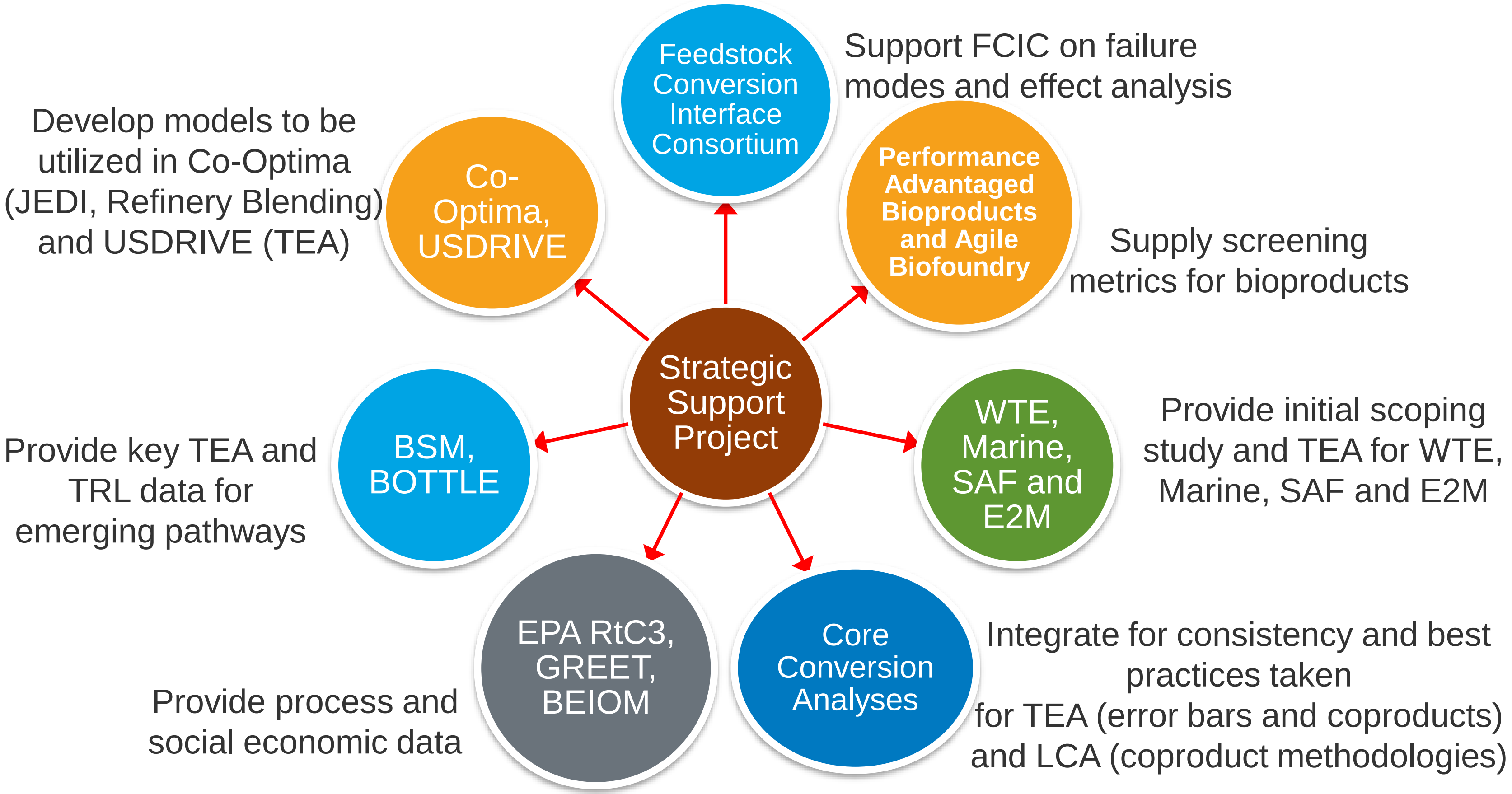
1. Management: Team and Risk Mitigation

Strategic Support / Strategic TEA (Ling Tao)	Sustainable Process Design (Eric Tan)	Refinery Optimization (Avantika Singh)	Jobs Analysis and Model Development (Yimin Zhang)

Risk	Mitigation Strategies
Project recommendations cannot keep up with rapid changing externalities	❑ Team stays current on technical literature and advancements of biofuel industry. ❑ Assumptions and tools used in the analysis are consistent with state-of-market and state-of-art. ❑ Frequent collaboration and check-ins with other offices and industrial experts to ensure **integration and alignment with BETO's mission and priority.**

1. Management

Outcomes Support and Bridge a Range of DOE BETO Projects and Beyond



2. Approach

Develop Models and Conduct Analysis to Support Strategic Decisions

Strategic Support (Ling Tao)	Provide analyses of emerging strategies
Strategic TEA (Ling Tao)	Identify drivers, barriers, and R&D need
Sustainable Process Design (Eric Tan)	Support informed process designs
Refinery Optimization (Avantika Singh)	Assess refinery integration opportunitie
Jobs Analysis and Model Development (Yimin Zhang)	Estimate jobs for a growing bioeconomy

Common approach:

- Models are **transparent** and rigorous with a **consistent set of assumptions** that allows for direct comparison.
- Each task is closely **integrated with four other tasks** to provide holistic output for strategy development.
- Analysis results and approaches are **verified by stakeholders.**

2. Approach

Critical Success Factors	Challenges	Approach to overcome
Model results are accurate and recommendations from the models are relevant.	• Availability and quality of input data. • Model is not representative.	• Consult subject matter experts globally to get the best and most accurate data. • Perform sensitivity analysis to understand impact of assumptions and uncertainty in data. • Engage third party reviewers to build transparent models.
Apply the appropriate method/tool to address questions.	A wide range of analysis approaches can be employed.	• Coordinate across analysis projects to identify appropriate tools to address questions. • Engage with industry and science experts to review and verify approach.
Clearly define critical questions to address.	Scope shift.	• Work closely with stakeholders to define needs and key questions.

2. Approach

Strategic Support (Ling Tao)

Strategic TEA (Ling Tao)

Sustainable Process Design (Eric Tan)

Refinery Optimization (Avantika Singh)

Jobs Analysis and Model Development (Yimin Zhang)

Communication/Outreach Strategy

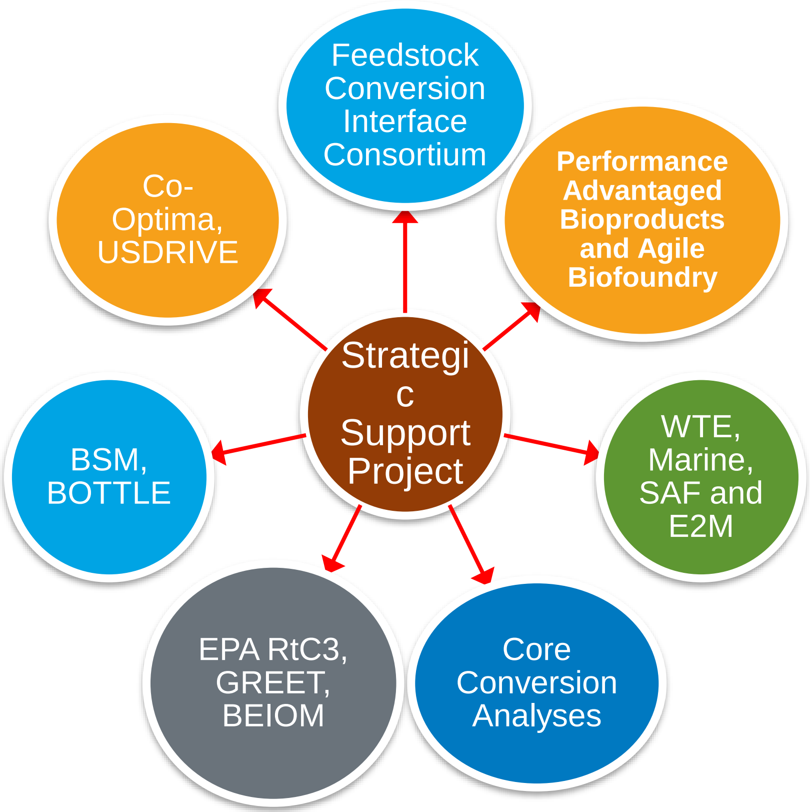
- **Quarterly check-ins** on work progress and report outcomes for meeting AOP defined QPMs/milestones.
- For projects directly supporting requests of A&S and BETO, we hold check-in on a **more frequent basis** (such as biweekly USDRIVE analysis PI calls).
- Participate in **monthly A&S platform calls** as well as bi-annual modeling workshop to ensure **coordination and collaboration** across the portfolio.
- Results and tool availability are communicated to stakeholders through peer-reviewed publications, presentations, web-based tools, and technical reports.

3. Impact

Outcomes Support and Bridge a Range of DOE BETO Projects and Beyond

Selected examples of impact:

- Waste-to-SAF can be cost competitive in existing market.
- Opportunities for bioproducts with oxygenated molecules conferring performance benefits.
- Biofuel pathways have the potential to get to near net zero carbon emission.



3. Impact

Provide strategic information to agencies outside of BETO

Strategic Support (Ling Tao)

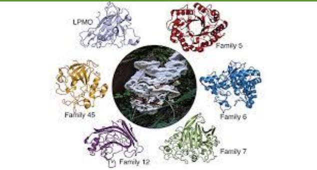
Strategic TEA (Ling Tao)

Refinery Optimization (Avantika Singh)

CAAFI
COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

VTO, AMO, FCTO
ATB
USDRIVE

BETO Conversion



Research Consortiums
Other Stakeholders

UNIVERSITY of WASHINGTON

- Promote discussions of key learnings and challenges in the field with academia experts.
- Partner with other federal agencies.

- 12 peer-reviewed papers and book chapters, >7 conference talks.

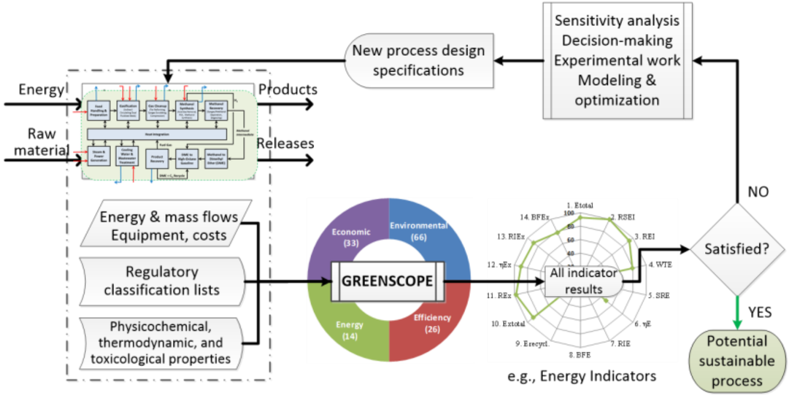
3. Impact

This project provides strategic information to agencies outside of BETO

Sustainable Process Design (Eric Tan)

Decision made by the interest parties

- Researchers
- Process designers
- Funding agency (BETO)
- Other stakeholders.



Jobs Analysis and Model Development (Yimin Zhang)

- Primarily state governm
- Biofuel developers
- Social justice

CALIFORNIA AIR RESOURCES BOARD

STATE OF OREGON
Office of Economic Analysis

4. Progress and Outcomes: Strategic Support Task

Strategic Goal:

- Support BETO’s strategic mission and analysis needs.
- Utilize a range of approaches, work collaboratively with partner labs and agencies, to investigate critical questions.
- Handoff results and outcomes of analyses to support core BETO projects.

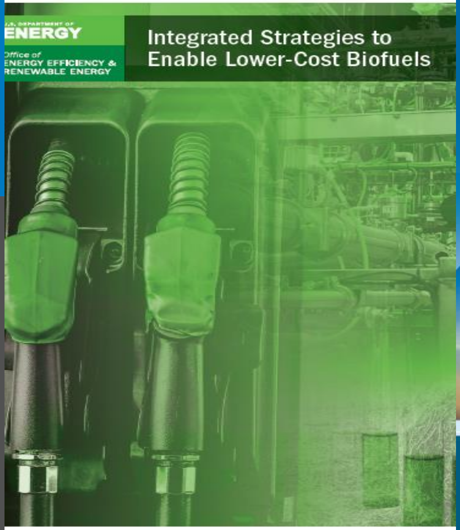
Integrated Strategies to Enable Lower-Cost Biofuels

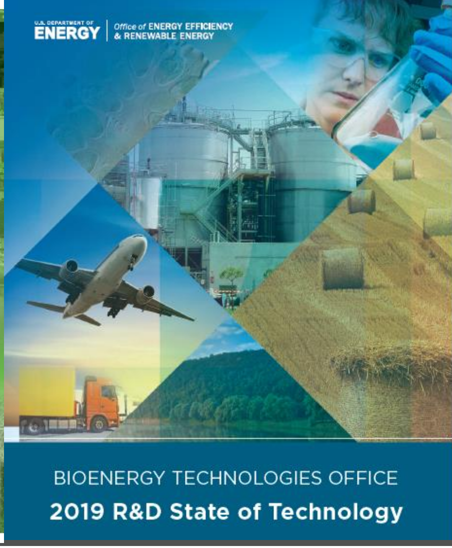
MOTIVATION: Address BETO strategies on producing biofuels at ≤ $2.5/GGE.

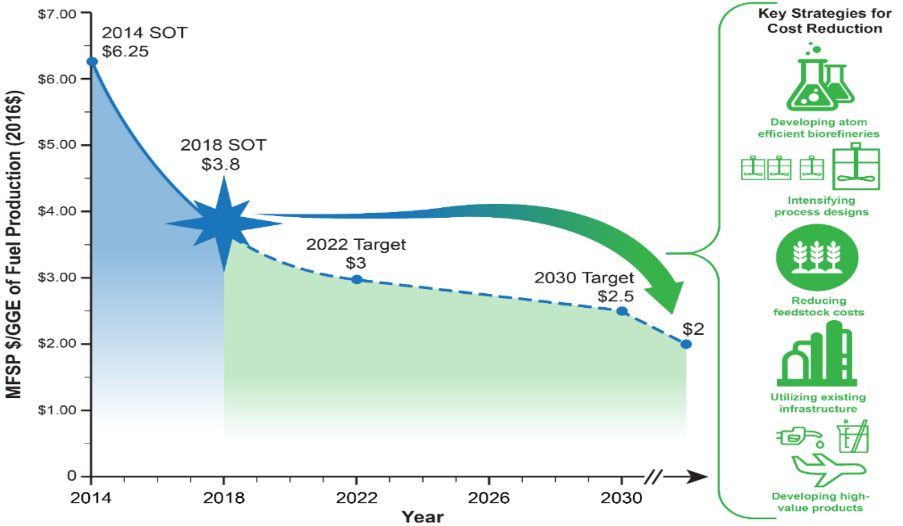
GOAL: Identify strategies and R&D opportunities for meeting a cost goal.

OUTCOMES:

- Interlaboratory collaborative efforts by NREL, PNNL, ANL, INL, ORNL.
- Provides a high-level overview of strategies for meeting cost goal of an integrated supply chain approach.
- Review work underdevelopment by both R&D and analysis.
- Provide initial, high-level estimates on potential cost savings.







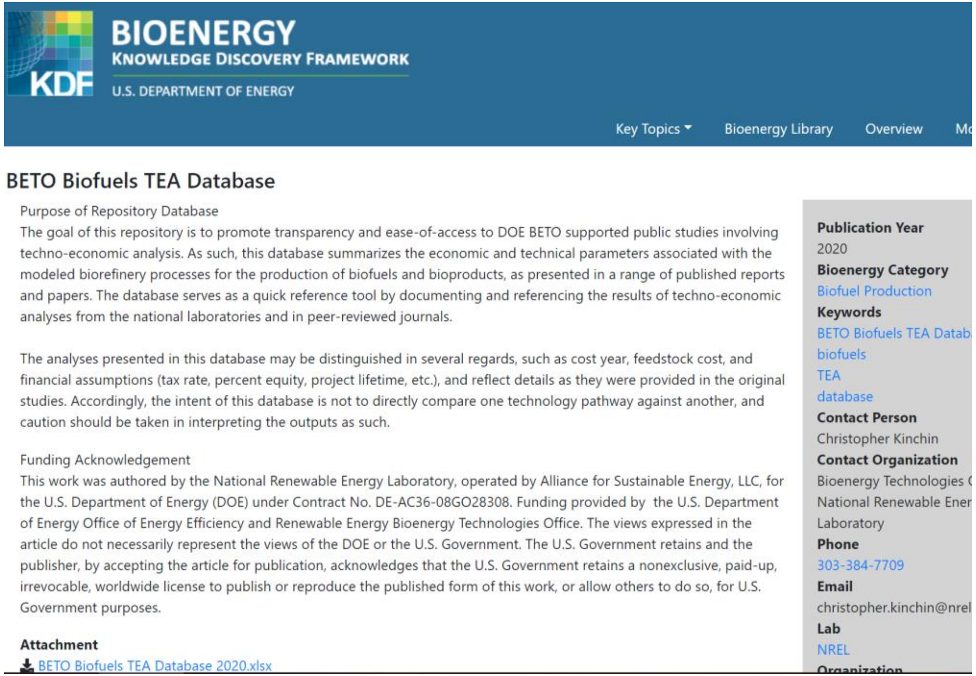
Public DOE BETO Biofuels TEA Database

MOTIVATION: Support transparency of and ease of access to DOE BETO supported public techno-economic analysis data.

GOAL: Develop and publicly release a biofuels cost data base that summarizes key inputs utilized in conversion TEAs.

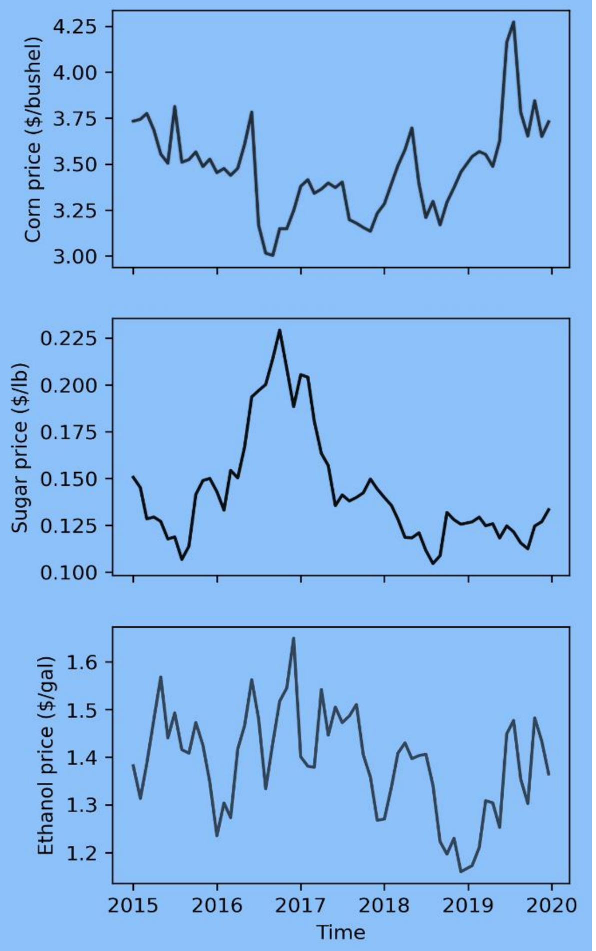
OUTCOMES:

- 50+ DOE BETO funded TEA studies, including design reports, SOT reports and publications.
- Reviewed by lead analysts to ensure consistency.
- Provide annual update with new TEAs.



Available for download on the Biomass KDF: https://bioenergykdf.net/content/beto-biofuels-tea-database

Estimate Uncertainty in Predictions



MOTIVATION

- Estimate error bars for MFSP with partner labs and agencies, investigate critical questions.
- Increase confidence in meeting a $2.5/GGE cost goal with bioproduct cost analysis.

KEY QUESTIONS BEING EXPLORED

- **What is the pioneer plant cost?**
- What is the level of confidence in the MFSP values? What is the level of MFSP uncertainty over a range of user-defined values or distributions?

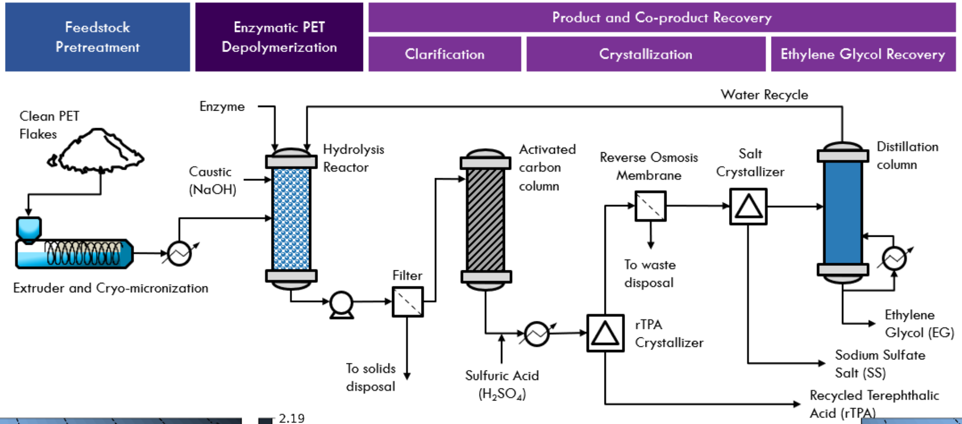
OUTCOMES:

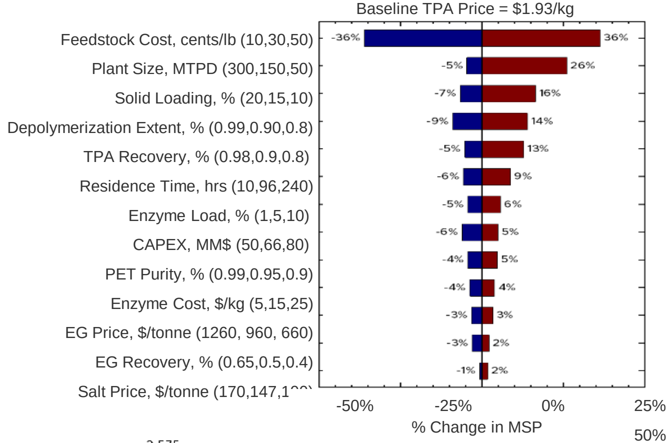
- Relate error bars to level of maturity of design.
- Prepare an analytical capability for quantifying risks. associated with technology development and technology transfer to market.

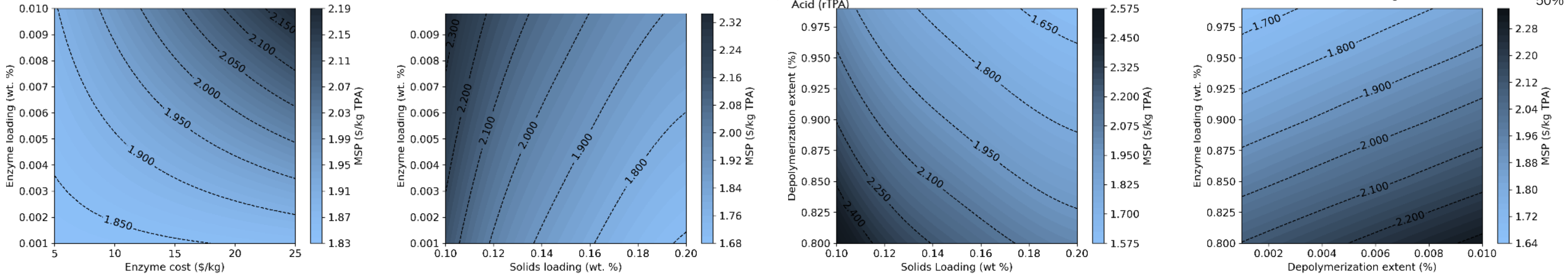
Multivariate Sensitivity Analysis

bottle
changing the way we recycle™
U.S. DEPARTMENT OF ENERGY

Multivariate sensitivity analysis is used to understand perturbation from varying 2+ inputs simultaneously







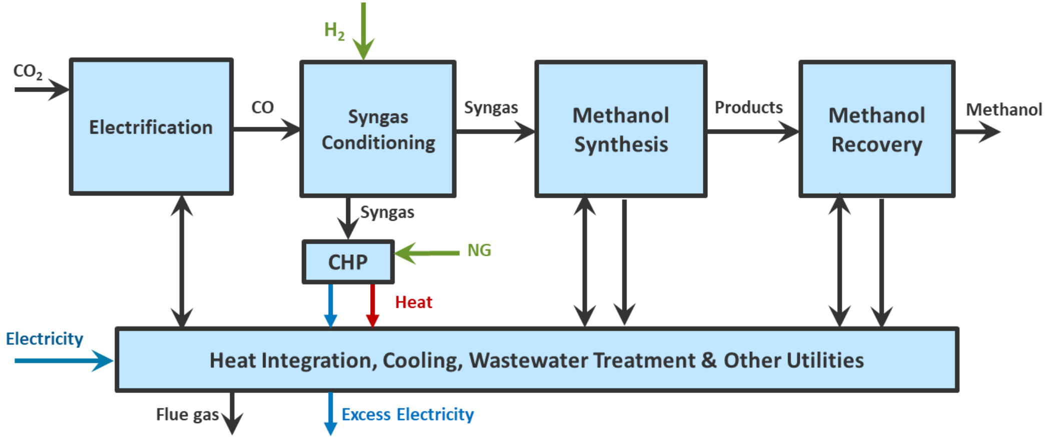
PET bales to terephthalic acid (TPA) including feedstock pretreatment, depolymerization, downstream separation, TPA crystallization and EG recovery (Courtesy of Avantika).

USDRIVE Net Zero Carbon Fuel Tech Team

MISSION: *Drive research, development, and demonstration of renewable energy solutions for the transportation sector through an assessment of the carbon intensity, technoeconomic readiness, and challenges for volume implementation of net-zero carbon fuel pathways.*

USDRIVE NZTT:

- Fuels Industry
- US Department of Energy
- Electric Utilities
- Automotive Industry
- Associate members
- Analysis task by the four participating National Labs (NREL, PNNL, ANL and LLNL)



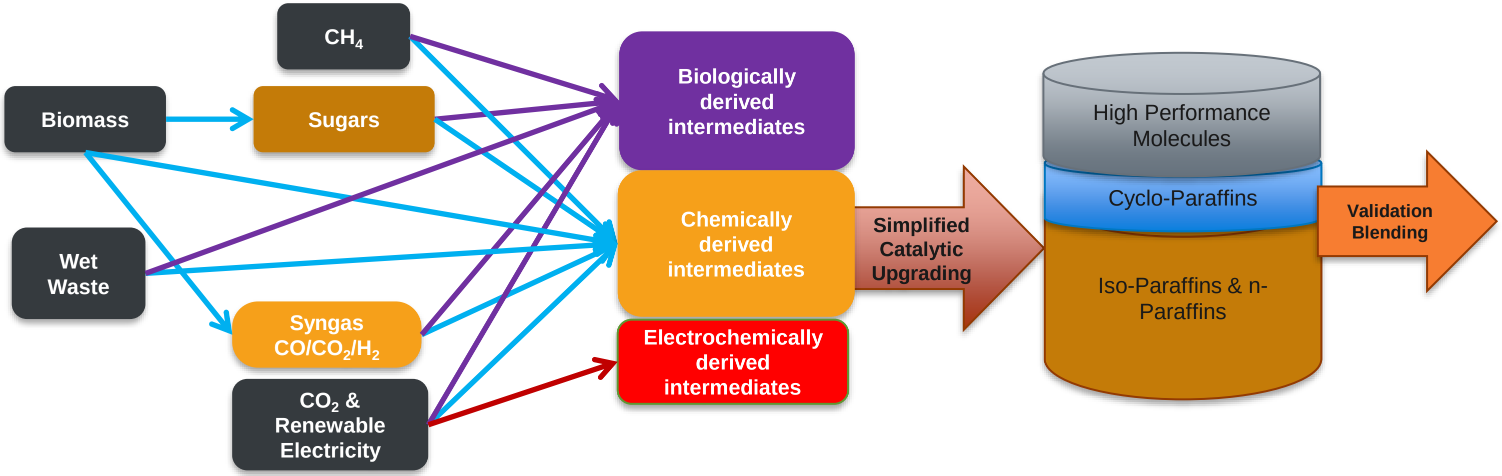
OUTCOMES: Completed initial TEA/LCA to understand the potential of 4 illustrative near-term pathways for generating net-zero carbon fuels.

4. Progress and Outcomes: Strategic TEA

Strategic Goal:

- Perform TEA to highlight R&D needs for emerging strategies.
- Supply key data for GREET, BSM analysis, and JEDI tools.
- Provide critical inputs to inform BETO.

Strategic TEA: SAF TEA Overview



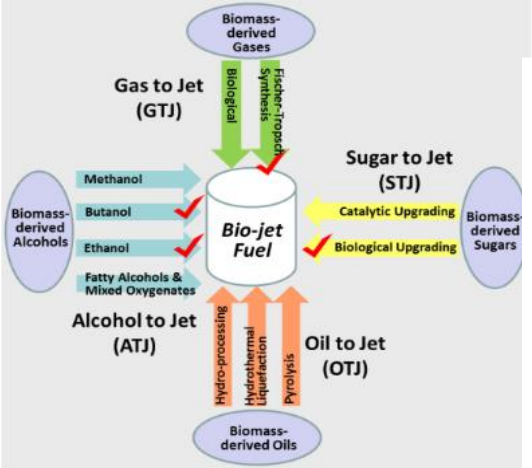
Frame with TEA and LCA

- Report key cost drivers and key cost related strategies for a path forward to approach $2.5/GGE to R&D, stakeholders.
- Consider cost impacts from process integration, hybrid/synthesis process design; regional, scales, 1st of kind.
- Consider cost impact from blending of various feedstocks to blending intermediates

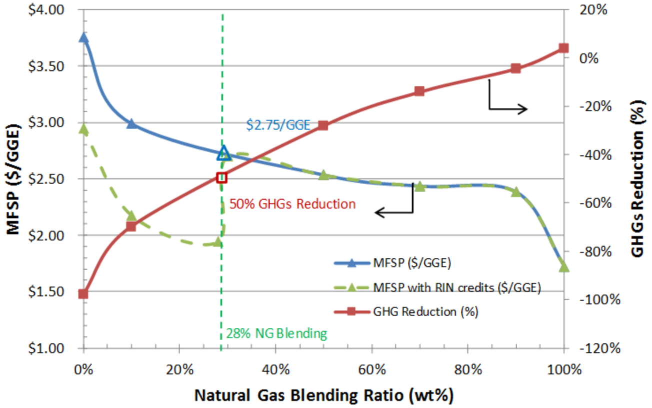
OUTCOMES: SAF costs from $3.5-6/GGE for selected pathways; ≤ $2.5/GGE needs.

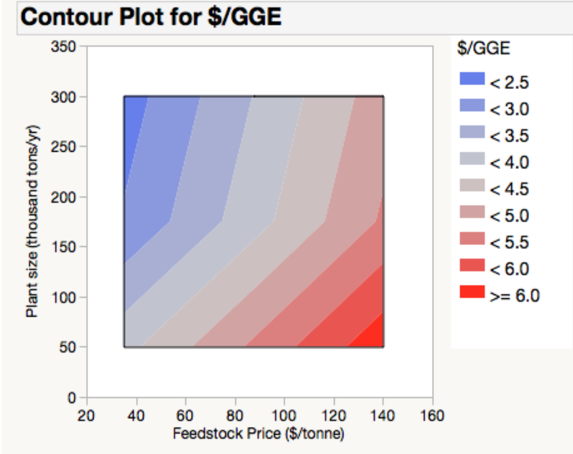
SAF TEA: Progress and Outcomes

Established a Library of TEA Models for Biomass-Derived SAF



Blending fossil and renewable feeds can provide optimal balance between GHG and cost

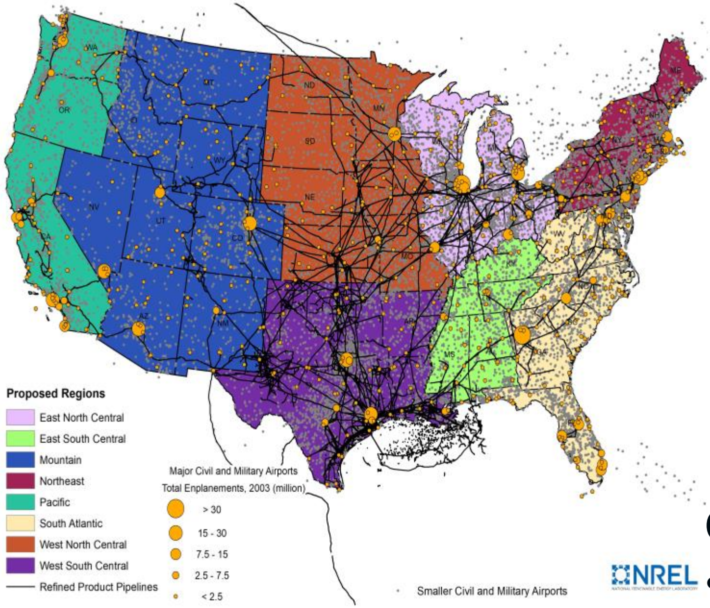




Key Takeaways to $2.50/GGE study: A combination of strategies required such as: 1) low-cost feedstocks, 2) high process yields, 3) larger scales, 4) coproducts, 5) renewable/cheap H_2 sources and 6) RIN/LCFS credits.

SAF TEA: Progress and Outcomes

Outline barriers, challenges, R&D needs to meet projected SAF in specific US regions and review how/why there are any region-specific needs



Rank	Airport	Code (IATA/ICAO)	Region	2017 Total Passengers
1	Hartsfield–Jackson Atlanta International Airport	ATL/KATL	South Atlantic	103,902,992
2	Los Angeles International Airport	LAX/KLAX	Pacific	84,557,968
3	O'Hare International Airport	ORD/KORD	East North Central	79,828,183
4	Dallas/Fort Worth International Airport	DFW/KDFW	West South Central	67,092,194
5	Denver International Airport	DEN/KDEN	Mountain	61,379,396

OUTCOMES:

- Consider top 5 busiest airports in US.
- Estimate SAF production potentials and percentage of conventional jet fuel that could be displaced.
- Estimate conversion costs for SAF.

4. Progress and Outcomes: Sustainable Process Design

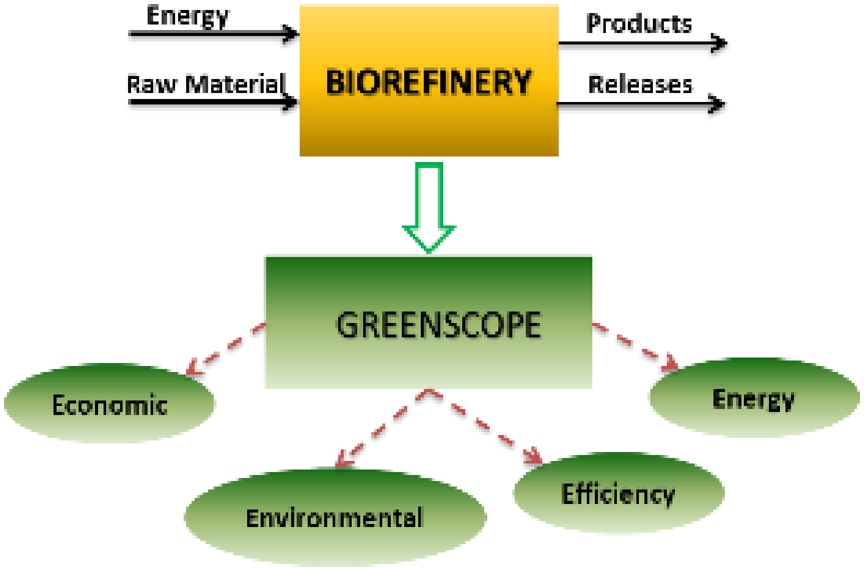
Strategic Goal:

Further incorporate and integrate sustainability into conversion process design.

Sustainable Process Design

APPROACH: Implementing **GREENSCOPE** methodology for sustainability performance assessment of biomass-to-fuel conversion processes.

- A holistic sustainability analysis where the designers and decision-makers can implement changes to the process design and understand impacts at the unit-operations level.

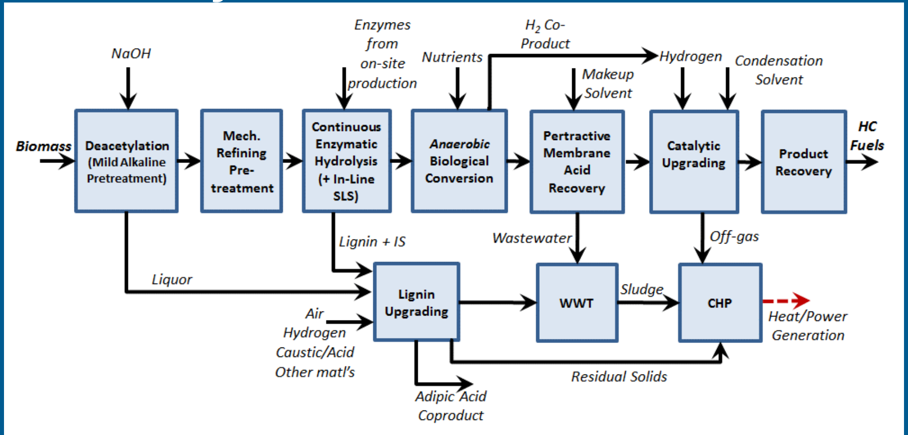


MODEL CAPABILITIES:

- Wide range of sustainability metrics.
- Four performance areas: Environment, Energy, Economics, and Efficiency.
- Integrated framework.

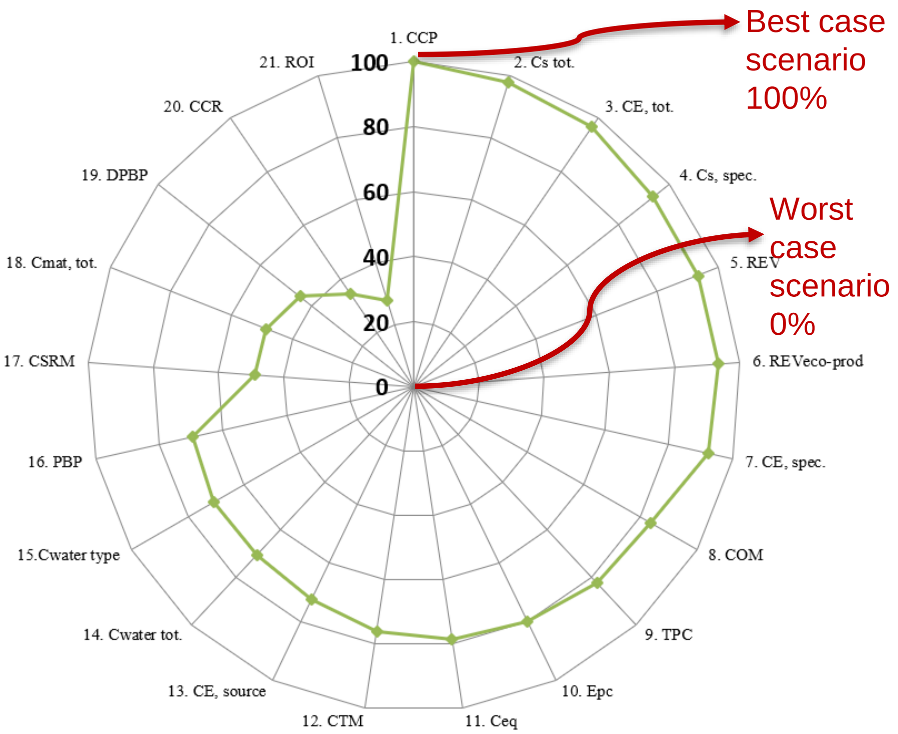
Integrate Sustainability in Biorefinery Design

Case Study



6 out of 21 economic indicators exhibit sustainability scores < 50%:

- Specific raw material cost (*17. CSRM).*
- Total material cost (*18. Cmat,tot*).
- Discounted payback period (*19. DPBP).*
- Cumulative cash ratio (20. CCR).
- Rate of return on investment (*21. ROI*).

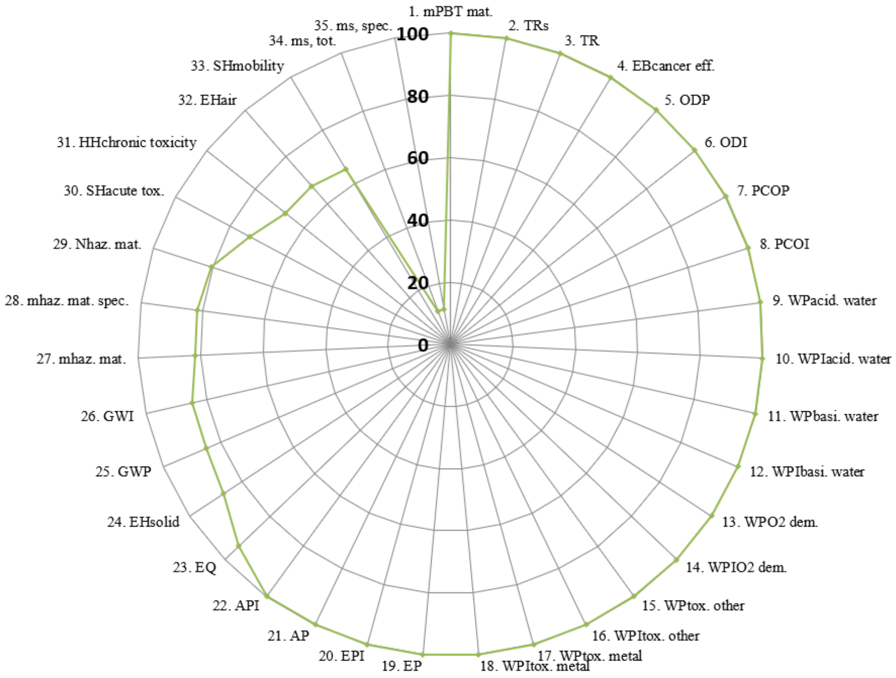


21 Economic Indicators

Integrate Sustainability in Biorefinery Design

Example of analysis outcome to inform R&D strategy

- Most of the environmental indicators exhibit a relatively high level of sustainability (i.e., > 50%).
- Indicative of good process performance for many environmental aspects.
- Critical aspect: total solid waste (ash, gypsum, lime, 34, 35).



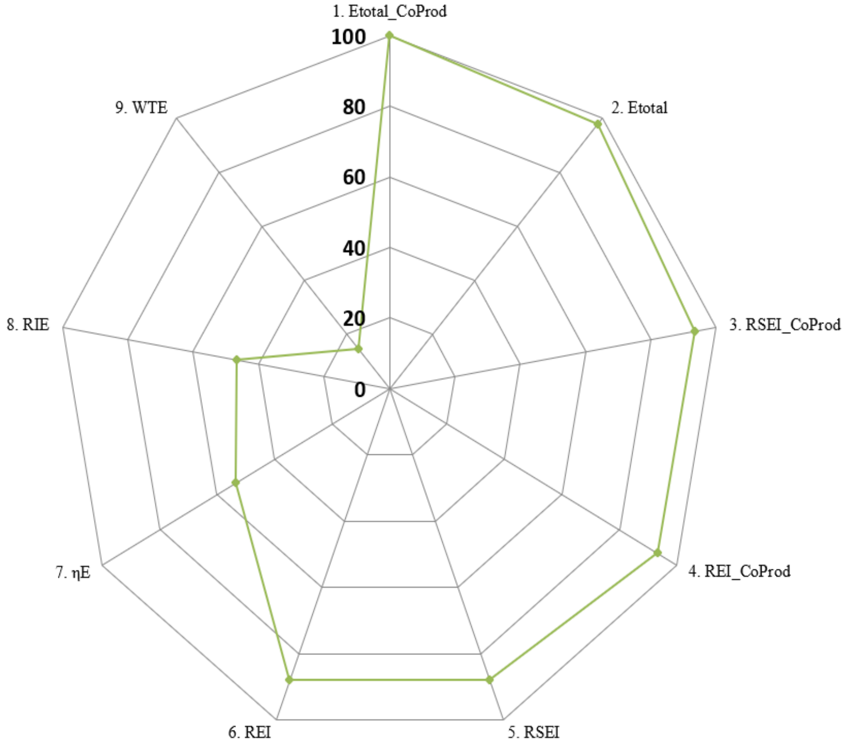
35 Environmental Indicators

Integrate Sustainability in Biorefinery Design

Example of analysis outcome to inform R&D strategy

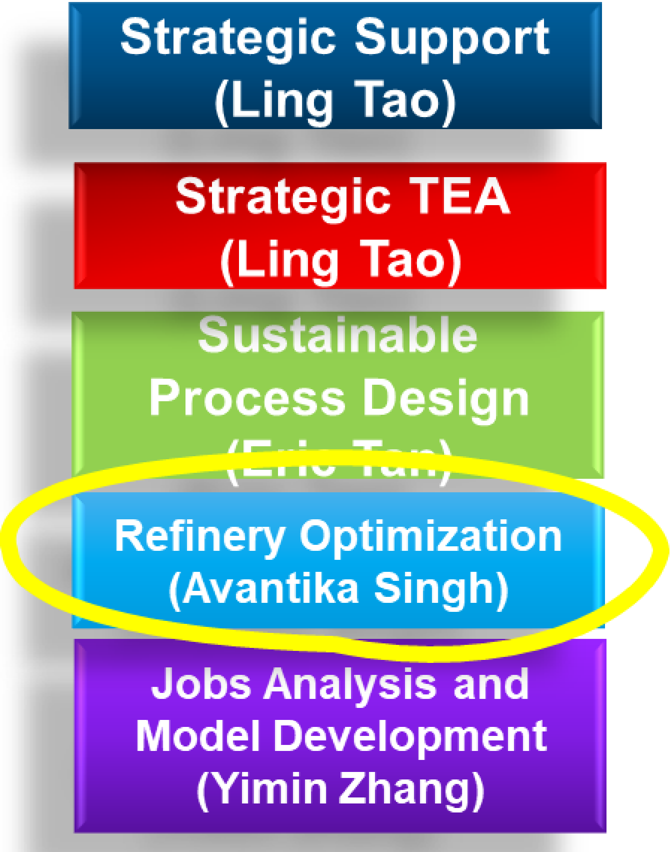
- Waste treatment energy indication (9. WTE) displays a low sustainability score.
- Low renewability-energy index (8. RIE), the ratio of the consumption of renewable energy to the total quantity of energy supplied to the process.

OUTCOMES: Identify the “hot spots” and opportunities for improving the sustainability of the biorefinery.



9 Energy Indicators

4. Progress and Outcomes: Refinery Optimization



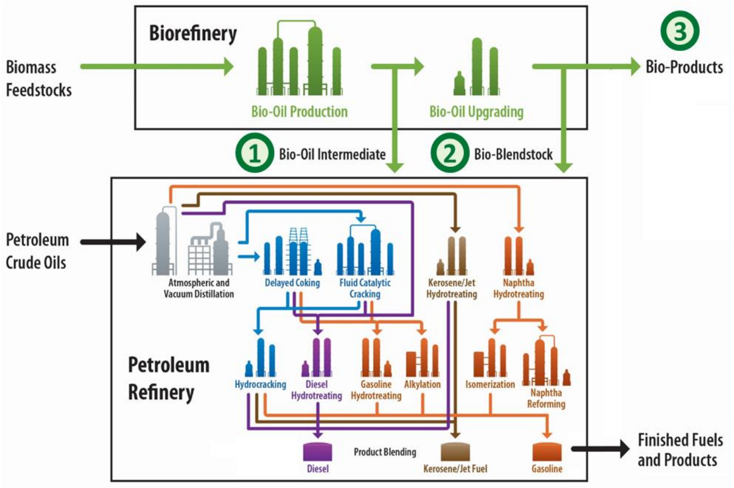
Strategic Goal:

Seek opportunities for biofuels in the context of petroleum refineries.

Petroleum Refinery Optimization

Opportunities for inserting bio-derived intermediates in refinery operations

1. Minimize cost of commodity bio-fuels through refinery integration.
2. Produce high-quality, high-value fuel blendstocks for emerging engine technologies.
3. Produce high-value bio-chemicals and other value streams.



OBJECTIVE:

- Develop and **leverage modeling innovations from other** DOE-funded projects (Co-Optima, SCR, TC Analysis) to inform petroleum refinery integration strategies.
- Identify primary finished fuel **challenges** and valuable **fuel properties**.
- Calculate the **value of bio-intermediates** and blendstocks through integration modeling to compliment cost analysis (TEA).

Petroleum Refinery Optimization: Marine Fuels

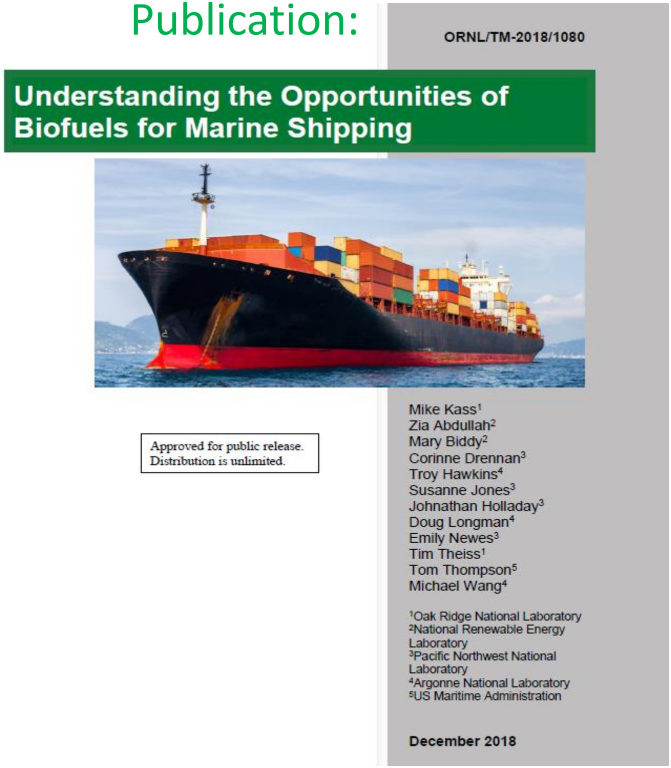
OBJECTIVE: Reduce sulfur (to 0.5%) in current heavy fuel oil in compliance with IMO rules. Marine vessels move over 80% of global trade volume (70% of trade value) and account for 4% of global oil demand.

APPROACH:

- Develop a preliminary minimum selling price that biofuel blendstocks must achieve to be comparable to the projected cost of low-sulfur marine fossil fuels.
- Evaluate the refinery impact if these bio-blendstocks were available for blending to produce low sulfur marine fuels.

OUTCOME: The relative economic benefit to a refiner depends on the biofuel pricing and properties, as well as the refinery configuration.

Publication:


ORNL/TM-2018/1080

Understanding the Opportunities of Biofuels for Marine Shipping

Approved for public release. Distribution is unlimited.

Mike Kass[1]
Zia Abdullah[2]
Mary Biddy[2]
Corinne Drennan[3]
Troy Hawkins[4]
Susanne Jones[3]
Johnathan Holladay[3]
Doug Longman[4]
Emily Newes[3]
Tim Theiss[1]
Tom Thompson[5]
Michael Wang[4]

[1]Oak Ridge National Laboratory
[2]National Renewable Energy Laboratory
[3]Pacific Northwest National Laboratory
[4]Argonne National Laboratory
[5]US Maritime Administration

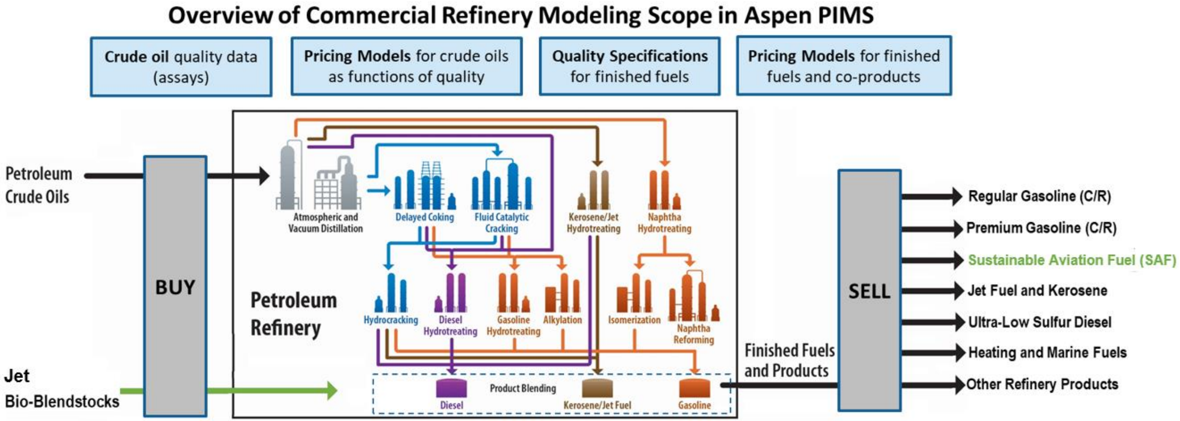
December 2018

Several national laboratories collaborated to publish a joint report that examined the economic potential to utilize bio-derived fuels in marine applications as well as outlined further research and development needs and uncertainties associated with the integration of bio-blendstocks.

Petroleum Refinery Optimization: Jet Fuels

OBJECTIVE: **Evaluate jet decarbonization** methods with changing jet fuel demand between 2020-2050 and the propose carbon offsetting and reduction scheme as imposed by CORSIA initiative.

APPOACH: Used linear programing for (1) assessing the baseline refinery product slate, particularly jet fuel range, as it evolves from 2020-2050 (2) analyzing opportunities for refiners by incorporating capital expansion cost estimates and jet fuel pricing dynamics for optimal decisions between CAPEX and OPEX.



OUTCOMES: Refinery profitability is most impacted by smoke point and sulfur content. Bio-blendstocks allow smaller refineries transitioning from selling off-spec distillate to producing SAF.

4. Progress and Outcomes: Job Analysis

Strategic Goal:

Understand the potential of job creation and economic benefits resulting from the build-out of new biorefineries.

Jobs Analysis for Bio-Derived Fuels

RELEVANCE: Publicly available tool for estimating the economic impacts of potential bioenergy technologies on local jobs.

PROBLEM: Lack of tools for evaluating the broad socioeconomic impact of bioenergy technologies.

APPROACH: Input-output model for estimating economic impacts for wet waste (sludge, in particular)-to-biofuel blendstocks.

OUTCOMES: Developed a **J**obs and **E**conomic **D**evelopment **I**mpact model to estimate the jobs impact of producing biofuels.

Project Descriptive Data - Sludge Hydrothermal Liquefaction and Biocrud	
Project Location	Texas
Year Construction Starts	2018
Construction Period (Duration in months)	36
HTL Plant Feedstock	Sludge from Waste Wa
Baseline Feedstock Rate (US dry tons/day)	110
Feedstock Rate Adjustment (percent change)	10%
Total Feedstock Utilized (US dry tons/year)	36,300
Fuel Produced	Renewable Diesel Blendstock and Naphtha
Total Renewable Fuel Production (Mil. gge/Year)	4.26
HTL Plant Share of Upgrading Plant Capacity	11%
Distance from HTL Plant to Upgrading Plant (miles one way)	100
Transportation Cost Per Mile ($/mile)	$1.54
Money Value (Dollar Year)	2014
Go To Summary Impacts	Review/Edit HTL Plant Cost Dat

https://www.nrel.gov/analysis/jedi/

Jobs Analysis for Gen 1.5 Technology

RELEVANCE: Potential job growth opportunities from bolt-on Gen 1.5 technologies to produce additional ethanol in dry mills in Midwest.

OBJECTIVE: How do bolt-on Gen 1.5 compare to stand-alone cellulosic ethanol biorefinery in terms of job creation?

APPROACH: LeveragE TEA for an economic input-output analysis to quality state-level job potential of adopting Gen 1.5 bolt-on technologies.

OUTCOMES:

- Between 0.89 and 1.27 annual jobs could be supported by each million gallons of Gen 1.5 ethanol produced.
- In comparison, a stand-alone biorefinery is expected to support 0.98 annual jobs per million gallons of ethanol production.

***Gen 1.5** uses feedstock fiber already on-site to produce cellulosic ethanol.

Quad Chart Overview

Timeline

- Project start date: FY2011
- Merit review cycle: FY2019-2021, 80% complete

	FY21	Total Planned (FY19-FY21)
DOE Funding	$450K	$1,350K

Project Partners*

- National laboratories: ANL, INL, LLNL, ORNL, PNNL
- NREL—core platform analysis; NREL—Market and Policy Impact Analysis Group; NREL—SI, NREL—VT,
- Industry: Exxon-Mobil, ICM, USDRIVE
- Government agencies: CAAFI, DOE-AMO, DOE-FCTO, DOE-VTO, DOD, DOT, EPA
- Academia: MIT, University of Chicago

Barriers addressed

At-A. Analysis to Inform Strategic Direction

At-D. Identifying New Market Opportunities for Bioenergy and Bioproducts

At-E. Quantification of Economic, Environmental, and Other Benefits and Costs

Project Goal

- Provide sound, unbiased, and consistent analyses to inform BETO strategic direction.
- Comparative analyses of biomass conversion processes to evaluate emerging areas of interest.
- Model and tool development to support BETO and to understand the impact of expanding bioeconomy.

End of Project Milestone

- Develop a standard methodology to estimate the prices of the chemical coproducts.
- Solidify strategy around alternative jet fuel production and guide R&D strategies on both TEA/LCA and non-technical barriers.

Future Works:

- Improve analysis rigor to meet any cost objective.
- Inform on-going **strategic goals** for **renewable jet fuel.**
- Evaluate **emerging technology pathways** to ensure both economic viability and sustainable design creditability.
- Develop JEDI for emerging technology pathways.

Summary

Management

- Five tasks directly relevant to BETO’s mission and MYPP.
- Integrate multiple dimension strategic supports for BETO, external/internal stakeholders.
- Stay current on bioeconomy advancements and state-of-art tools to mitigate risk of rapid changing externality

Approach

- Transparent, rigorous models with a consistent set of assumptions.
- Integrated task structure to provide holistic output for strategy development.
- Consult experts globally to get the best data; work closely with stakeholders to define needs and key questions.

Impact

- Support and bridge a range of DOE BETO projects.
- Provide strategic and critical information to industry and agencies outside of BETO.
- Disseminate technical results to web-based tools and in high impact publications.

Progress & Outcomes

- Developed strategies to meet a <$2.5/GGE cost goal for hydrocarbon fuels and SAF.
- Supported USDRIVE on net zero carbon fuels strategies.
- Identified opportunities for improving the sustainability of the biorefinery.
- Developed Gen 1.5-focused JEDI model for employment potentials.

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Additional Slides

3. Impact: Contribute Directly to BETO Goals & MYPP

BETO Goal	Project Contributions
“Develop and maintain analytical tools, models, methods, and datasets to advance the understanding of bioenergy and its related impacts.” (A&S Performance Goal) [2-130]	**Developed a suite of tools and models that are publicly availabl**e, including **JEDI and the Biofuels Database.** Both tools work to ensure transparency in modeling approaches and are user-friendly tools to support stakeholder outreach.
“The Office supports the development and deployment of new analytical tools and methods and guides the selection of assumptions and methodologies to be used for all analyses to ensure consistency, transparency, and comparability of results.” [2-134]	**Strategic Support** future work is focused on improving the rigor associated with the analysis to meet any cost objective as well as improving methodologies for incorporating the cost of coproducts in TEA. Additionally, in FY19/20 worked with ANL and core conversion project on coproduct considerations in LCA of biorefinery analyses and published the joint BETO reports.
Support efforts to “provide an analytical basis for BETO planning and assessment of progress.” [2-129]	**Strategic Support collaborative** analysis for $2/GGE. **Strategic TEA** results have supported the initial analyses and transition to strategic areas for WTE.
Develop analyses to “quantify the environmental and socio-economic effects of bioenergy production, assess opportunities for improvement, disseminate technical information..” [2-121]	**JEDI tools** help to understand bioenergy’s **impact and potential benefits on creating and supporting domestic job growth.** Work over last years has focused on expansion to align with core BETO funded strategies
Technology-specific analyses explore sensitivities and identify areas where investment may lead to the greatest impacts. [2-129]	Project has long history in supporting this goal. **Strategic TEA** models identify key cost drivers for jet fuel and new emerging technologies, as well as develop pioneer plant costs for near-term deployment.

Market Trends

Product	Gasoline/ethanol demand decreasing, diesel demand steady
	Increasing demand for aviation and marine fuel
	Demand for higher-performance products
	Increasing demand for renewable/recyclable materials
Feedstock	Sustained low oil prices
	Decreasing cost of renewable electricity
	Sustainable waste management
	Expanding availability of green H_2
	Closing the carbon cycle
Capital	Risk of greenfield investments
	Challenges and costs of biorefinery start-up
	Availability of depreciated and underutilized capital equipment
Social Responsibility	Carbon intensity reduction
	Access to clean air and water
	Environmental equity

NREL's Bioenergy Program Is Enabling a Sustainable Energy Future by Responding to Key Market Needs

Value Proposition

- An array of analysis tools to support BETO strategic direction
- Assess impacts and potential for emerging technologies and outline R&D needs/barriers for further development
- Outreach to bioenergy community to support impacts on the bioeconomy.
- Strategic support efforts have maintained external collaborations with EPA, DOE FCTO/VTO, USDRIVE to provide key biofuel production metrics.
- Evaluation of the emerging pathways of interest of BETO by 1) exploring the emerging strategies and ensuring no unintended consequences resulting for focusing on lower cost costs, 2) highlighting key sustainability and 3) working with R&D teams and BETO to review and propose alternative opportunities to improve sustainability designs and economic viability

Key Differentiators

- Consider a wider range of metrics (costs, GHGs, sustainability indicator, jobs, refinery integration) that allow for more comprehensive direct comparison bioeconomy alternatives.
- Bridge analysis with R&D, conversion platform, national labs, federal agency, industrial and academia

Abbreviations and Acronyms

A&S: Analysis and Sustainability
AMO: DOE Advance Manufacturing Office
ANL: Argonne National Laboratory
AOP: Annual operating plan
BETO: Bioenergy Technologies Office
CAAFI: Commercial Aviation Alternative Fuels Initiative
CARB: California Air Resources Board
DOD: Department of Defense
EPA: US Environmental Protection Agency
FOA: Funding Opportunity Announcement
GGE: Gasoline gallon equivalent
INL: Idaho National Laboratory
IRR: Internal Rate of Return
ISU: Iowa State University
JEDI: Jobs and Economic Development Impact
LCA: Life-cycle analysis
LCFS: Low Carbon Fuel Standard
MFSP: Minimum fuel selling price
MYPP: Multi-year program plan
NREL: National Renewable Energy Laboratory
NZTT: Net Zero Tech Team
ORNL: Oakridge National Laboratory
PNNL: Pacific Northwest National Laboratory
RIN: Renewable Indication Number
TEA: Techno-Economic Analysis
WTE: Waste To Energy
VTO: Vehicles Technology Office

Publications and Technical Reports

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Publications and Technical Reports

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2. “Evaluating Indicators and Life Cycle Inventories for Processes in Early Stages of Technical Readiness,” 2017 AIChE Annual Meeting, Minneapolis, MN, October 29 – November 3, 2017.
3. “An Integrated Sustainability Evaluation of Indirect Liquefaction of Biomass to Liquid Fuels,” 7th International Congress on Sustainability Science & Engineering, Cincinnati, OH, August 12-15, 2018.
4. “Sustainable Process Design for Biofuel Production via Syngas Conversion Pathway,” 8th International Congress on Sustainability Science & Engineering, Kuala Lumpur, Malaysia, July 1-3, 2019.
5. “Estimating Chemical Releases and Evaluating Indicators for Manufacturing Processes: Biorefinery Case Studies,” 2020 AIChE Annual Meeting, Virtual, November 15-20, 2020.
6. “Sustainable Process Design for Biofuel Production Via Syngas Conversion Pathway”. 8th International Congress on Sustainability Science & Engineering (ICOSSE ’19: Industry, Innovation and Sustainability), Kuala Lumpur, Malaysia 2019 https://www.osti.gov/biblio/1542267
7. “The Technical and Economic Feasibility of CO2 Reduction Using Low-Cost Electrons”. USCAR/BETO Joint Workshop, USCAR offices, Detroit, MI. 2019 Jul.

Responses to Previous Reviewers' Comments

- **Reviewer comment:** This team provided excellent work results. This type of analysis in industry is routine and often starts early in large projects. The value of such analysis work at early, middle and late-stage projects is critical to BETO programs. These analyses increase dramatically the speed of development providing where to focus future efforts to drive down cost or where to stop working since further refinement is not impactful. Only question is can BETO provide some level of techno-economics to even smaller start projects to make sure that the original strategy has right to succeed. Only other comment is funding for plant capital for new technologies typically, from my experience, is not 20 years payout but more like 10 years, thus only true for nth plant. Also never know a plant to come in on original capital cost estimates. Some confidence info on calculations i.e. +- x% would be helpful as well for reviewers.
- **Response:** We thank the reviewers for their helpful feedback and comments. Going forward, we will work to adopt suggestions from the panel to estimate cost ranges and to consider more near-term cost estimation (pre-Nth plant evaluations) for these new and novel technologies. We will also consider payback period potential for these new technologies as replacement for incumbent baseline technologies and further expand our sustainability analysis to consider a wider range of metrics.