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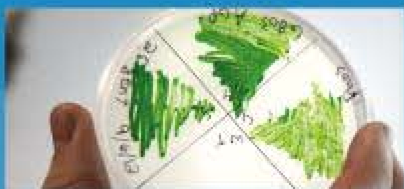
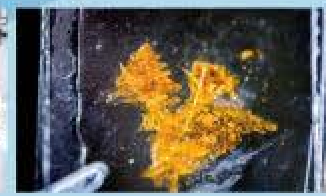



Strategic Analysis Support

Mary J. Biddy, Ling Tao, Michael Talmadge, Yimin Zhang

National Renewable Energy Laboratory (NREL)

March 7, 2017
Analysis and Sustainability Peer Review
2017 U.S. Department of Energy (DOE)
Bioenergy Technologies Office (BETO) Project Peer Review

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Goal Statement

Goal: Develop tools and perform analyses to address key questions in support of the strategic direction of the DOE Bioenergy Technologies Office.

Outcomes:

- Assess the current and future market drivers for the production of biomass-derived chemicals.
- Provide comparative economic analyses for jet fuel production pathways.
- Evaluate alternative waste feed streams for the production of fuels and chemicals.
- Investigate the economics of biofuel quality in blending.
- Estimate the number of jobs that will be created in the United States with biorefinery deployment.

Relevance: Assess impacts of the emerging bio-economy and outline R&D needs/barriers for further development by BETO and industry.

Quad Chart Overview

Timeline

Start Date: October 2015
End Date: Expected to undergo merit review in FY18
Percent Completion: 50%

Barriers

At-A: Comparable, transparent, and reproducible analyses
At-B: Analytical tools and capabilities for system-level analysis
At-C: Data availability across the supply chain

Budget

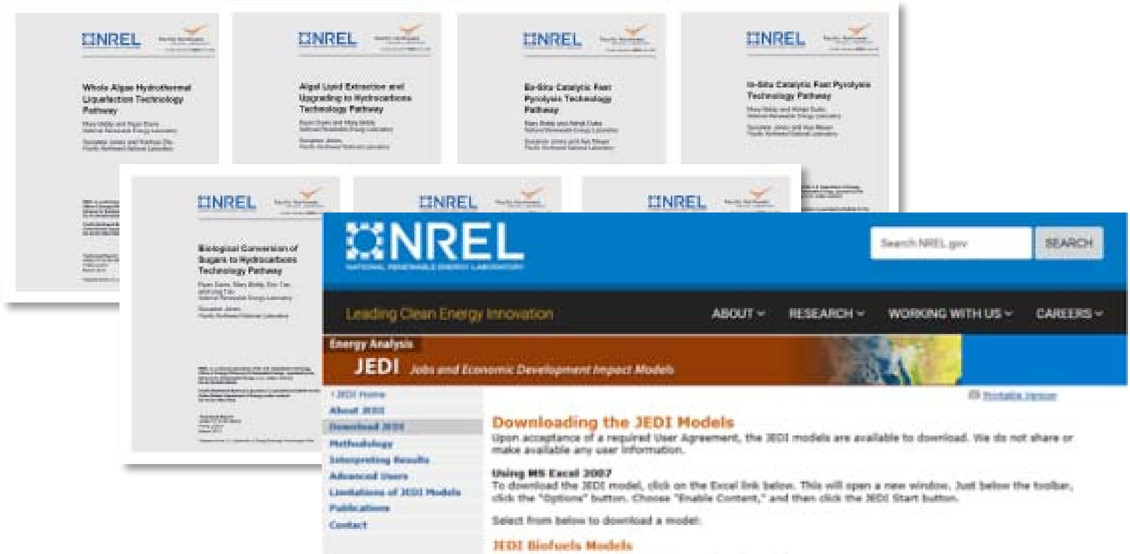
	DOE Funded
FY12–FY14 (Total)	$2.0M
FY15	$600k
FY16	$650k
(FY17–Project End Date) Total Planned Funding	$1.3M

Interactions/Collaborations

- National laboratories: *ANL, INL, NREL—core platform analysis; NREL—Market and Policy Impact Analysis Group; NREL—SI, NREL—VT, ORNL, PNNL*
- Industry: *Celanese, Exxon-Mobil, U.S. DRIVE*
- Government agencies: *CAAFI, DOE-BETO DMT, DOE-VTO, DOD, EPA*
- Academia: *CU, ISU, MIT*

Project Overview: History

- **Comparative analyses of biomass conversion processes to evaluate emerging areas of interest for BETO and Bioindustry.**
  - COP/ISU/NREL collaboration focused on techno-economic analysis (TEA) of biofuels (FY11).
  - NREL/PNNL hydrocarbon technology pathways (FY12/13).
  - Jet fuel economics and chemicals market assessment.
  - Provide quick turnaround analyses to support BETO and EERE.
- **Model and tool development to support BETO and to understand the impact of expanding the biomass economy .**
  - Estimate job growth potential for the developing bioeconomy.
  - Investigate the optimal biorefinery economics.
  - Develop economic analysis tools.



Project Overview: Objective

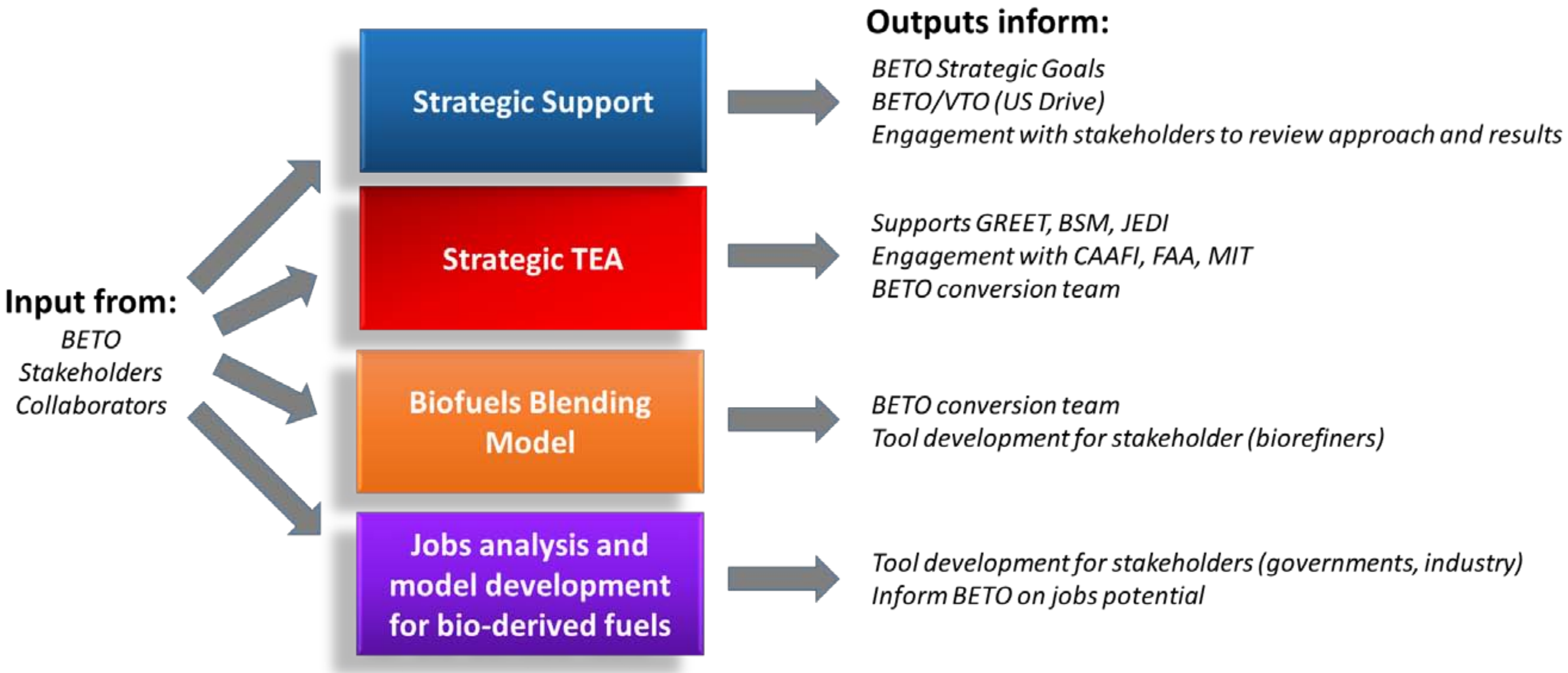
Develop and utilize an array of analysis tools to support the strategic direction of BETO and understand the development of a biomass economy:

- **Analysis** to identify the market drivers and uncertainties in the deployment of **chemicals production from biomass.**
- **Integrated biorefinery optimization** to guide BETO on the development of biofuels and bioproducts.
- **Techno-economic analysis** in support of the expansion of strategic programmatic technologies to **jet fuel production.**
- Estimates of **job growth** and the broader impacts of emerging industries.

Provide credible results to assist decision making in bioenergy investment by applying appropriate analyses and models.

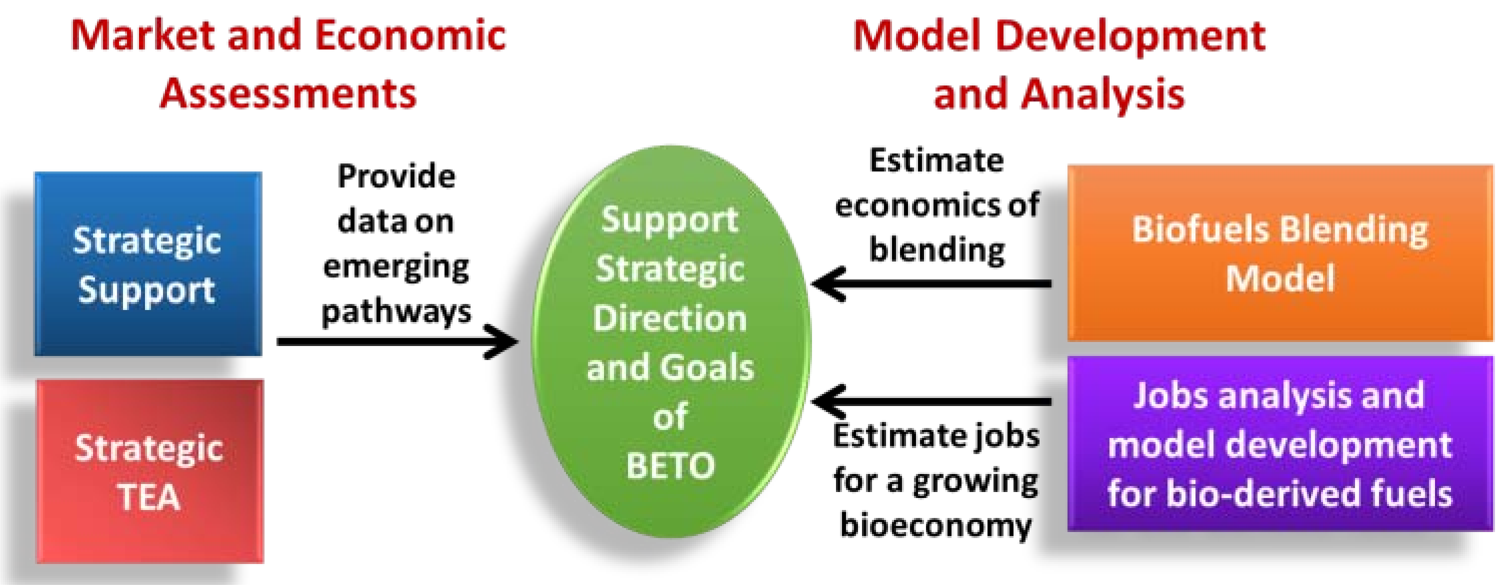
Project Management Approach

- **Critical success factors:**
  - On-time and on-budget delivery of results.
    - Track progress through quarterly reports/updates.
    - Set intermediate goals to show continuous progress and received feedback from DOE on direction of analysis to project objectives.
    - Clearly defined objectives and milestones of the project.



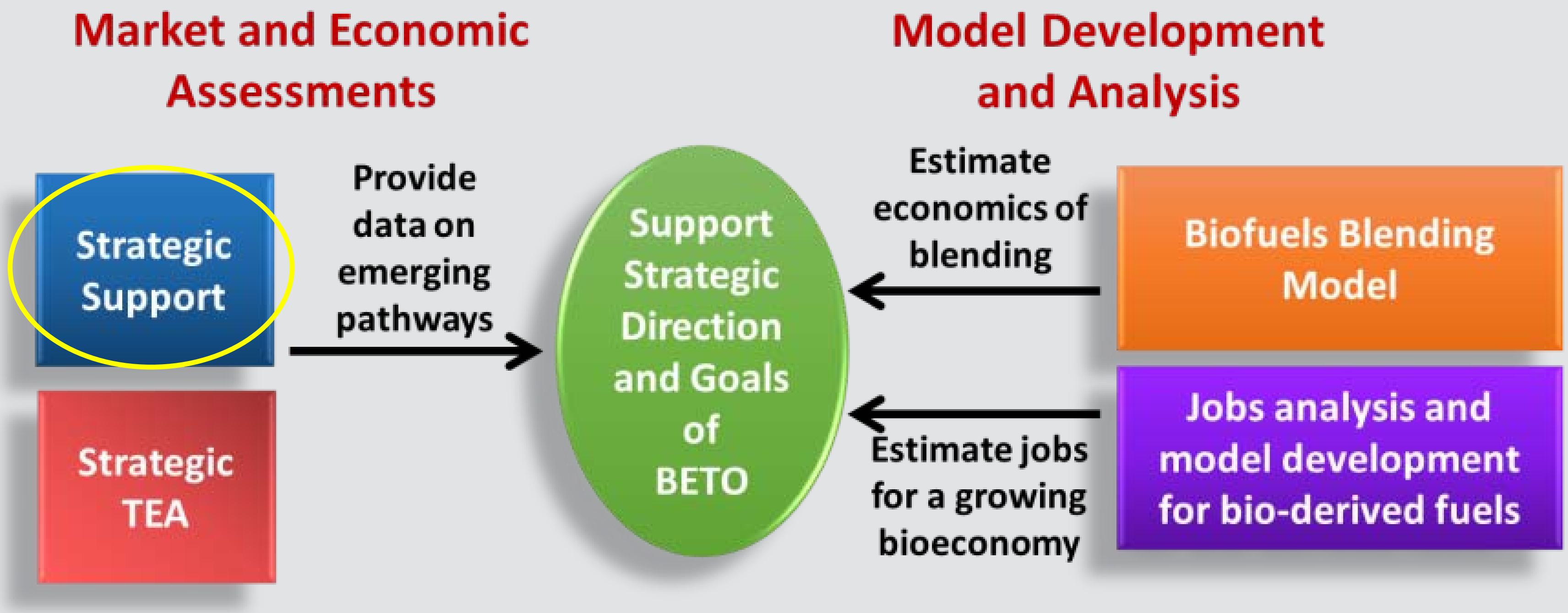
Project Technical Approach

Develop Models and Conduct Analysis to Support Strategic Decisions



- **Common approach for all projects:**
  - **Models are transparent and rigorous** with a consistent set of assumptions that allows for direct comparison.
  - Analysis results and approaches are **vetted by stakeholders**.
  - **Results and tool availability is communicated** to stakeholders through peer-reviewed publications, presentations, and technical reports.
- **Critical success factors:** Availability and quality of data. Work with BETO to identify relevant stakeholders and collaborators for vetting and for data sources.

Strategic Support Task



Strategic Goal: Support BETO's strategic mission and analysis needs by utilizing a range of methodologies and tools to investigate critical questions. Handoff results and outcomes of analyses to support core projects in BETO.

Strategic Support: Market Analysis Methodology

Market analysis report for the production of bio-derived chemicals based on public information.

- Initially identified **27 biomass-derived products.**
- Down-selected to **12 products** based on market potential.
- Report reviewed by over 15 experts from academia, national laboratories, and industry.
- **Expanded report in FY15** to include additional products and information based on reviewer feedback.

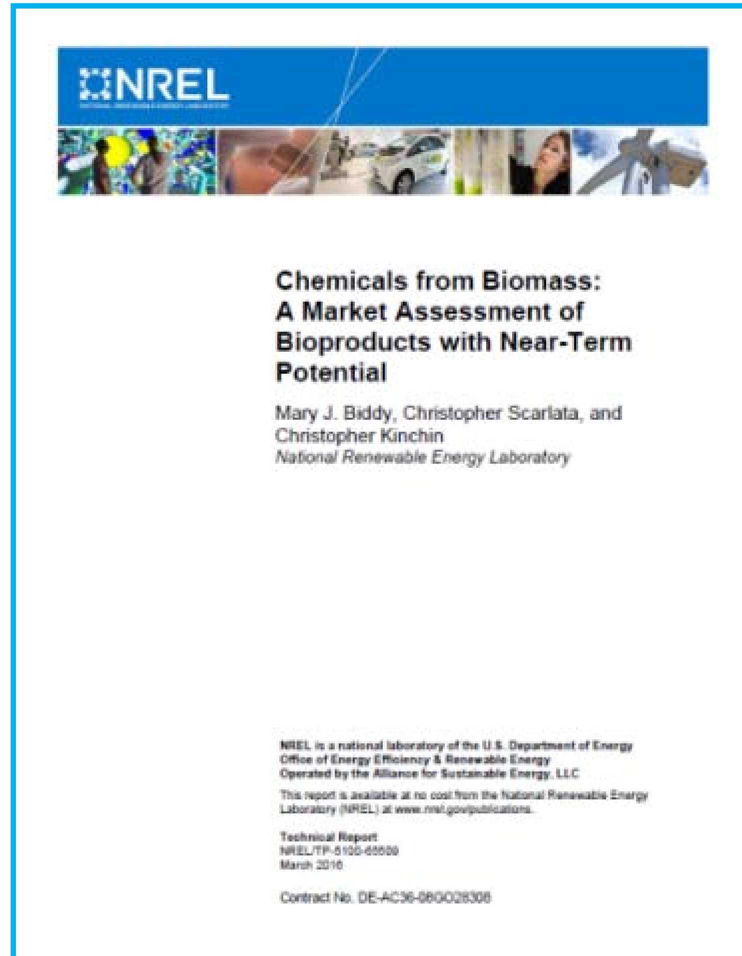
Criteria used to evaluate the market potential of biomass-derived products

High Volume/Value	Market maturity	High growth (domestic)
High growth (global)	Feedstock flexibility	Platform chemical
DOE interest/funding	Integrated with conversion pathways	Avoids competition with natural gas
Market pull	End-user specifications	Bioprocess advantage
Current scale	Favorable life cycle	Near-term deployment (high technology readiness level [TRL])

Strategic Support: Market Analysis Accomplishments

Significance and Impact

- Focus of report is on products that will have **near-term market impact**.
- Reviews current projects and planned efforts for bio-derived chemicals.
- **Identifies major drivers** for moving biomass-derived products to market and current market champions.
- Assesses ways in which chemicals production can be **leveraged to expand and accelerate the growth of biofuels.**
- Report published in FY16 and presented at three different conferences including Bioenergy 2016.



Chemicals from Biomass: A Market Assessment of Bioproducts with Near-Term Potential

Mary J. Biddy, Christopher Scarlata, and Christopher Kinchin

National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Technical Report
March 2016

www.nrel.gov/docs/fy16osti/65509.pdf

Strategic Support: Market Analysis Accomplishments

Chemical	Type	Conversion Pathway	TRL based on commodity feedstocks	Research & development (R&D) ongoing for lignocellulosic feedstocks
Butadiene (1,3-)	Drop-in	BC—Biological TC/BC—Gasification/Fermentation	6	Y
Butanediol (1,4-)	Drop-in	BC—Biological	8	Y
Ethyl Lactate	Functional	BC—Biological	9	Y
Fatty Alcohols	Drop-in	TC—Gasification, BC—Biological, Algae	9	Y
Furfural	Functional	TC—Pyrolysis, BC—Catalytic	9	Y
Glycerol	Functional	Algae	9	Y
Isoprene	Drop-in	BC—Biological		
Lactic Acid	Functional	BC—Biological		
Propanediol (1,3-)	Functional	BC—Biological		
Propylene Glycol	Functional	BC—Biological		
Succinic Acid	Functional	BC—Biological		
Xylene (para)	Drop-in	BC—Catalytic TC—Pyrolysis		

Strategic Support: Market Analysis Results

- Selection of products based on a number of metrics (e.g., market considerations, TRLs, and life cycle analyses [LCA]).
- Range of drivers for bio-derived products:
  - Supply/demand and market need (fossil replacements).
  - Consumer demand.
  - Superior properties and potential lower costs.

- Majority of scaled processes are focused on commodity feedstocks; however, there is growth in lignocellulosic feedstocks.
- Expansion and utilization of data/study in a number of other projects:
  - CEMAC Clean Energy Manufacturing Analysis Center www.manufacturingcleanenergy.org
  - AGILE BioFoundry http://agilebio.lbl.gov/
  - Strategic Analysis Bioproduct Transition System Dynamics Model

Strategic Support: Analysis Results

- Support BETO and provide TEA for U.S. Drive C2G team.
- Awarded 2016 Joint Fuel Cell Technologies and Vehicle Technologies Office Award.

ANL/ESD-16/7
Rev. 1

Cradle-to-Grave Lifecycle Analysis of U.S. Light-Duty Vehicle-Fuel Pathways: A Greenhouse Gas Emissions and Economic Assessment of Current (2015) and Future (2025–2030) Technologies

https://greet.es.anl.gov/publication-c2g-2016-report

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[3]National Renewable Energy Laboratory
[4]Electric Power Research Institute
[5]FCA US LLC
[6]General Motors
[7]Chevron Corporation
[8]Ford Motor Company

- Describes approaches to handling co-products and impact of assumptions.
- Reviewed by 10 external reviewers.
- Work ongoing to finalize and publish in FY17.

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The Impact that Coproduct Valuations have on the Economics of an Integrated Biorefinery

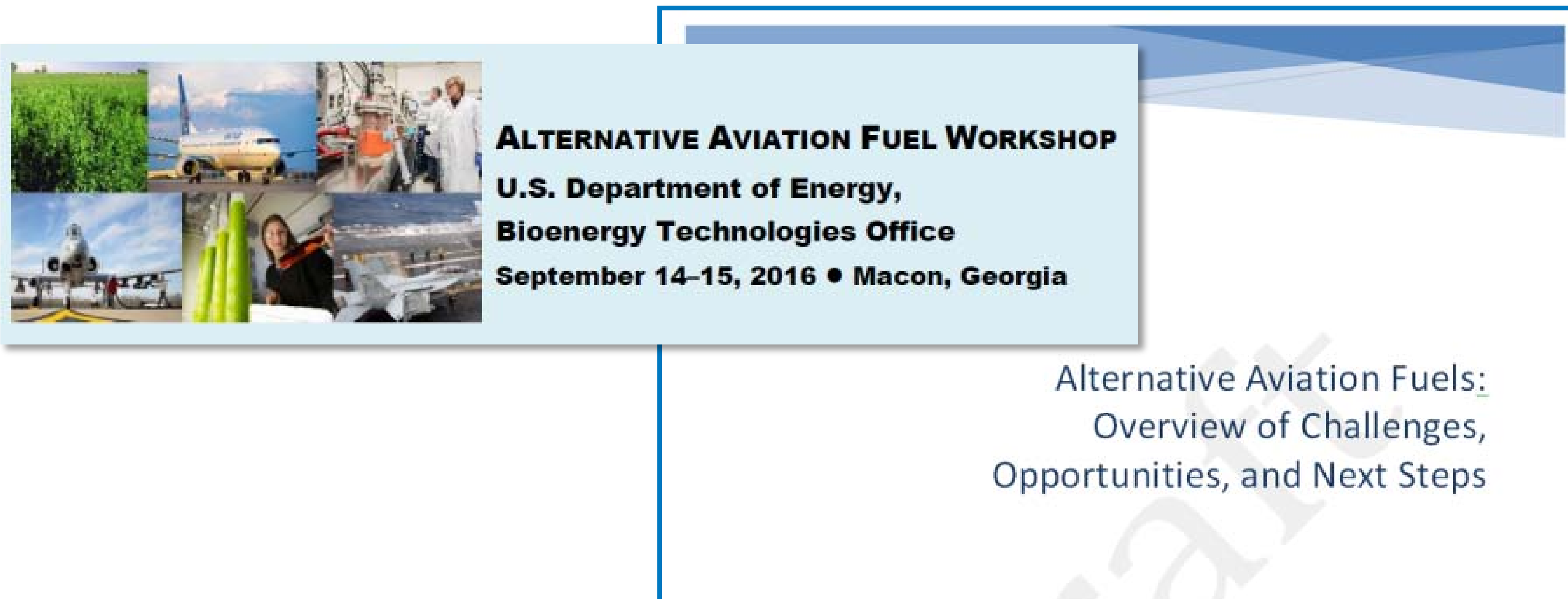
Mary J. Biddy
National Renewable Energy Laboratory

DRAFT

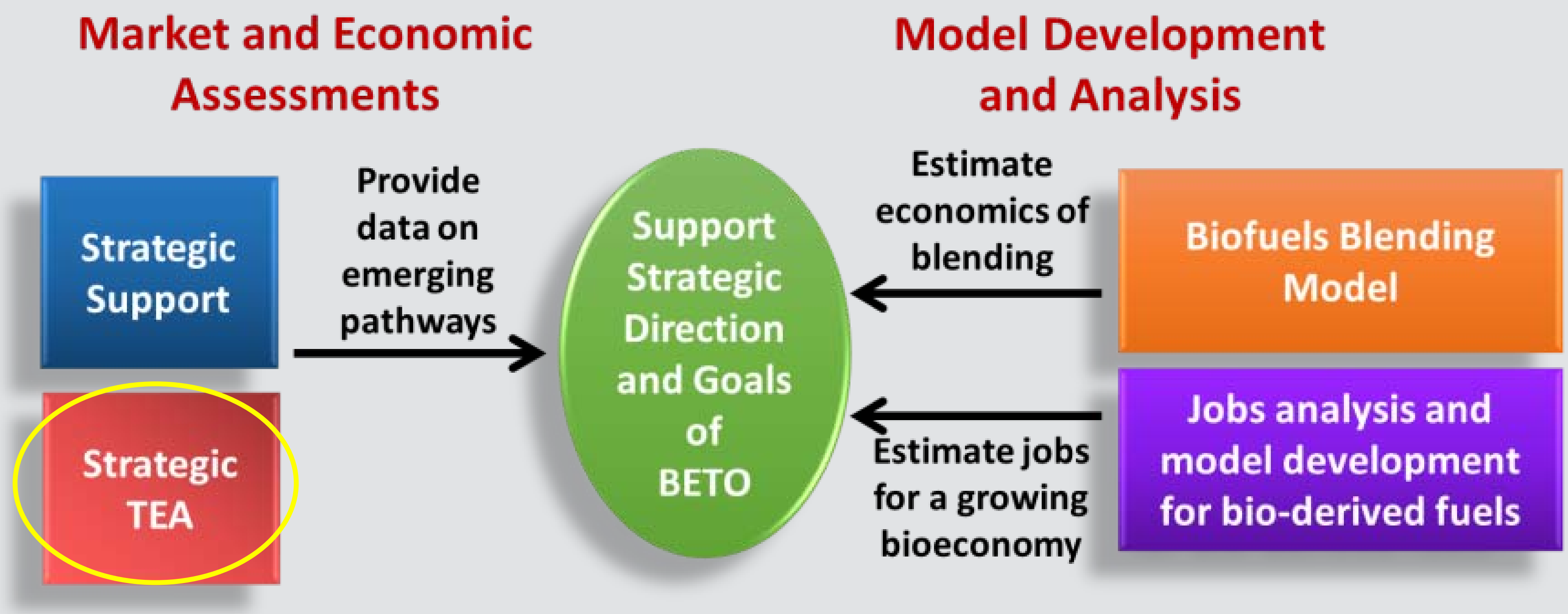
Strategic Support: Stakeholder Engagement Accomplishment

Supported the development and organization of the 2016 Alternative Aviation Fuel Workshop (with PNNL):

- Over 100 stakeholders took part in 2-day meeting.
- Organized location and logistics of meeting.
- Supported development of think tank questions presented during meeting.
- Helped to develop final workshop report/aviation biofuels white paper (to be published in 2017).



Strategic Techno-Economic Analysis

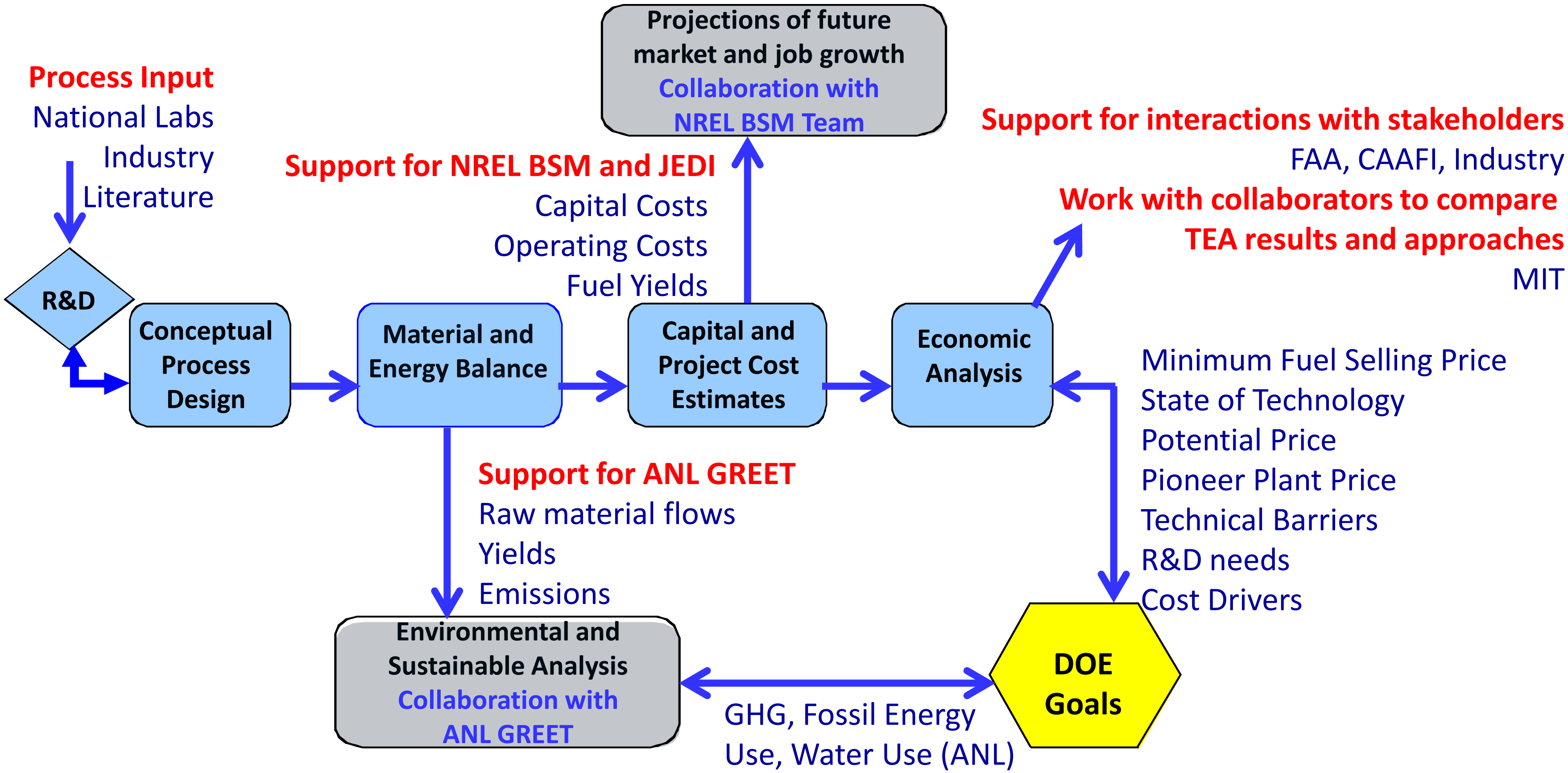


Strategic Goal: Perform techno-economic analyses to understand potential costs, outline barriers, and highlight R&D needs for emerging conversion strategies. Provide critical input to inform BETO supported models.

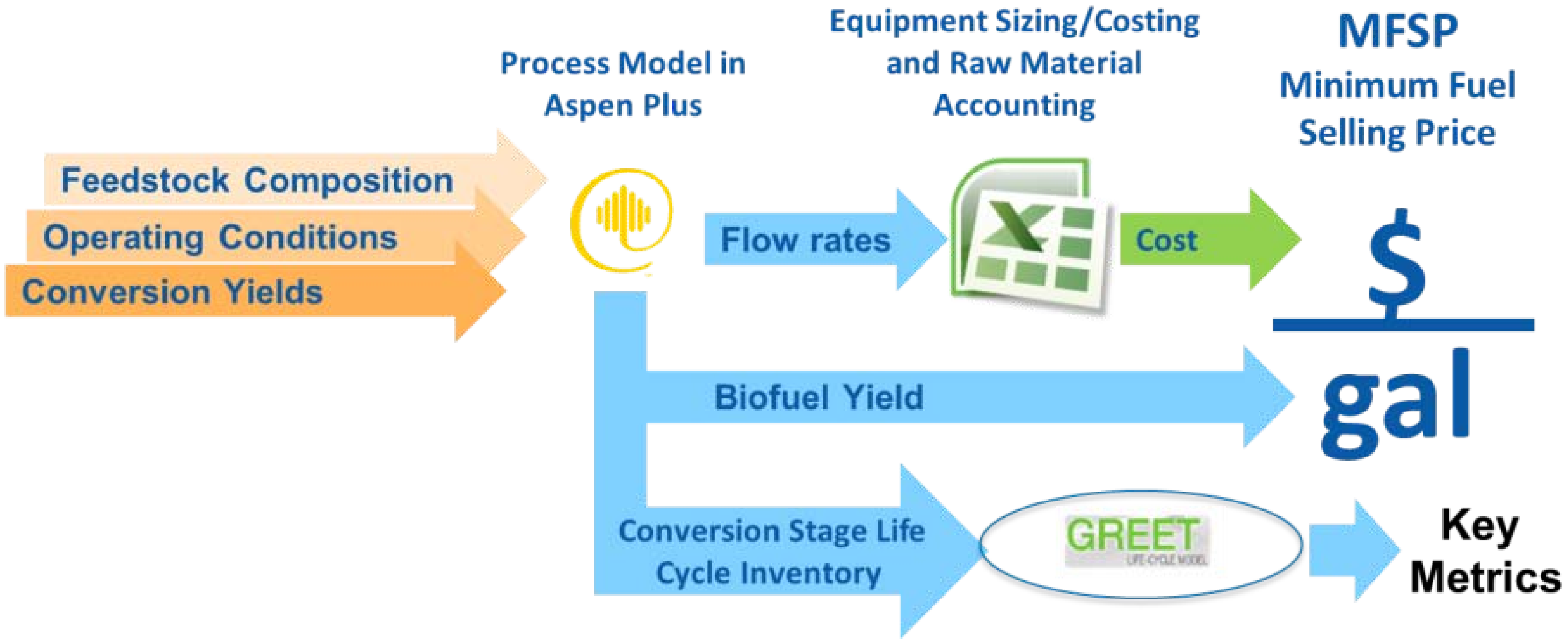
Strategic TEA: Overview

Provide comparative economic analyses for biomass conversion technologies.

- Identify R&D data needs for emerging pathways.
- Supply key process data for expansion of GREET LCA pathways, BSM analysis and JEDI tools.



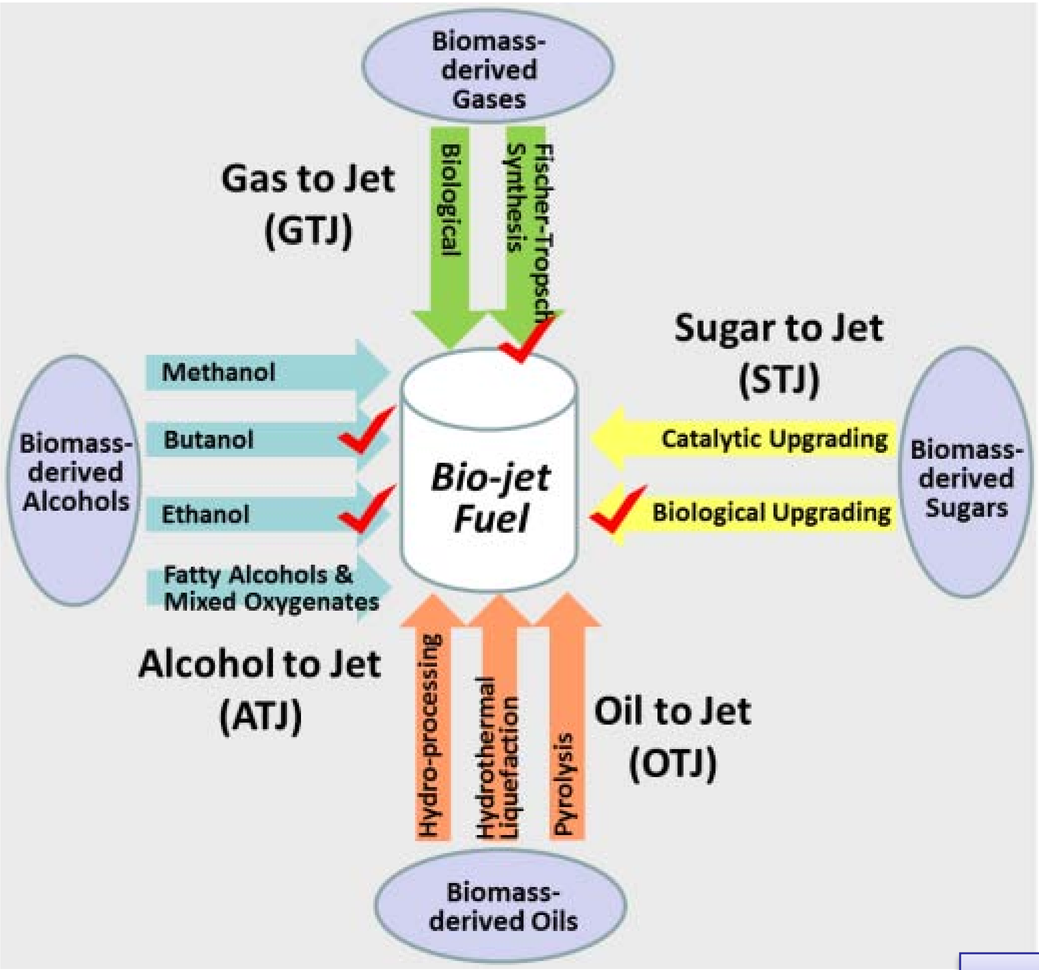
Strategic TEA: Methodology



- Modeling is rigorous and detailed with **transparent assumptions**.
- Baseline assumes n^{th}-plant equipment costs.
- Perform **pioneer plant** evaluations to understand the near-term cost of jet fuel production pathways.
- Quantify the underlying uncertainties through **sensitivity analysis**.
- Prioritize TEAs based on programmatic requests and data availability.

Strategic TEA: Progress

Established a library of TEA models for biomass-derived sustainable alternative jet fuel.




NREL

Review of Biojet Fuel Conversion Technologies

Wei-Cheng Wang, Ling Tao, Jennifer Markham, Yanan Zhang, Eric Tan, Liaw Batan, Ethan Warner, and Mary Biddy

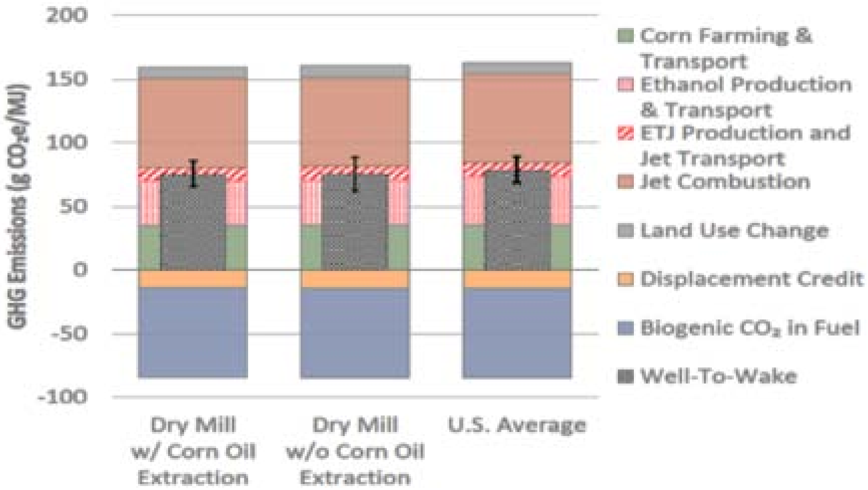
National Renewable Energy Laboratory

Technical Report

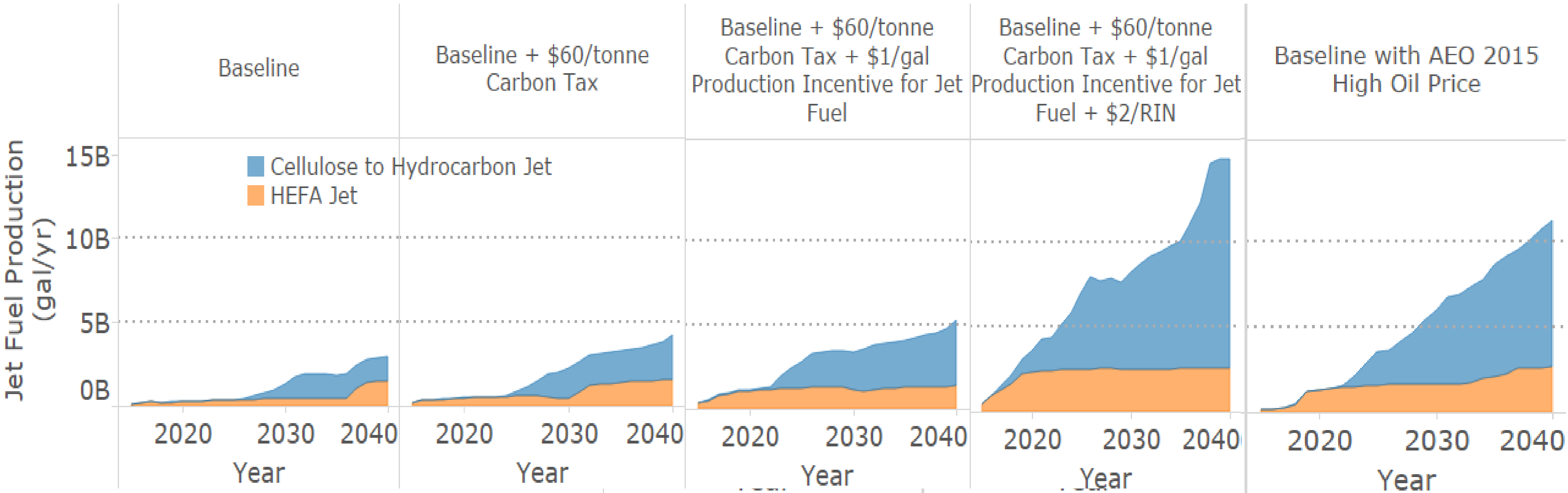
More information from: http://www.nrel.gov/docs/fy16osti/66291.pdf

Strategic TEA: Results

TEA provides critical input for a range of models to address BETO strategic goals.

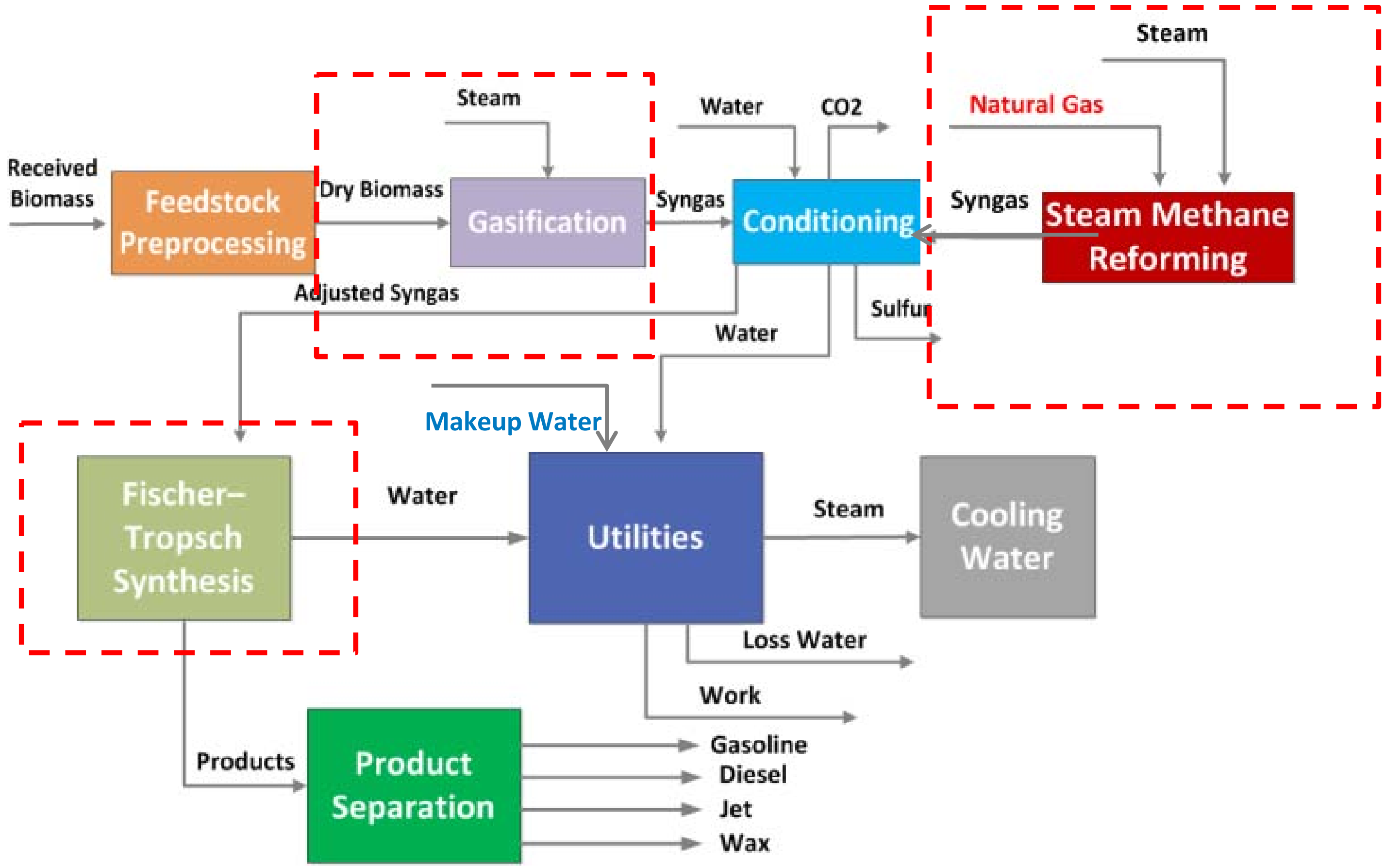


- Provided TEA data for GREET expansion (*Han et al. 2017*)
- Provided key input and data for NREL BSM study and Biojet White Paper: ***Assessment on displacement of 30% of aviation fuels with low carbon alternative bio-derived jet fuels by 2030***



Strategic TEA: Progress/Results

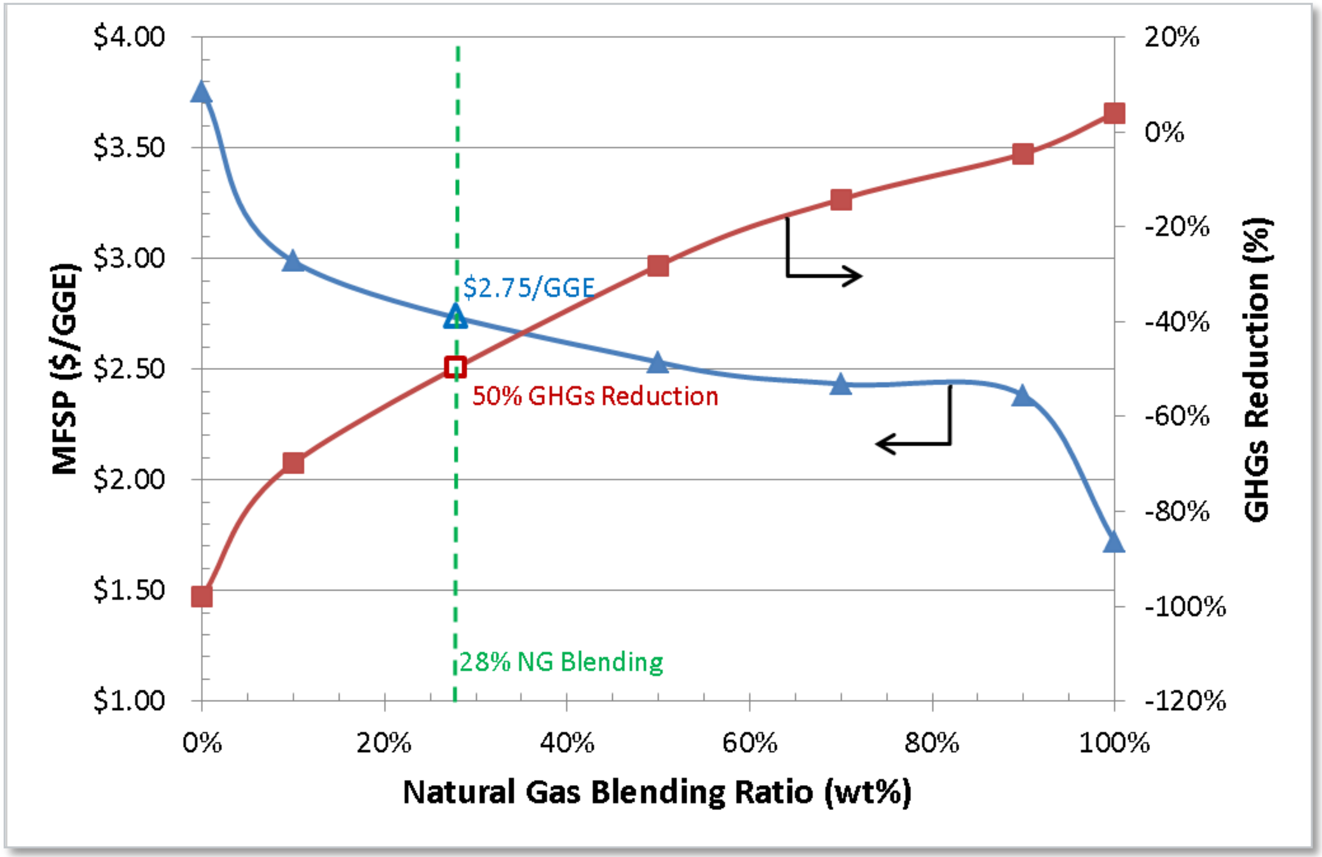
Opportunities to reduce cost by co-production with fossil feedstocks.



Natural gas and biomass-derived syngas are blended for Fischer-Tropsch synthesis to consider a range of conversion facility sizes.

Strategic TEA: Progress/Results

Understanding economic and sustainability tradeoffs could influence investment decisions.

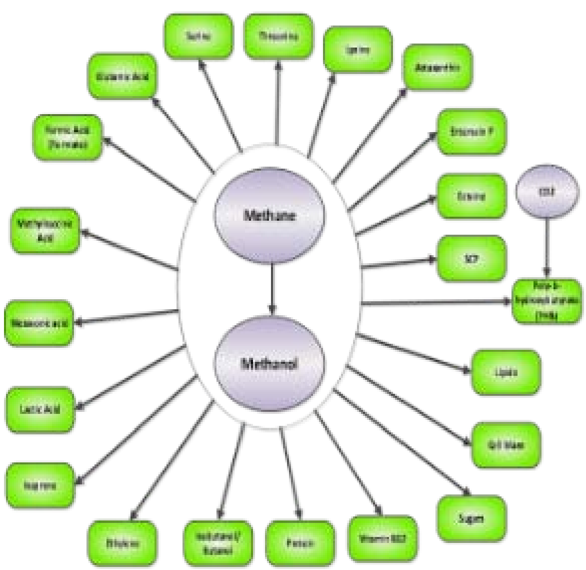


Co-processing natural gas enables the economic feasibility of converting biomass to the liquid fuel but at the expense of the environmental sustainability.

Strategic TEA: TEA Progress/Results

Evaluating opportunities and risk for conversion of waste streams to value-added co-products.

- Analysis of alternative waste stream feedstocks (methane and CO_2) to fuels and chemicals using biological, thermochemical, or hybrid concepts.
- Initial study focused on:
  - Availability of waste feedstocks considering impurity.
  - Potential pathways for upgrading with current SOT and R&D needs.

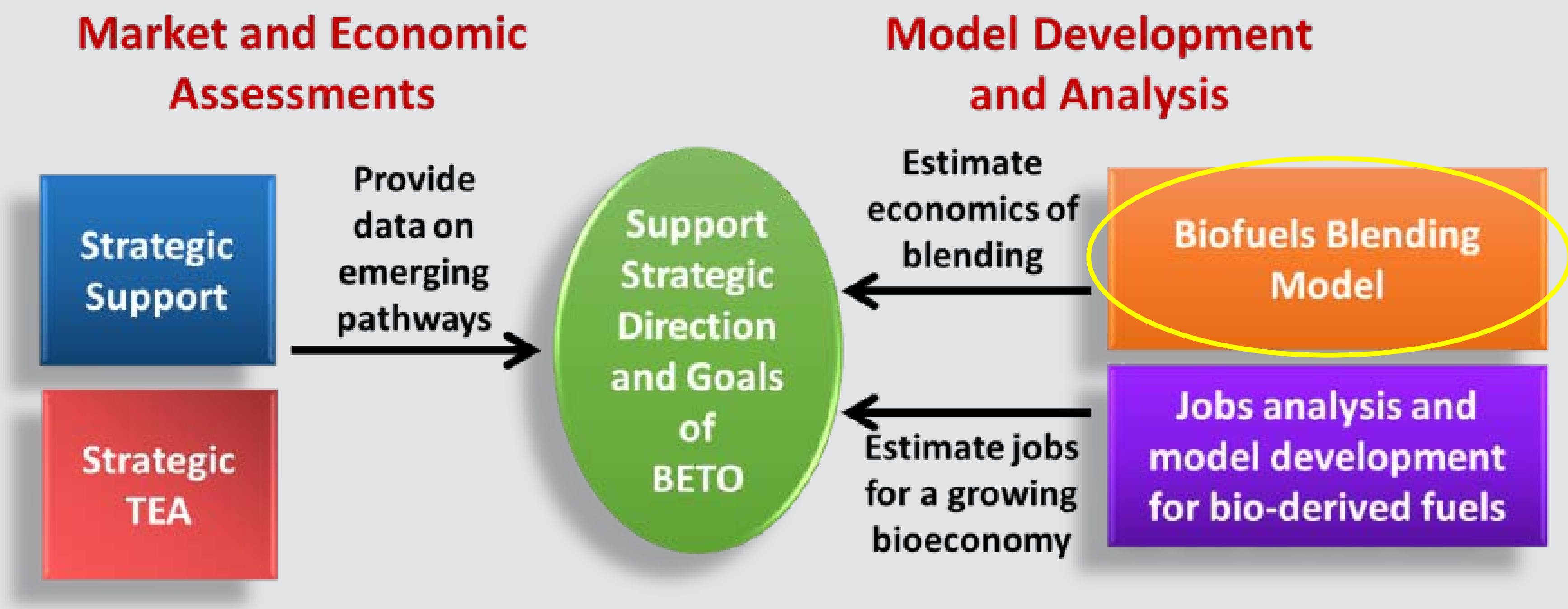


Biological Pathways

Thermochemical Pathways

CO_2 Valorization

Biofuels Blending Model



Strategic Goal: Understand how fuel quality will impact blending economics and evaluate potential for biofuels market growth.

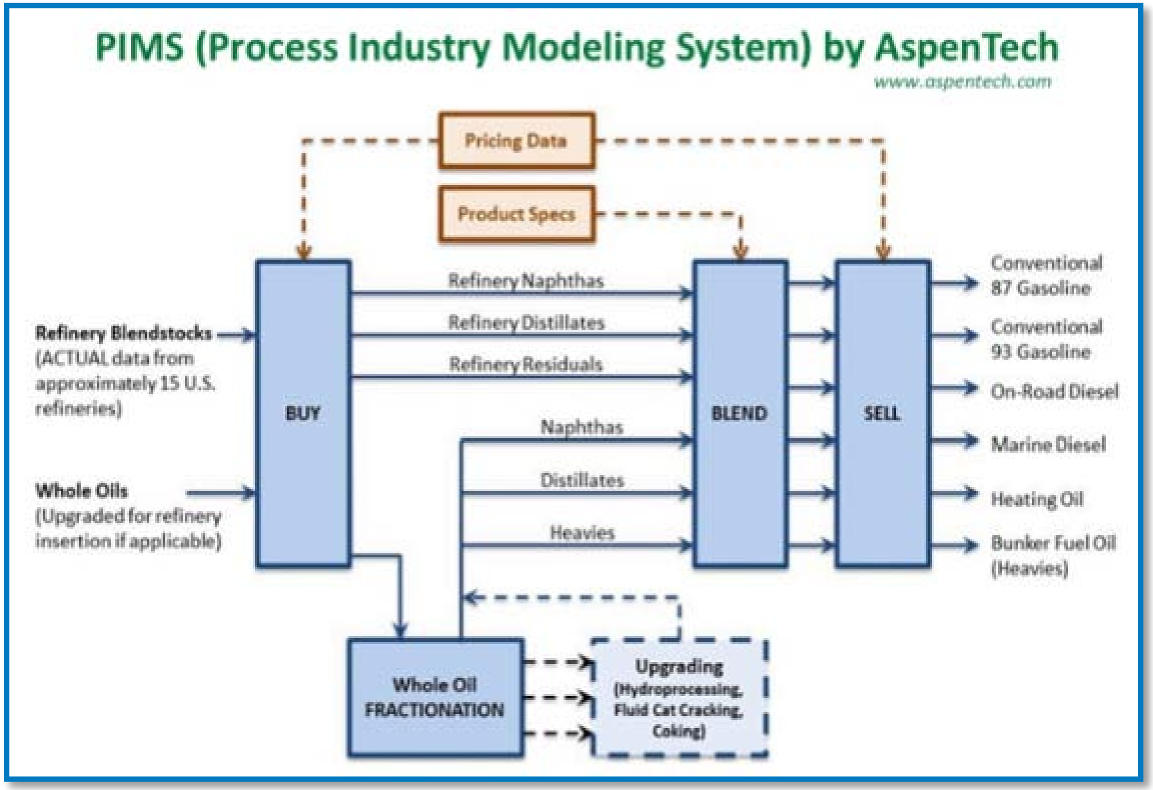
Biofuels blending model: Overview

Approach: Incorporate **actual process data** from 15 U.S. refineries.

- Varying complexity of refineries that span all 5 U.S. PADDs.
- Data includes overall capacity, unit capacity, and blend stream qualities.
- Bio-derived data from public sources and collaborative partners.

Model Capabilities:

- Estimate the **value of a bio-blendstock** to a refiner/fuel blender based on quality.
- Identify **blending limits and constraining properties.**
- Pursue analyses for all hydrocarbon pathways under development by BETO core platform R&D.
- Have key stakeholders continuously vet tools and results.

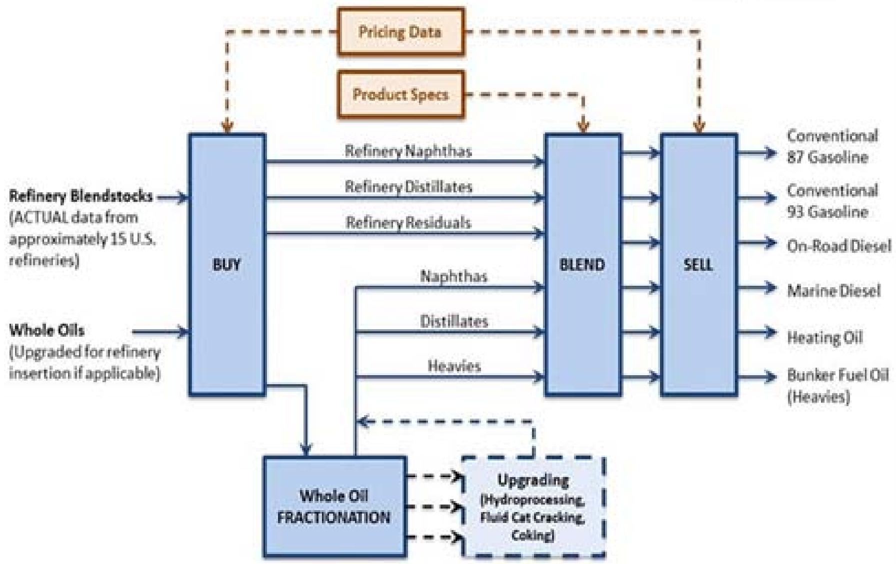


Biofuels blending model: Approach

Leveraging process simulation capabilities to validate biofuels blending model

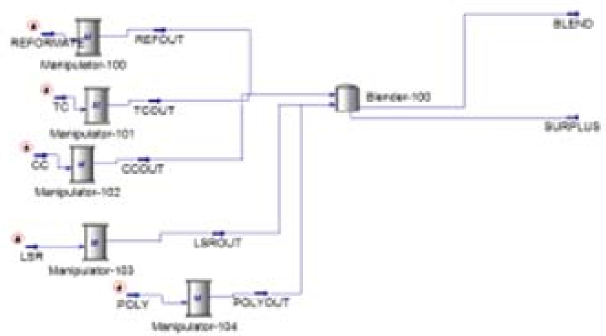
PIMS (Process Industry Modeling System) by AspenTech

www.aspentech.com



Validate process simulation predictions with published literature studies.

Blending Simulations in Aspen Plus and Aspen HYSYS



Improve ASPEN PIMS models based in comparison of results with process simulations

Compare ASPEN PIMS and Process Simulation results on finished fuels

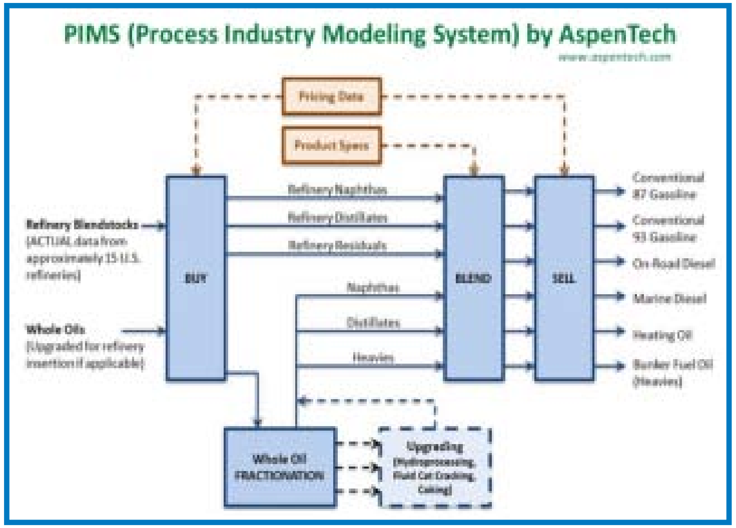
Additionally, worked with AspenTech and stakeholders for initial review.

Biofuels blending model: Accomplishments

Support Core Conversion / Algae Project R&D decisions:

- TEA calculates the cost of adding hydroisomerization process to the pathway.
- The Biofuels Blending Model is utilized to assess the increase in value and blendability.

Base Diesel Blendstock from Hydroprocessing → **Hydroisomerization of Lipid Diesel Blendstocks** → **Isomerized Diesel Blendstock with Improved Cold-Flow Properties**



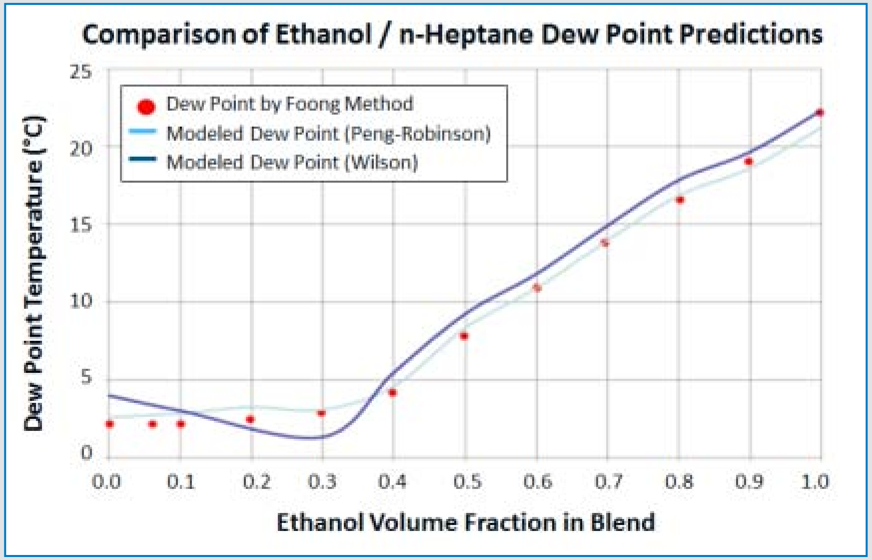
Key Results	Base Diesel	Isomerized Diesel
Blendstock Value	Base	Base + $0.25 / Gallon
Blended Volume	<10%	>90%

Biofuels blending model: Accomplishments

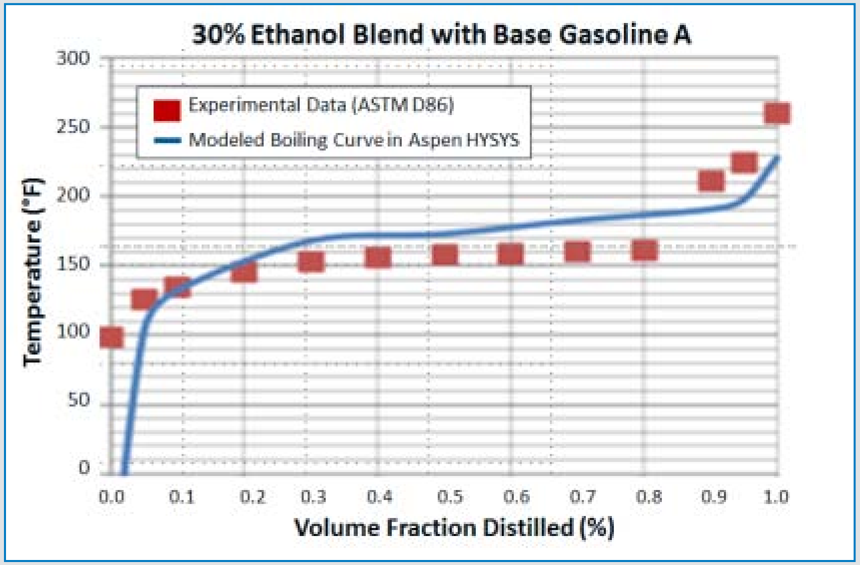
Support Core Conversion and Co-OPTIMA R&D efforts:

- Overall goal is to expand analysis capabilities beyond hydrocarbon blending (near-zero oxygen blendstocks and products) to benefit emerging fuel analysis and tool development.

Demonstrating capabilities for modeling emerging fuels in engines. Example shows dew point estimates using ASPEN PLUS to assess predictions relative to literature.



Exploring the impact of **high-ethanol contents (10%–40%)** on predictability of finished blending properties using the Biofuels Blending Model and process modeling tools.



Biofuels blending model: Accomplishments

Developing Public Tool for Blending of Bio-Derived Hydrocarbons

- NREL has completed beta versions of simplified gasoline and diesel blending models for review by BETO and other stakeholders. **Plan to publish in FY17.**

EXCEL Based Version of the Biofuels Blending Model - Gasoline Feedstocks

Simplified Instructions to User

1. Enter input values in yellow cells with blue text. User Input Cells
2. Once required inputs are entered, click the macro button to "Run Blending Calculations".
3. Review the results of the blending calculations.
4. Review the results of the blending analysis for each refinery in columns J to N

Run Blending Calculations

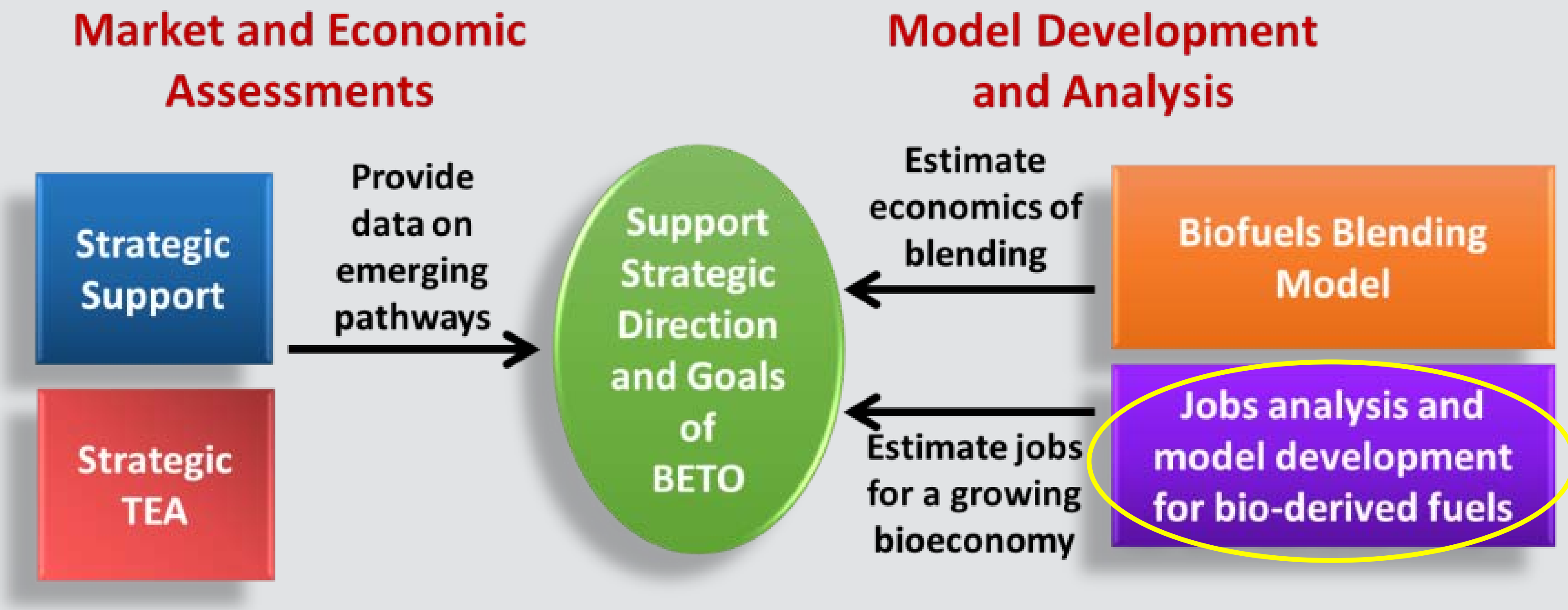
Enter crude oil price basis for blending calculations 110.00 $ / Barrel of WTI crude
(pricing based on West Texas Intermediate benchmark crude oil price)

Select the gasoline grade specifications (R87 or R93) R87
If preferred, select default properties for the "User-Defined Blendstock". ☑ Restore defaults

Enter the properties for the fuel blendstock to be assessed by the blending model

Blending Property	User-Defined Blendstock	R87 Specification Minimum	R87 Specification Maximum
Specific Gravity	0.80		
Reid Vapor Pressure, RVP (PSI)	8.80		8.80
Motor Octane Number (MON)	82.00	82.0	
Research Octane Number (RON)	92.00		
Anti-Knock Index, AKI (R+M/2)	87.00	87.0	
10 Vol.% Distilled Temperature (°F)	158.00		158
50 Vol.% Distilled Temperature (°F)	170.00	170	250
90 Vol.% Distilled Temperature (°F)	374.00		374
EP Vol.% Distilled Temperature (°F)	430.00		430
Volume Distilled at 200°F (%)	30.00	30.0	70.0
Volume Distilled at 300 °F (%)	25.00	70.0	100.0
Benzene (Mole %)	1.30		1.3
Aromatics (Mole %)	50.00		50.0
Olefins (Mole %)	25.00		25.0
Existing Gum (mg / 100 mL)	0.10		4.0
Oxygen (Weight %)	0.10		1.0
Mercaptan Sulfur (wppm)	20.00		20.0
Sulfur (wppm)	80.00		80.0
Total Acid Number, TAN (mg KOH / g)	0.01		0.01

Jobs analysis and model development for bio-derived fuels



Strategic Goal: Understand the potential for job creation and economic benefits in the emerging bio-economy.

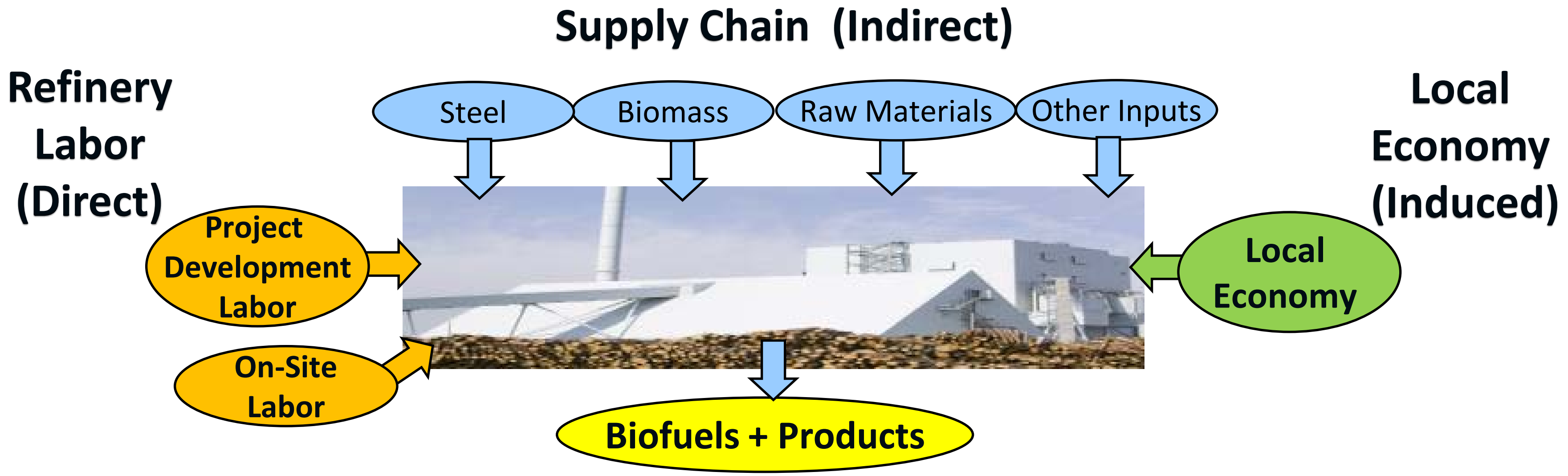
Jobs analysis for bio-derived fuels: Methodology

Development of a suite of Jobs and Economic Development Impact (JEDI) models.

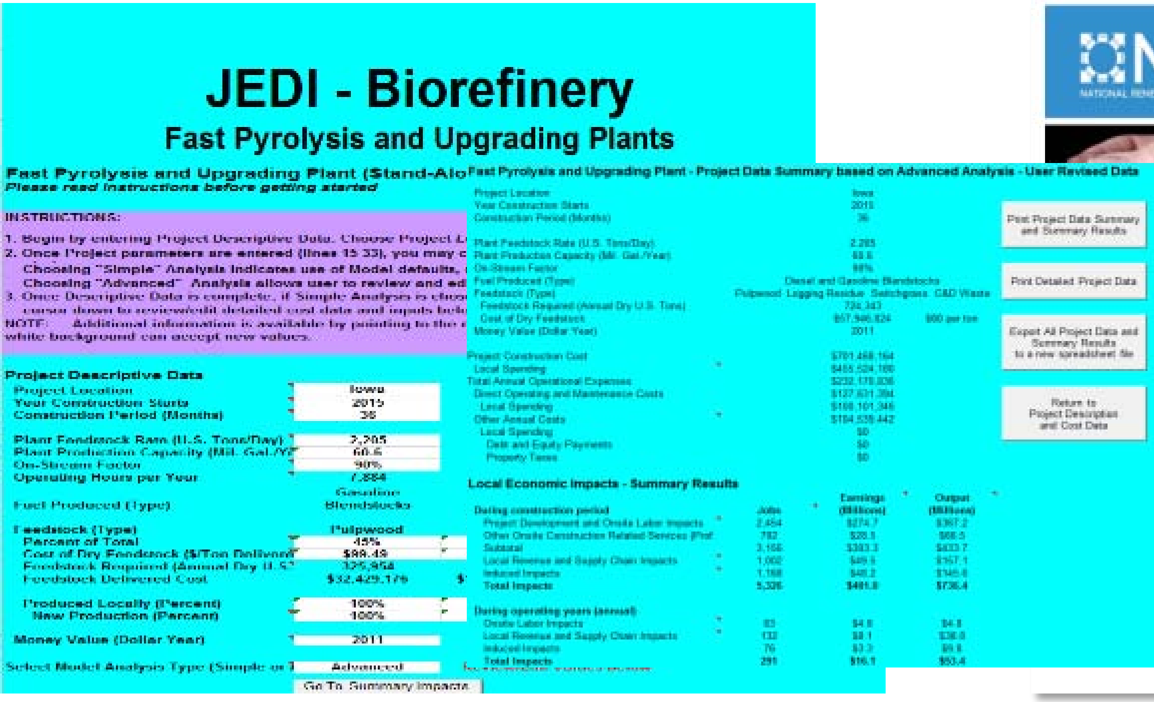
- Publicly available tools found at www.nrel.gov/analysis/jedi/

The model represents the entire economy as a system of linkages between subsectors of the economy.

- The linkages are represented by multipliers (derived from IMPLAN, 2014) that determine the impact of construction and operation of a new project on employment, earnings, and output in other sectors
- Uses input-output analysis to capture impacts throughout the supply chain.



Jobs analysis for bio-derived fuels: Overview



- Publicly available, user-friendly, Excel-based models.
- Each JEDI model has a **user guide** that summarizes input requirements, interpretation of results, and limitations of the tool.
- Recently developed JEDI tools are based on hydrocarbon design reports and the latest design of biomass logistics systems.
- Models are reviewed and vetted by PIs (INL, NREL, PNNL) prior to release.
- Validated model with cellulosic ethanol industry estimates (FY15).
- **Validation is continuous** as job estimates become available.

Jobs analysis for bio-derived fuels: Accomplishments

Overview:

- Identify key factors that contribute to job growth resulting from biorefinery construction and operation
- Gain a better understanding of which sectors will benefit from new biofuel production.

Modeling and Analysis

Biofpr Biofuels Bioproducts & Biorefining

Estimation of economic impacts of cellulosic biofuel production: a comparative analysis of three biofuel pathways

Yimin Zhang, National Renewable Energy Laboratory, Golden, CO, USA
Marshall Goldberg, MRG & Associates, Nevada City, CA, USA
Eric Tan, National Renewable Energy Laboratory, Golden, CO, USA
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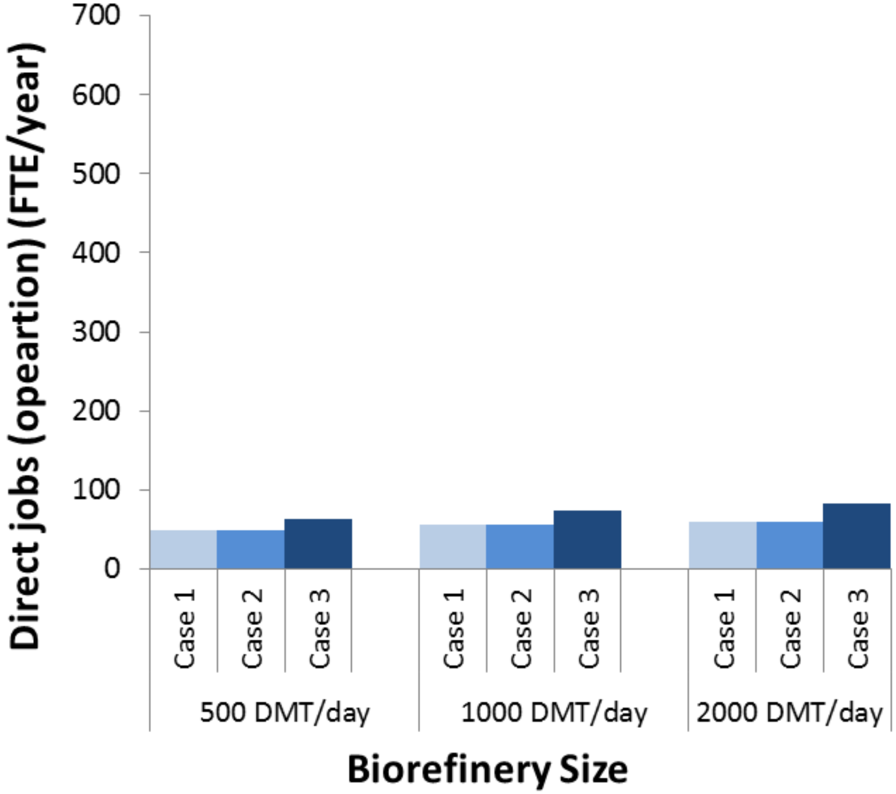
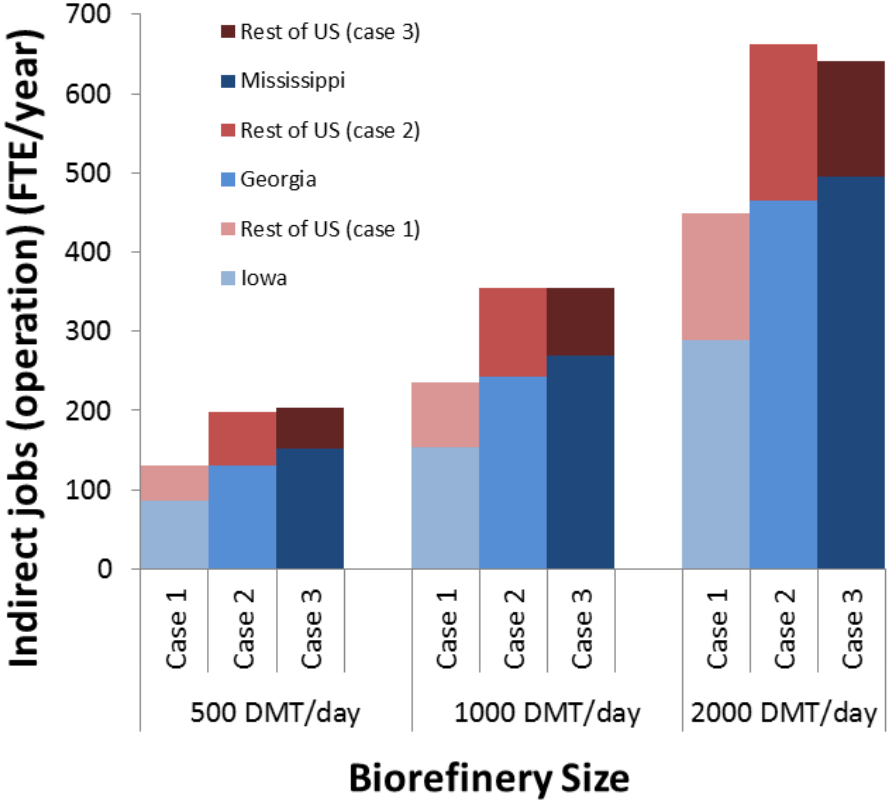
DOI: 10.1002/bbb.1637; *Biofuels. Bioprod. Bioref* 10:281–298 (2016)

Jobs analysis for bio-derived fuels: Accomplishments

Understanding job development – direct versus indirect jobs

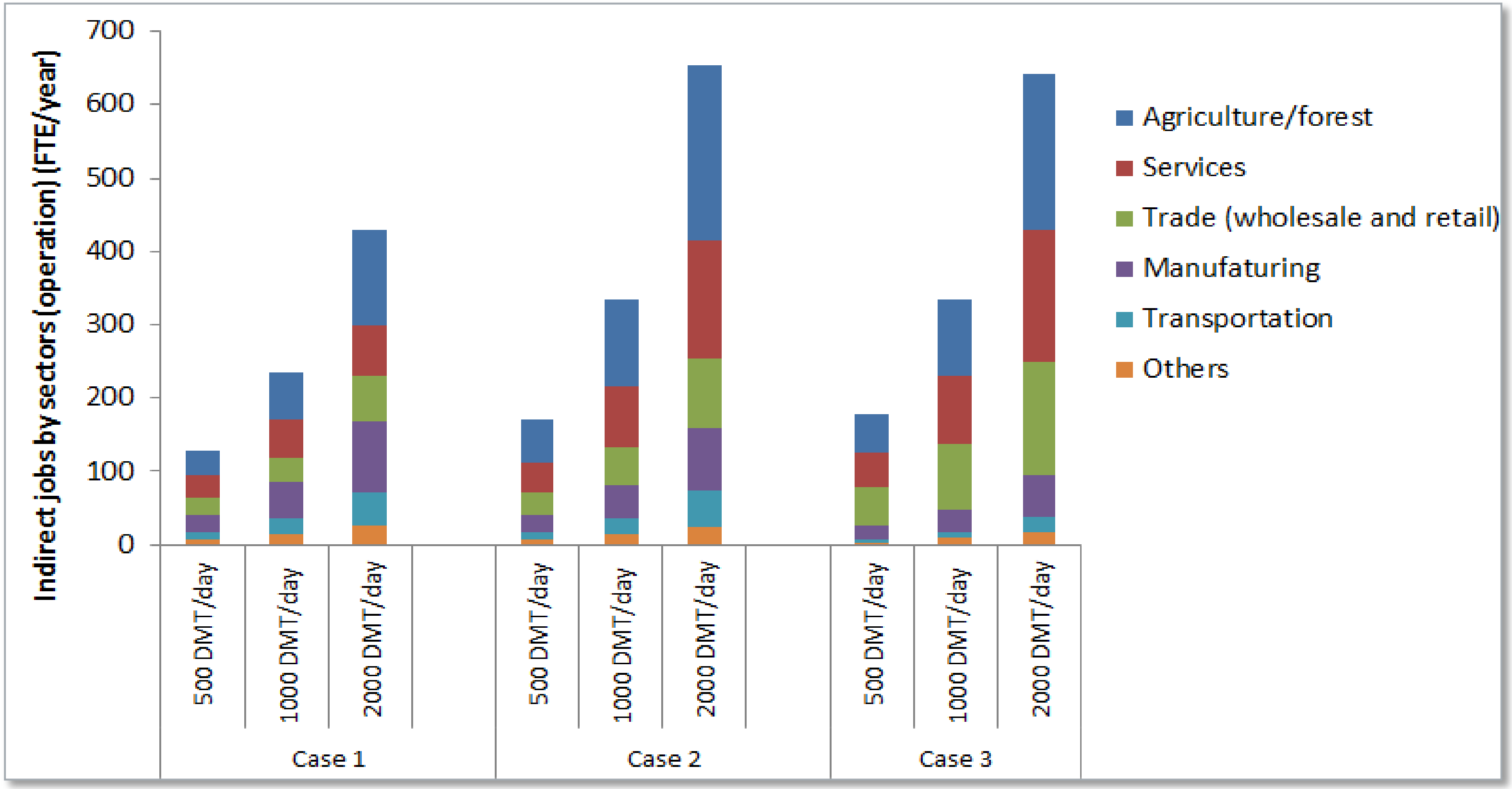




Case 1: cellulosic ethanol biorefinery in Iowa
Case 2: renewable diesel biorefinery in Georgia
Case 3: renewable diesel and gasoline biorefinery in Mississippi
DMT/day = dry metric tons per day, FTE = full-time equivalent

Jobs analysis for bio-derived fuels: Accomplishments

- **Understanding which sectors benefit from biorefinery operation**



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Relevance

Outreach to bioenergy community to support impacts on the bioeconomy.

Engage and communicate results of analyses to stakeholders:

- **JEDI models** (biofuels, biopower, and petroleum fuels) **are widely used** and are publicly available (via the NREL website and the Bioenergy KDF) with **over 1,500 downloads** in the last 2 years.
- **Strategic TEA** on jet fuel pathways are utilized to **expand** the conversion processes in **GREET** and **support collaborative relationships** with CAAFI, DOD, EPA, and MIT.
- Strategic support efforts have maintained external collaborations with **DOE VTO, U.S. DRIVE, and USCAR** teams to provide cost numbers and key biofuel production metrics.
- **Published eight peer-reviewed papers and technical publications** with six more drafts in preparation for peer-reviewed journals; gave more than 10 presentations.

Relevance

Project directly contributes to BETO goals per 2016 Multi-Year Program Plan:

BETO Goal	Project Contributions
Develop models and methodologies to advance the understanding of the impacts and socio-economic benefits in the United States due to the growth of the bioeconomy.	**JEDI tools** help to understand bioenergy's **impact on creating and supporting domestic jobs.**
Provide analyses that "help the Office focus its technology development priorities and identify key drivers and hurdles for industry growth".	**Chemicals market report** focused on understanding **potential commercial success**, market **uncertainties**, and financial backing.
Provide an analytical basis for BETO planning and assessment of progress.	**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.
Apply these models to conduct systems-level analyses that support decision-making at different levels (e.g., policy, industry, and bioenergy projects).	The **biofuels blending model** estimates the **value of a bio-blendstocks** to a petroleum refiner.

Relevance

Project directly contributes to BETO goals per 2016 Strategic Plan:

Strategy: Conduct analysis to inform R&D and programmatic priorities

Substrategy:
Provide an analytical framework for bioproducts research

Chemicals market report discusses the market pull and value proposition that are enabling the scale-up of chemicals from biomass.

Substrategy:
Better understand the benefits of bioenergy to rural communities

On-going studies for **JEDI** to consider the effect of income distribution due to the scaling up of the biofuels industry.

Substrategy:
Analyze the environmental and social sustainability of bioenergy

Analysis of a range of metrics including jobs development, technical and economic evaluations, and market assessments.

Relevance

Project directly contributes to BETO goals per 2016 Strategic Plan:

Strategy: Reduce cost and improve performance

Substrategy: Develop robust technologies to convert waste streams to fuels and chemicals

On-going work in **Strategic TEA** to evaluate potential for the use of waste streams to a range of chemicals and fuels.

Substrategy: Reduce capital costs through process intensification and modularization

On-going work in **Strategic Support** to evaluate scalability and modularity of hydrocarbon pathways.

Substrategy: Develop bioproducts that enable biofuels

Chemicals market report focused on how lessons learned from the production of chemicals can be leveraged to accelerate production of biofuels.

Future Work

Strategic support

Aim 1: Determine whether the hydrocarbon design cases are representative of the near-term business case for each pathway.

- Perform comparative study of biofuel hydrocarbon pathways from a venture capitalist perspective (FY17).

Aim 2: Given the commodity nature of the chemicals industry, understand if co-products always improve the economic viability of a biorefinery.

- Quantify the impact of co-product cost assumptions for the economic viability through case studies on oil-price-dependent scenarios (FY18).
- Develop alternative strategies to estimate chemical coproduct prices.

Strategic TEA

Aim 1: Understand the potential costs and R&D needs for the production of fuels and chemicals from waste streams (FY17/18).

Aim 2: Provide tools to the stakeholder community for developing conceptual process designs.

- Develop tools that support both economic and sustainability considerations for conceptual process designs (via engagement with EPA) (FY17/FY18).

Future Work

Biofuels blending model

Aim 1: Examine the impacts to petroleum refinery economics due to biofuels blending stream displacement (in support of the FY18 A&S platform milestone) (FY17 go/no-go/FY18).

Aim 2: Understand impact of refinery integration in the blending value chain economics (FY17/FY18).

Jobs analysis for bio-derived fuels

Aim 1: In-depth analysis on the benefits of bioenergy to rural communities.

- Examine case studies with JEDI to consider the effect of income distribution (*e.g.*, rural vs. urban households) due to the scaling up of a biofuel industry (FY17).

Aim 2: Incorporate strategies for feedstock logistics.

Future Work

- **Support/collaborate with other BETO projects:**
  - Leverage existing tools for **Co-OPTIMA** evaluations—biofuels blending model (BLEND) and JEDI
  - Utilize biofuels blending model to further analyze **conversion platform** hydrocarbon pathways
  - Bioproduct market evaluation supports initial studies in **CEMAC, Agile Biorefinery project, and strategic analysis Bioproduct Transition System Dynamics Model**
  - Work with **GREET team** to consistently evaluate both economics and sustainability the impact of functional deviates in a biorefinery.
- **Planned peer reviewed journal articles and public milestone reports by the end of FY17 / early FY18.**
  - Journal article on blending model methodologies and capabilities and release public version of tool.
- **Continue to vet models and analyses through stakeholder engagement and collaboration.**

Summary

- **Develop tools and perform analyses to address key questions in support of the BETO strategic direction.**
- **Progress over past 2 years includes:**
  - Market report analysis and publication on bioproducts to enable biofuels.
  - Development of TEAs for understanding jet fuel production.
  - Support for conversion R&D strategies to understand fuel quality valuation.
  - JEDI case studies to identify key factors that contribute to job growth.
- **Future deliverables include:**
  - Case studies with JEDI to consider the effect on income distribution.
  - Comparison of biofuel hydrocarbon pathways for near-term scale-up.
  - Development of TEAs for understanding waste stream upgrading.
  - Assessment of refinery economics due to biofuels blending stream displacement.
- **Provide credible results to assist decision making in bioenergy investment by applying appropriate analyses and models.**
  - Document sources of data, understand uncertainties, vet analysis approach and results, and quantify impact of uncertainties.

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National Laboratory Partners (PNNL, INL, ORNL)

Industrial and Academic Partners

Additional Slides

Responses to reviewer feedback

The JEDI model offers an opportunity for stakeholders to estimate the employment impacts of a given bioenergy system. The tool is limited in its ability to evaluate indirect impacts or endogenous response, but the direct impacts offered are still of value and clearly in demand given the number of public downloads the tool has had in recent years.

- The JEDI models built on economic input-output approach, apply historical relationships between demand (i.e., specific expenditures within a given industrial sector) and the resulting economic activity to estimate how new expenditures will affect economic development metrics including jobs. The accuracy of these inter-industry relationships (i.e., input-output coefficients or multipliers) is dependent on parameters including the date of the multipliers reflecting the relationships, how well the defined industrial sectors reflect the particular inputs and outputs of the technology project being studied, and how well the multipliers reflect the geography of where the technology project is located. The JEDI models do include supply chain related indirect impacts. However, like all input-output models, JEDI models have limitations. JEDI models are static models, which do not take into account some endogenous variables such as how changes in demand for certain inputs might affect the price of the inputs. We do update the multipliers every two years for all JEDI models to ensure we use the best information to reflect the most up-to-date inter industry relationships.

Responses to reviewer feedback

The refinery and blending optimization work is also important, but its value is hard to judge based on what has been presented thus far.

- Work that has been developed over the past several years has focused on utilizing these tools to consider cost from a refiner's perspective and value the fuel streams being considered based on quality and properties relative to petroleum equivalent streams. This talk outlines recent work to demonstrate the impact that this analysis has had on conversion platform and algal platform efforts. Further, we outlined on-going efforts to utilize this tool in the Co-Optima project.

Abbreviations and Acronyms

A&S: Analysis and Sustainability
ANL: Argonne National Laboratory
AOP: Annual operating plan
BETO: Bioenergy Technologies Office
CAAFI: Commercial Aviation Alternative Fuels Initiative
COP: ConocoPhillips
CU: University of Colorado
DOD: Department of Defense
EPA: US Environmental Protection Agency
GGE: Gasoline gallon equivalent
JEDI: Jobs and Economic Development Impact
INL: Idaho National Laboratory
ISU: Iowa State University
LCA: Life-cycle analysis
MFSP: Minimum fuel selling price
MYPP: Multi-year program plan
NREL: National Renewable Energy Laboratory
ORNL: Oakridge National Laboratory
PNNL: Pacific Northwest National Laboratory
VTO: Vehicles Technology Office

Publications

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- U. Lee, J. Han, M. Urgun Demirtas, M. Wang and L. Tao, "Lifecycle analysis of renewable natural gas and hydrocarbon fuels from wastewater treatment plants' sludge", Argonne National Laboratory (ANL), DOI: 10.2172/1327830, ANL/ESD--16/19-130493, 2016.
- J. N. Markham, L. Tao, R. Davis, N. Voulis, L. T. Angenent, J. Ungerer and J. Yu, "Techno-economic analysis of a conceptual biofuel production process from bioethylene produced by photosynthetic recombinant cyanobacteria," Green Chemistry, DOI: 10.1039/C6GC01083K, 2016
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- Zhang, Y., Goldberg, M., Tan, E. and Meyer, P.A., 2016. Estimation of economic impacts of cellulosic biofuel production: a comparative analysis of three biofuel pathways. Biofuels, Bioproducts and Biorefining.

Presentations

- M. Biddy "Chemicals from biomass: A market assessment of bioproducts with near-term potential" Bioenergy 2016, Washington DC June 2016.
- M. J. Biddy, "Techno-economic motivations for coproduct manufacturing that enable hydrocarbon fuel production from lignocellulosic biomass." Invited presentation, 2016 SIMB Annual Meeting and Exhibition, New Orleans, LA, July 2016
- M. J. Biddy and L. Tao (invited talk) "Techno-economic Approach towards Alternative Jet Fuel Conversion Pathways" Alternative Aviation Fuel Workshop, Macon, GA, September 14-15, 2016.
- A. H. Sahir, M. Talmadge, M. Biddy. "Finished Fuel Blending Models for Assessing Integration of Biomass-Derived Products with Petroleum Refinery Products", Oral Presentation at 2016 AIChE Annual Fall Meeting, San Francisco, CA, November 13–18, 2016.
- A. H. Sahir, M. Talmadge and M. Biddy. "Finished fuel blending models for assessing integration of biomass-derived products with petroleum refinery products", Oral Presentation at TCS 2016, Chapel Hill, NC, November 1-4, 2016.
- M. Talmadge, L. Batan, P. Lamers, D. Hartley, M. Biddy, L. Tao, E. Tan. "Optimizing Biorefinery Design and Operations via Linear Programming Models", Poster Presentation at TCS 2016, Chapel Hill, NC, November 1-4, 2016.
- Y. Zhang, "Estimated Economic Impacts of Biofuel Production - a Comparative Analysis of Three Cellulosic Biofuel Pathways" 2016 AIChE Annual Fall Meeting, paper 726d, 2016, San Franscico, CA, November 13–18, 2016.
- E. C. D. Tan "Overview on Evaluation of Sustainable Biofuel Conversion Processes" 2016 AIChE Annual Fall Meeting, paper 619m, 2016, San Franscico, CA, November 13–18, 2016.
- A. H. Sahir, Y. Zhang, L. Tao, "Co-conversion of natural gas and biomass to transportation fuels: A techno-economic and a process engineering perspective", Energy Frontiers International-Gas Flare Monetization Forum, Denver, May, 2016.
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