NREL
Transforming ENERGY

DOE Bioenergy Technologies Office (BETO) 2023 Project Peer Review

Environmentally-extended Multi-regional Projection of Lifecycle and Occupational energyY futures - EMPLOY (WBS# 4.2.1.31)

April 3rd, 2023
Data, Modeling & Analysis

Dr. Andre Fernandes Tomon Avelino
National Renewable Energy Laboratory

This presentation includes unpublished preliminary data and analysis that is subject to change not for distribution, quotation, or citation

Project Overview

Goal

Develop a coherent methodology and consistent model framework to quantify the net effects of an expanding US bioeconomy across economic, environmental and workforce dimensions.

Inform BETO's strategic decision making.

Outcome

Economy-wide assessment of environmental and socio-economic **effects** of individual BETO pathways or **portfolios** thereof **at industry-scale** and across **future decarbonization scenarios.**

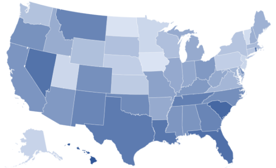
Scientific input to other **government agencies**, **industry**, and **multilateral activities** that assess bioeconomy effects.

Relevance

BETO

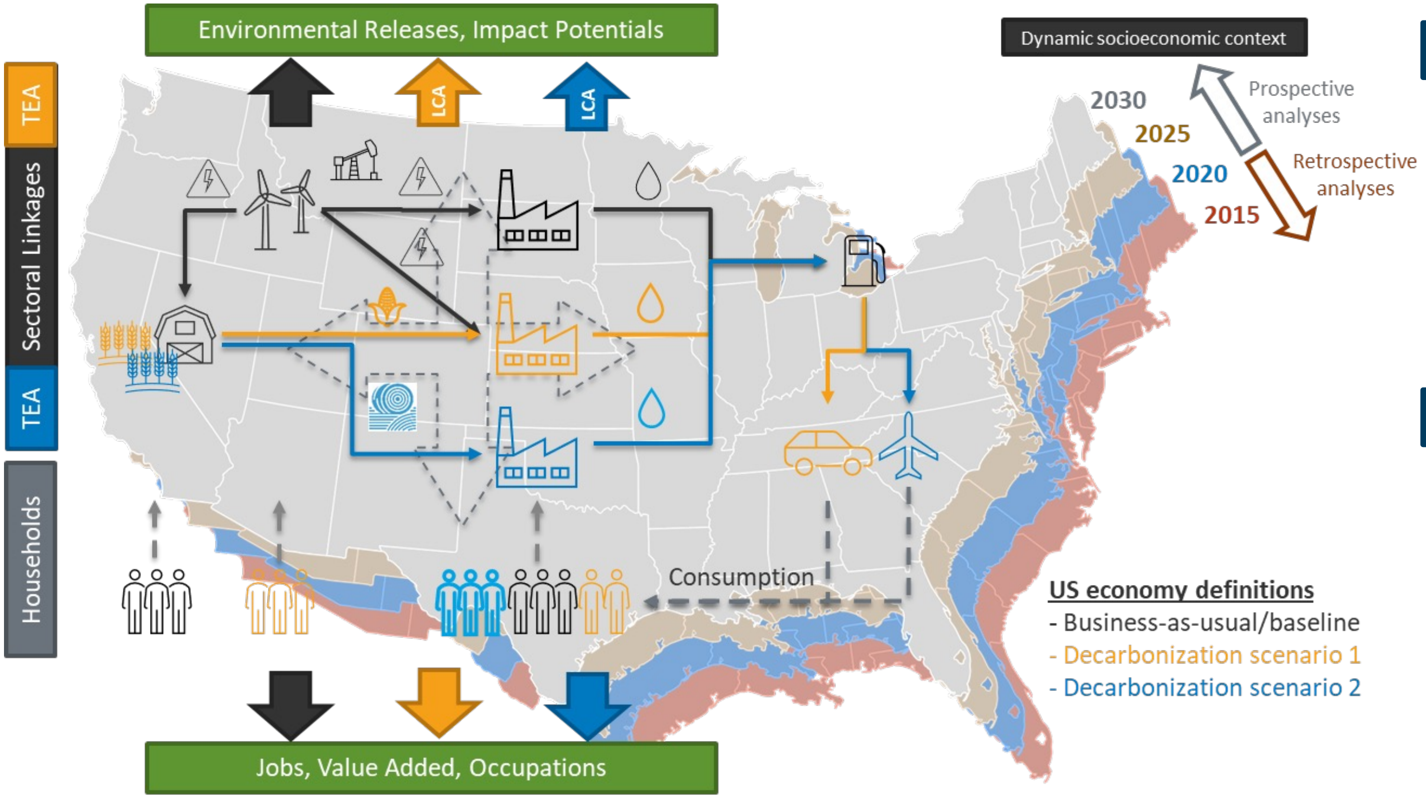
Complementary

Federal + State levels



Working Group

1. Approach: Environmentally-Extended Input-Output Model



Framework

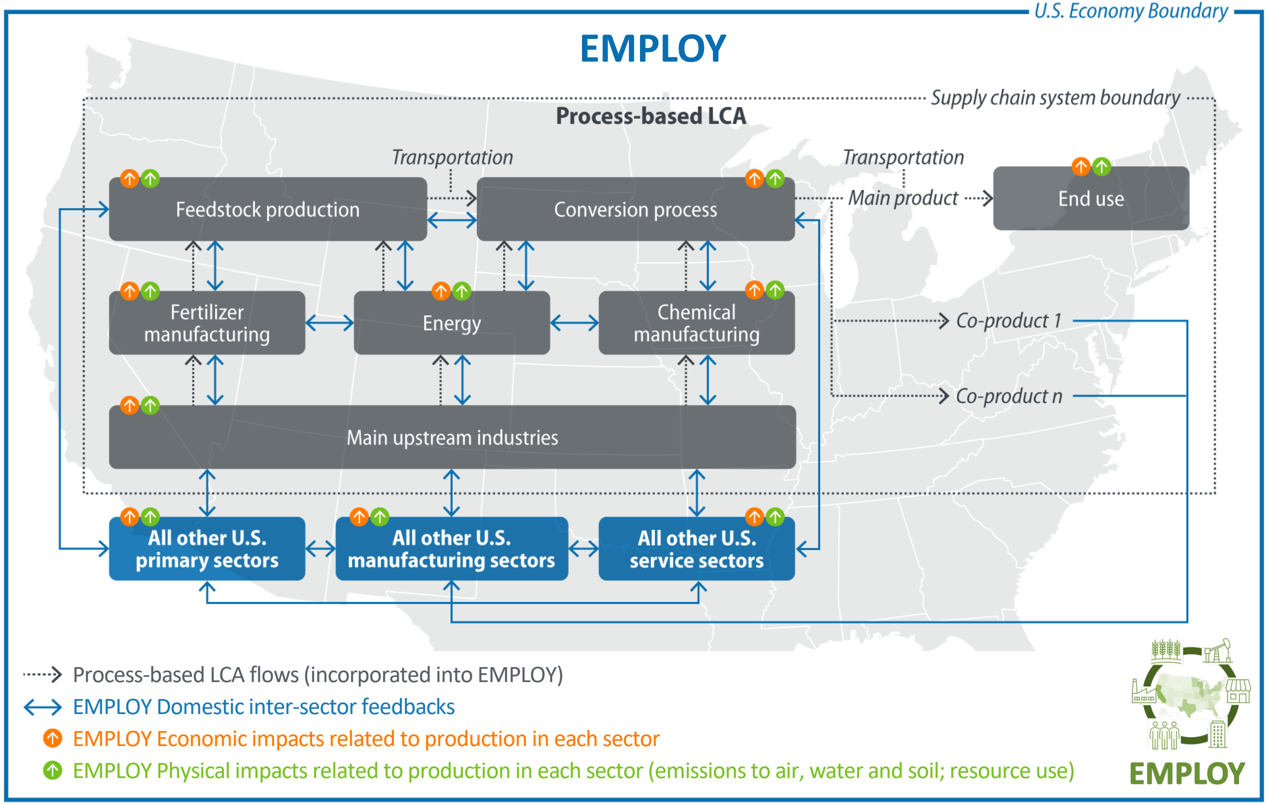
- ✓ Economy-wide
- ✓ Cross-sectoral
- ✓ Multi-dimensional
- ✓ Consistent

Analyses

- ➢ Feedback & indirect effects
- ➢ Net system effects
- ➢ Supply-chain impacts
- ➢ Industry or portfolio analysis

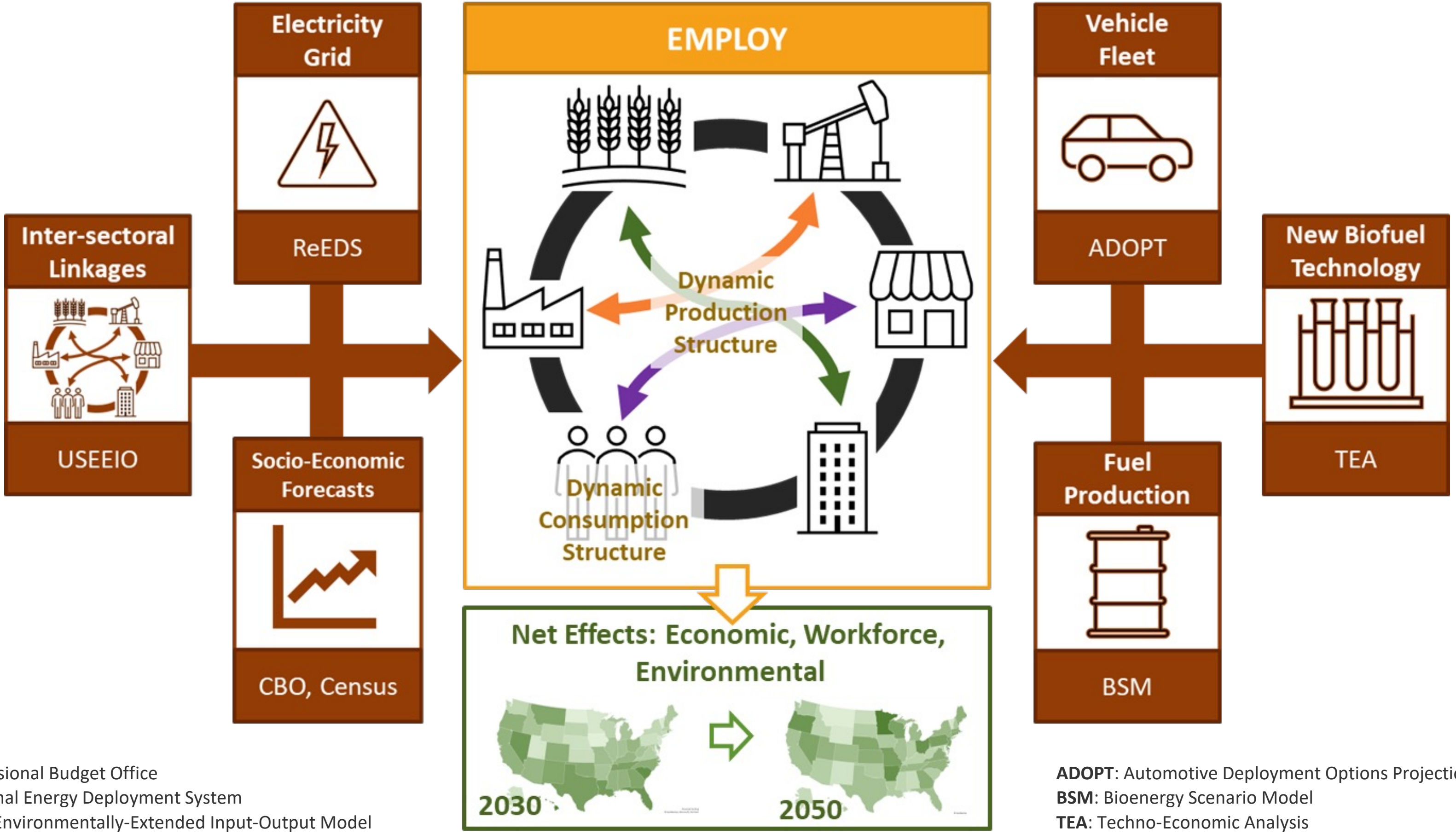
LCA: Life Cycle Analysis (data) | **TEA**: Techno-Economic Analysis (data)

1. Approach: Comprehensive and Complementary



Value Added (GDP)	US$
Jobs (Employment)	persons
Occupations (Categories)	persons
RESOURCES	
Freshwater Withdrawals	m^3
Land Occupation	m^2
Energy Use	MJ
Mineral Use	kg
ENVIRONMENTAL	
Global Warming	kg CO_2 eq
Smog Formation	kg O_3 eq
Eutrophication	kg N eq
Acidification	kg SO_2 eq
Freshwater Ecotoxicity	CTU e
Human Toxicity	CTU h
Respiratory Effects	kg $PM_{2.5}$ eq
Ozone Depletion	kg CFC-11 eq

1. Approach: Future Scenarios Modeling



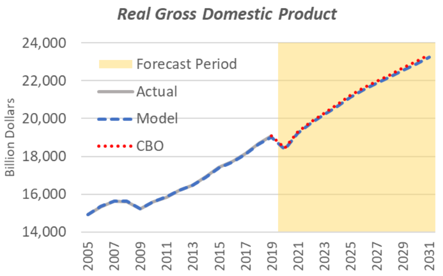
CBO: Congressional Budget Office
ReEDS: Regional Energy Deployment System
USEEIO: U.S. Environmentally-Extended Input-Output Model

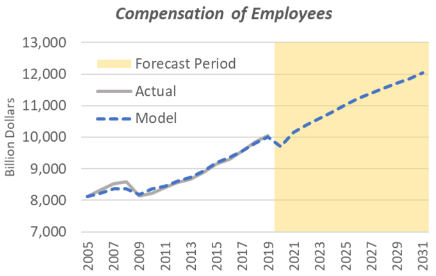
ADOPT: Automotive Deployment Options Projection Tool
BSM: Bioenergy Scenario Model
TEA: Techno-Economic Analysis

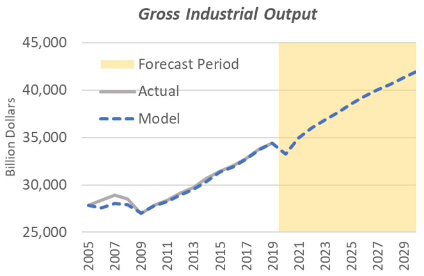
1. Approach: Go/No-Go – Prospective Model Capability (FY21 Q2)

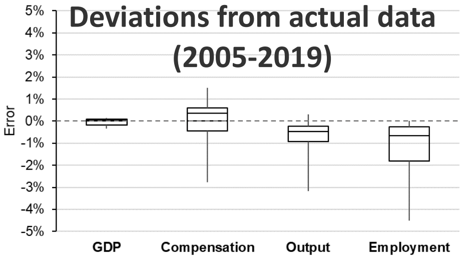
A **Go Decision** will require the prototype framework to **provide sectoral detail** for potential **cross-sectoral effects over time**, i.e., quantify potential net effects of an expanding bioeconomy over time.

Methodology Validation Through Backcasting Historic Data



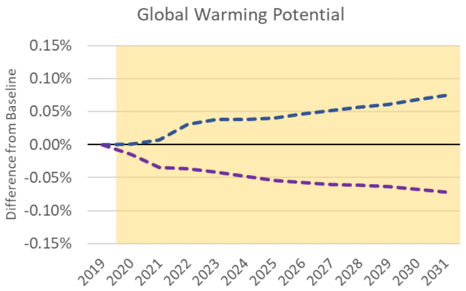


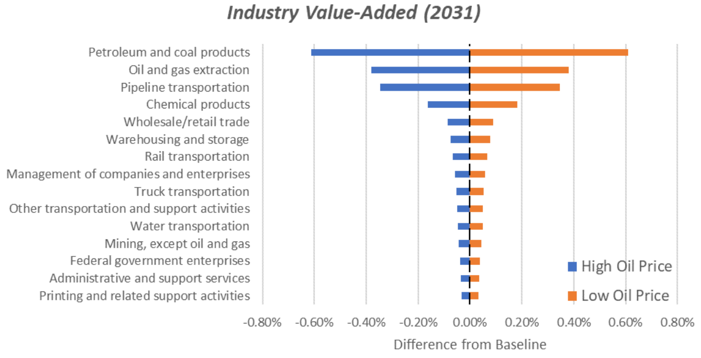




Maximum errors below +/-5% for the period (larger deviations concentrate in the 2008-crisis).

High/Low Oil Price Simulations (Annual Energy Outlook)





CBO: Congressional Budget Office, Long-Term Economic Projections (March 2021)

PRELIMINARY RESULTS - DO NOT DISTRIBUTE, QUOTE, OR CITE

1. Approach: Potential Challenges

Complexity of interactions between bioeconomy sectors and the rest of the economy

- ➢ A tradeoff of economy-wide models is approaching problems from a **top-down perspective**, i.e., due to the complexity of modeling for all sectors of the economy and their linkages, **firm-level interaction is often limited** in a macroeconomic approach;
- ✓ We **complement** this top-down framework **with external bottom-up models** that focus on specific markets (fuel production, electricity generation, new vehicle purchases), providing a more accurate dynamics to EMPLOY.

Feasibility of future scenarios

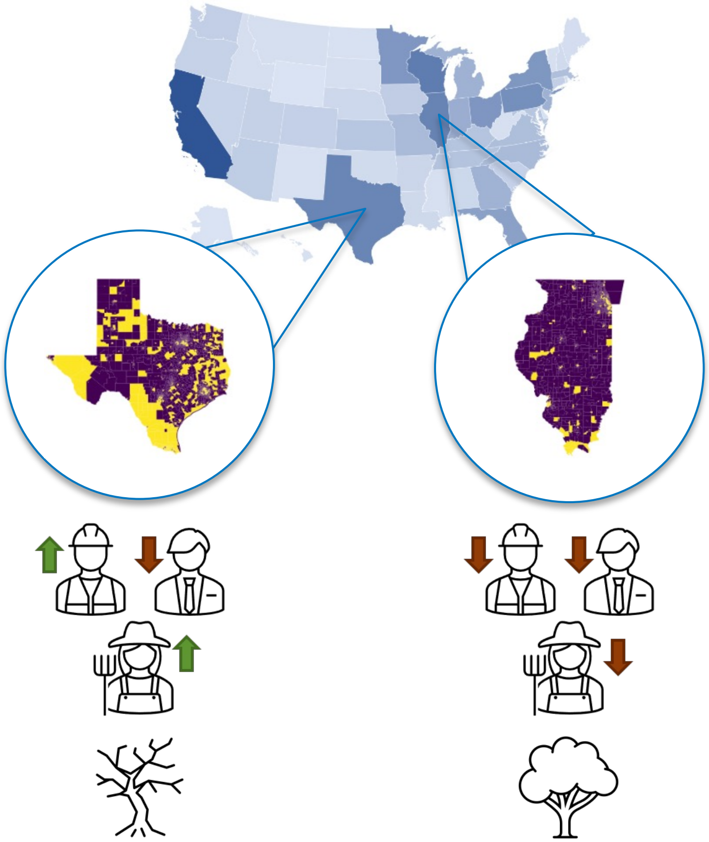
- ➢ Despite regulatory goals, **target fuel production** and decarbonization strategies might not materialize given **changing overall economic environment and industry dynamics** (upstream and downstream in the supply chain);
- ✓ Outreach to the sustainable aviation fuel (**SAF**) **industry** and **stakeholders** will provide feedback to **adjust forecasts** and better **reflect the expectations of the industry**.

1. Approach: Risk Analysis

RISKS	MITIGATION
COMPLEXITY Integrating new bioeconomy products in established industry-commodity relationships	Structured, continued reviews from practitioners to validate the method development and results for additional pathways
DATA INTENSITY Required state-level economic and LCI data and industry-level Workforce characteristics data	Proactive outreach to other federal agencies and modeling communities to vet options and plan resources and engagement accordingly
FUTURE SCENARIOS Lack of consensus around future bioeconomy scenarios	Proactive outreach to SAF industry stakeholders to embed their forecasts/plans in the simulations + several sensitivity cases around external forecasts to develop an error band around the results

1. Approach: Energy Justice and Diversity, Equity and Inclusion

- The **expansion** of the bioeconomy will **impact both urban and rural communities**.
- **Spatial tradeoff** analysis can benefit regional and federal level decision making:
  - E.g., **particulate matter emissions** from farming are largely **rural** while air quality benefits from ethanol are mainly **urban**.
  - E.g., socio-economic **benefits are not distributed equally** along the supply chains / regions.
  - E.g., change in local workforce demand can lead to benefits/losses for underserved communities and highlight gaps in **workforce development**.
- Framework can inform **social** and **environmental equity decision making**.

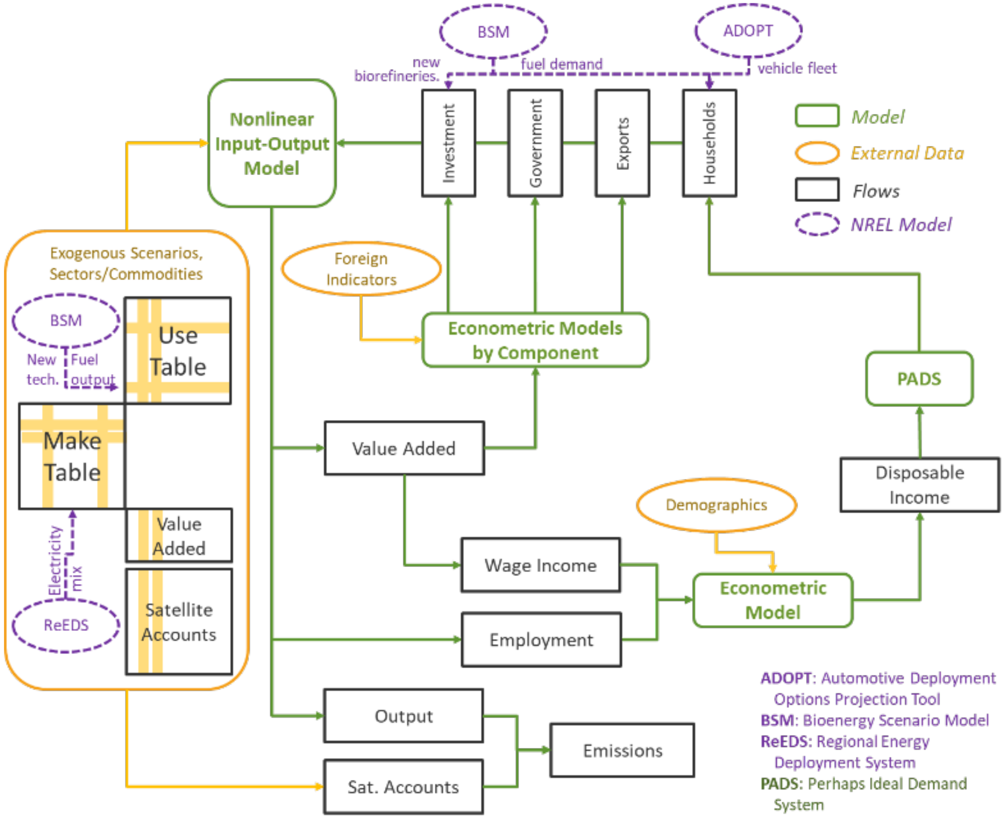


2. Progress & Outcome: Model Evolution

FY19 – FY20	FY21	FY22-FY23	FY24-FY25
EMPLOY v.1	**EMPLOY v.2**	**EMPLOY v.3**	**EMPLOY v.4**
• **Region**: U.S. (domestic)	• **Region**: U.S. (domestic)	• **Region**: U.S. **States** (domestic)	• **Region**: U.S. States + **World**
• **Impact Metrics**: Economic, Environmental, Resource Use	• **Impact Metrics**: Economic, Environmental, Resource Use	• **Impact Metrics**: Economic, Environmental, Resource Use, **Occupations**	• **Impact Metrics**: Economic, Environmental, Resource Use, Occupations
• **Model: static**, retrospective analysis	• **Model: dynamic**, prospective analysis	• **Model: dynamic**, prospective analysis	• **Model: dynamic**, prospective analysis
• **Years**: **2002, 07, 12, 17**	• **Years**: **2019-2030**	• **Years**: **2019-2050**	• **Years**: 2019-2050
• **Pathways: first generation biofuels**	• **Pathways:** first generation biofuels, **second generation biofuels, bio-plastics**	• **Pathways:** first generation biofuels, second generation biofuels, bio-plastics, **sustainable aviation fuels**	• **Pathways:** first generation biofuels, second generation biofuels, bio-plastics, sustainable aviation fuels, **TBD**

2. Progress & Outcome: EMPLOY Forecasting Model

- **EMPLOY v.3** is a **prospective model** that highlights potential **cross-sectoral effects** resulting from the **future expansion** of **fuels/products** associated with a growing U.S. bioeconomy.
- The model is **designed for limited information** conditions and can be quickly deployed in different regions.
- National-level framework capable of forecasting up to 2050.
- State-level model under development



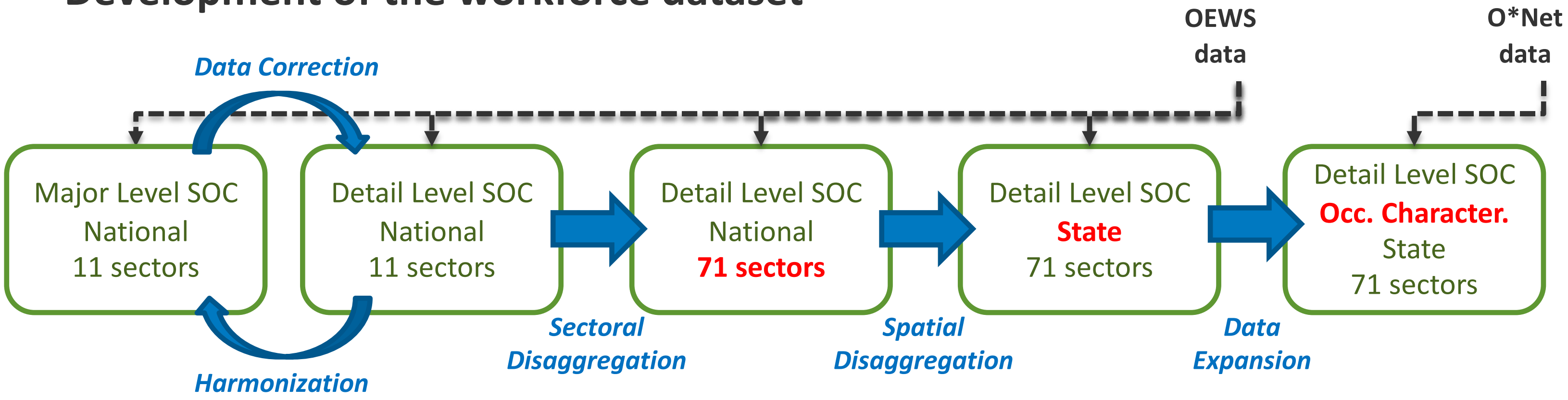
Source: Avelino, A. F. T., P. Lamers, Y. Zhang, G. Avery and M. Li (2021, Nov. 8). "BIOCAST: A Non-Linear Demo-Economic Forecasting Model for the U.S. Bioeconomy" [Conference session]. 68th North America Meetings of the Regional Science Association International, Denver, CO, United States.

2. Progress & Outcome: Economic and Workforce Data

- **Collaboration with the USEEIO team at EPA**
  - Feedback and testing of state-level input-output tables (2012-2020)
  - Initial release for 50 U.S. states plus the District of Columbia

baseline to calibrate the state-level EMPLOY model

- **Development of the workforce dataset**



USEEIO: U.S. Environmentally-Extended Input-Output Model | *SOC: Standard Occupational Code* | *OEWS: Occupational Employment and Wage Statistics (U.S. Bureau of Labor Statistics)*

2. Progress & Outcome: Pathways implemented in EMPLOY

- **Light/Heavy Duty Vehicles**
  - Ethanol
    - *Dry-mill: corn starch*
  - Biodiesel
    - *HEFA: soybean*

FY20/21

  - Cellulosic Ethanol
    - *Biochemical: corn stover, switchgrass*
    - *Thermochemical: woody biomass*

FY21

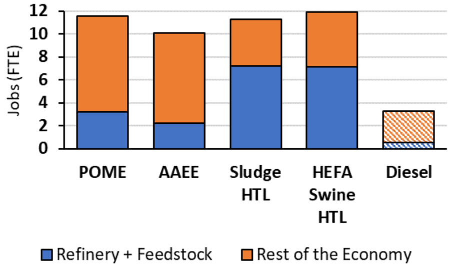
  - Renewable Diesel
    - *Co-Optima Fuels*
- **Aviation**
  - Sustainable Aviation Fuel
    - *Fischer-Tropsch: woody biomass*
    - *HEFA: FOG, algae biomass*
    - *Hydrothermal liquefaction: sludge, swine manure*

FY22

- **Bioplastics**
  - Polyethylene terephthalate (TPA)

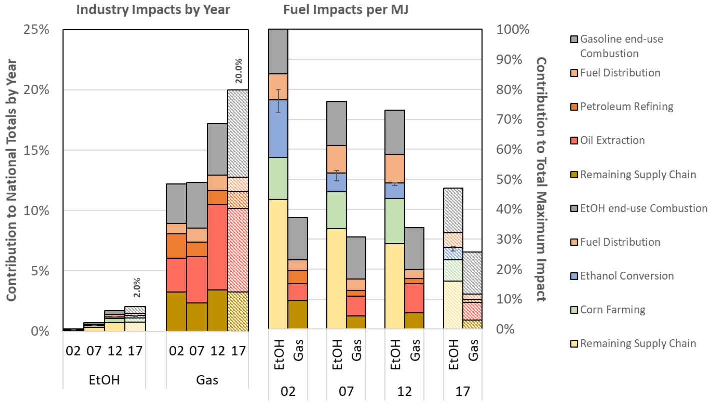
FY21

Co-Optima Renewable Diesel O&M Impacts (Per MMgal)



POME: Polyoxymethylene Dimethyl Ether
AAEE: Alkoxy Alkanoate Ester Ether
HEFA: Hydroprocessed Esters and Fatty Acids
HTL: Hydrothermal Liquefaction

Evolution of smog formation potential for corn ethanol (EtOH) vs. gasoline (Gas), 2002-2017

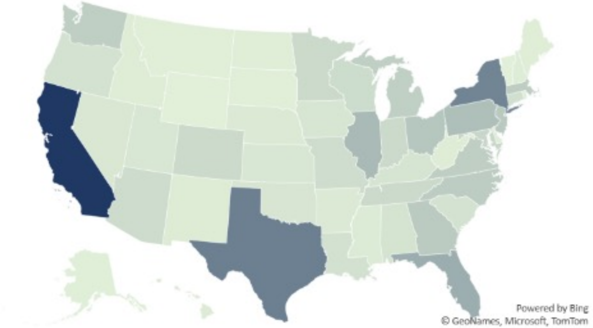


PRELIMINARY RESULTS - DO NOT DISTRIBUTE, QUOTE, OR CITE

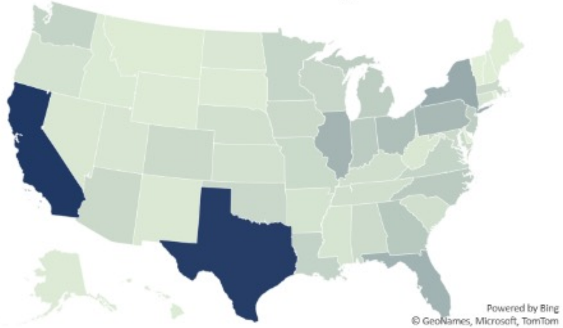
2. Progress & Outcome: State-level Satellite Accounts, 2017

Total (absolute) jobs/value added/resource use/impact potentials by state in 2017

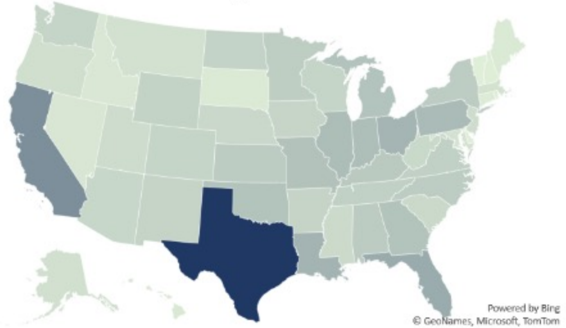
Value Added



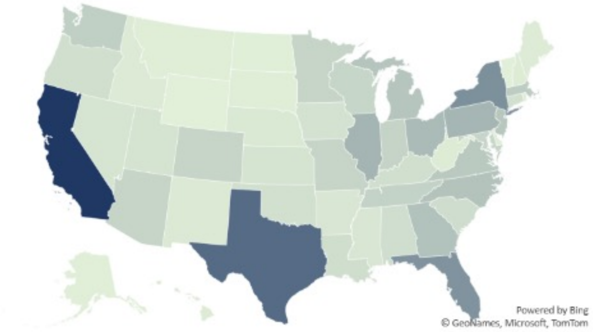
Global Warming



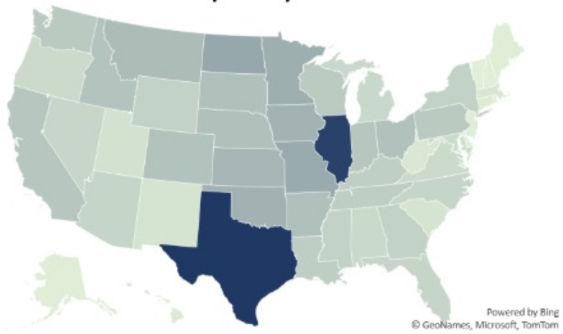
Smog Formation



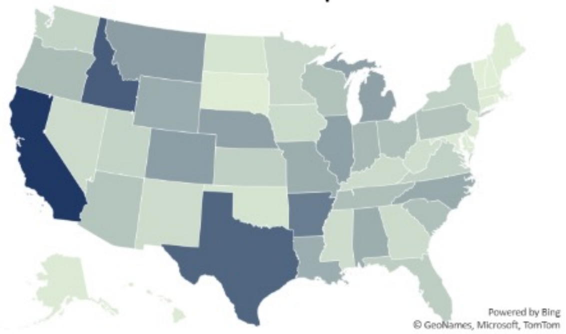
Jobs



Respiratory Effects



Water Consumption



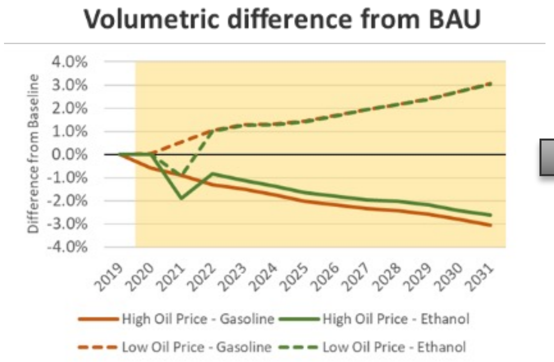
PRELIMINARY RESULTS - DO NOT DISTRIBUTE, QUOTE, OR CITE

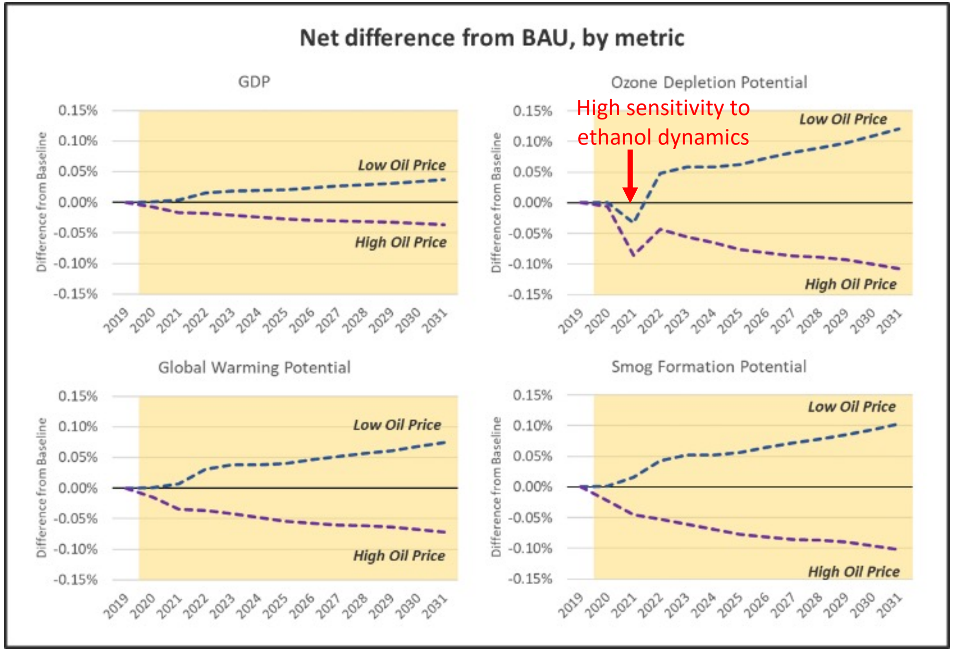
2. Progress & Outcome: EMPLOY Forecasting Model

Annual Energy Outlook Scenarios:

High oil prices: price of Brent crude oil >> $173/b by 2031 vs $95/b in the baseline

Low oil prices: price of Brent crude oil >> $48/b by 2031 vs $95/b in the baseline





- For most metrics, dynamics from both fuels is balanced.
- For ozone, ethanol's dynamics significantly influences the results: corn ethanol's supply chain emits more hydrofluorocarbons (HFC) than gasoline's on an energy basis.

Source: Avelino, A. F. T., P. Lamers, Y. Zhang, G. Avery and M. Li (2021, Nov. 8). "BIOCAST: A Non-Linear Demo-Economic Forecasting Model for the U.S. Bioeconomy" [Conference session]. 68th North America Meetings of the Regional Science Association International, Denver, CO, United States.

3. Impact: BETO and DOE

- **Supports BETO goals and Multi-Year Plan (MYP) objectives:**
  - **By 2024**: quantify the net socioeconomic, environmental and workforce effects of expanding the U.S. bioeconomy into 2050 to assess tradeoffs of different future decarbonization pathways.
  - **By 2025**: identify critical supply chains for bioeconomy expansion, their exposure to global supply-chains, and measure the tradeoffs of incentivizing domestic production of strategic goods and raw materials.
- **Supports several DOE projects:**

- **Co-Optimization of Fuels and Engines Project (BETO/VTO):**
  Job analysis for different heavy-duty diesel bio-blendstocks
- **BOTTLE Consortium:**
  Socio-economic impact analysis of enzymatic recycling of poly(ethylene terephthalate)
- **MarkeRs Project (BETO):**
  Regional socio-economic impacts of CO_2-utilization pathways
- **WIRED Project (SA):**
  Occupational datasets to update NREL's Jobs and Economic Development Impact (JEDI) models

Workforce Impacts and Regional Economic Development

3. Impact: Other Federal Agencies

- **Supports Congressional and agency level strategic decision making:**
  - EPA's proposed rule change in the Renewable Fuel Standards for 2023, 2024, and 2025, on its regulatory impact analysis,
  - EPA's Third Triennial Report to Congress (RtC3) on the environmental effects of the Renewable Fuel Standard (RFS),
  - Interagency (DOE, DOT, USDA, EPA) Sustainable Aviation Fuel Grand Challenge, on modeling SAF supply chains.

- **Supports several projects outside DOE:**

- **Biofuels and the Environment: Third Triennial Report to Congress:**
  Socio-economic retrospective comparison between first generation biofuels and conventional fuels
- **U.S. Environmentally-Extended Input-Output (USEEIO) Model:**
  Review and input on new coding and data

3. Impact: Research Community and Industry Engagement

- Avelino, A., Lamers, P., Zhang, Y., Avery, G., and Li, M. (2021, Nov. 8). **BIOCAST: A Non-Linear Demo-Economic Forecasting Model for the U.S. Bioeconomy** [Conference session]. 68th North American Meetings of the Regional Science Association International, Denver, CO.

- Avelino, A., Lamers, P., and Zhang, Y. (2022, Feb. 23). **Bio-based circular carbon economy Environmentally-extended Input-Output Model (BEIOM)** [Presentation]. Presentation about EMPLOY's capabilities to members of the aviation sector.

- Avelino, A. (2022, Oct. 4). **Measuring the Bioeconomy: the BEIOM Model** [Presentation]. Presentation about EMPLOY's methodology to researchers from the U.S. Bureau of Economic Analysis.

NORTH AMERICAN REGIONAL SCIENCE COUNCIL

UNITED

LanzaJet

Airlines for America

bea Bureau of Economic Analysis U.S. DEPARTMENT OF COMMERCE

3. Impact: Advancing the State-of-the-Art

1. Singh, A., Rorrer, N., Nicholson, S., Erickson, E., DesVeaux, J., Avelino, A., Lamers, P., Bhatt, A., Zhang, Y., Avery, G., Wu, C., Tao, L., Pickford, A., Carpenter, A., McGeehan, J., and Beckham, G. (2021) Techno-economic, life cycle, and socio-economic impact analysis of enzymatic recycling of poly(ethylene terephthalate), ***Joule***, 5, 2479-2503. DOI: 10.1016/j.joule.2021.06.015

2. Cowie, A. L., Berndes, G., Bentsen, N. S., Brandão, M., Cherubini, F., Egnell, G., George, B., Gustavsson, L., Hanewinkel, M., Harris, Z. M., Johnsson, F., Junginger, M., Kline, K. L., Koponen, K., Koppejan, J., Kraxner, F., Lamers, P., Majer, S., Marland, E., Nabuurs, G.-J., Pelkmans, L., Sathre, R., Schaub, M., Smith Jr., C. T., Soimakallio, S., Van Der Hilst, F., Woods, J., and Ximenes, F. A. (2021) Applying a science-based systems perspective to dispel misconceptions about climate effects of forest bioenergy, ***GCB Bioenergy***, 13(8), 1210-1231. DOI: 10.1111/gcbb.12844

3. Tan, E. C. D., and Lamers, P. (2021). Circular Bioeconomy Concepts - A Perspective, ***Frontiers in Sustainability***, 2(53), 1-8. DOI: 10.3389/frsus.2021.701509

4. Lamers, P., Avelino, A., Zhang, Y., Tan, E., Young, B., Vendries, J. and Chum, E. (2021) Potential Socioeconomic and Environmental Effects of an Expanding U.S. Bioeconomy: An Assessment of Near-Commercial Cellulosic Biofuel Pathways, ***Environmental Science & Technology***, 55(8), 5496-5505. DOI: 10.1021/acs.est.0c08449

5. Avelino, A., Lamers, P., Zhang, Y., and Chum, H. (2021) Creating a Harmonized Time-Series of Environmentally-Extended Input-Output Tables to Assess the Evolution of the U.S. bioeconomy: A retrospective analysis of corn ethanol and soybean biodiesel, ***Journal of Cleaner Production***, 321, 128890. DOI: 10.1016/j.jclepro.2021.128890

6. Vera, I., Wicke, B., Lamers, P., Cowie, A., Repo, A., Heukels, B., Zumpf, C., Styles, D., Parish, E., Cherubini, F., Berndes, G., Jager, H., Schiesari, L. C., Junginger, M., Brandão, M. M. R., Bentsen, N. S., Hoefnagels, R., Daioglou, V., Harris, Z., and Hilst, F. v. d. (2022) Land use for bioenergy: synergies and trade-offs between Sustainable Development Goals (SDGs), ***Renewable & Sustainable Energy Reviews***, DOI: 10.1016/j.rser.2022.112409

Summary

This project provides BETO with a new state-of-the-art modeling capability able to quantify the *net effects* of different decarbonization strategies across the agricultural, transportation and industrial sectors, in terms of socio-economic (GDP, jobs), environmental (releases to air, water, and soil plus resource uses) and workforce impacts assuring that the Administration's Energy Justice (EJ), Diversity, Equity and Inclusion (DEI) goals are achieved.

Main Accomplishments:

- National-level retrospective (2012-2017) and prospective analysis (up to 2050) capabilities
- 12 energy pathways analyzed (biofuels and bio-plastics)
- 6 peer-reviewed publications with methodology and applications
- Support for Congressional and agency level strategic decision making regarding RtC3, RFS and SAF
- Ongoing cooperation with EPA ORD (USEEIO project)
- External requests for EMPLOY analyses from several EPA and DOE projects

Environmentally-extended Multi-regional Projection of Lifecycle and Occupational energY futures: EMPLOY / 4.2.1.31

PI: Andre F. T. Avelino/NREL

DOE TM Lead: Michael Shell

Collaborations: EPA, Wes Ingwersen

Timeline

- **Project Start Date:** 10/01/2022
- **Project End Date:** 09/30/2025

Technology Readiness Level

- **TRL at Project Start:** N/A
- **TRL at Project End:** N/A
- Modality 5 (Strategic, Market and Techno-Economic Analysis)

Project Goal

Develop a state-level multi-regional model to quantify the net socio-economic, environmental and workforce effects of expanding the U.S. bioeconomy into 2050 within a global supply chain context. Support BETO in measuring Energy Justice and Equity impacts. Support IEA Bioenergy T45.

End of Project Milestone

FY25: Delivery of a prospective model able to quantify the net environmental and socioeconomic including workforce effects and regional tradeoffs for the U.S. economy with state-level detail. Application of the model for a series of sector and economy-wide decarbonization pathways aligning with DOE and U.S. government goals and ambitions, considering global supply chain dependencies.

Funding Mechanism

Lab Call: DE-LC-0000015 (National Lab Funding for Fiscal Year 2023)

Topic Area: Data, Modeling and Analysis

Subtopic Area: 4c. Model Design and Updates

Project Partners

- N/A

Thank you

www.nrel.gov

NREL/PR-6A20-85522

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Bioenergy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government.

NREL Transforming ENERGY

EMPLOY Team FY23-25

Dr. Andre F. T. Avelino
Economist
Lead Model Developer
Principal Investigator
Andre.Fernandestomonavelino@nrel.gov

Dr. Patrick Lamers
Advisor
IEA Bioenergy
Patrick.Lamers@nrel.gov

Dr. Yimin Zhang
Senior LCA Expert
LCI Data Curation
Yimin.Zhang@nrel.gov

Mengming Li
Economist
PhD Graduate Intern
Mengming.Li@nrel.gov

Greg Avery
LCA Analyst
LCI Data Curation
Greg.Avery@nrel.gov

Responses to FY21 Peer-Review

Additional Metrics and DEI

COMMENTS: The project would benefit from the inclusion of more and diverse economic indicators to create a more nuanced understanding of the expanding bioeconomy's economic impacts; It would be helpful in the future to have more explicit evaluations (i.e., for communities or regions, rather than economic sectors) of the equity impacts for different products or pathways to illustrate the models' contributions to decision making.

- ✓ In FY23-FY25 the project is developing **workforce metrics** to better detail job impacts (e.g., by type of occupations, educational and training requirements, average wages) as well as **expanding the spatial dimension** from national to **state level** to highlight **regional tradeoffs** of specific pathways and decarbonization strategies.

Responses to FY21 Peer-Review

Model Complexity

COMMENTS: Expert vetting will best assist this model's outcomes; The team would do well to engage a variety of stakeholders in their work, outside of federal agencies and labs.

✓ Apart from **existing exchanges** with **process-level LCA and TEA teams** at **ANL**, **NREL**, and **PNNL**, and **economic data** team at **EPA**, we plan to expand our **engagement with industry stakeholders** (e.g., airline companies and SAF producers) to vet future simulation scenarios and assess their feasibility. The team showed the project's capabilities to representatives of the aviation industry in 2022 and aims to expand this connection when performing prospective scenario analysis in FY24.

Responses to FY21 Peer-Review

BETO Portfolio Model Integration

COMMENTS: It would be encouraging to see more explicit collaboration between this team and other deeper but less broad models in the BETO portfolio to ground-truth broad impact assumptions.

✓ In FY22 the model was connected to the Bioenergy Scenario Model (BSM) to capture future fuel production market dynamics in the US. In FY23 the model will develop additional interfaces with the Regional Energy Deployment System Model (ReEDS) and the Automotive Deployment Options Projection Tool (ADOPT) to better represent dynamics in the electricity grid and vehicle fleet.

Publications and Presentations (Chronological Order)

1. Singh, A., Rorrer, N., Nicholson, S., Erickson, E., DesVeaux, J., Avelino, A., Lamers, P., Bhatt, A., Zhang, Y., Avery, G., Wu, C., Tao, L., Pickford, A., Carpenter, A., McGeehan, J., and Beckham, G. (2021) Techno-economic, life cycle, and socio-economic impact analysis of enzymatic recycling of poly(ethylene terephthalate), ***Joule***, 5, 2479-2503. DOI: 10.1016/j.joule.2021.06.015

2. Cowie, A. L., Berndes, G., Bentsen, N. S., Brandão, M., Cherubini, F., Egnell, G., George, B., Gustavsson, L., Hanewinkel, M., Harris, Z. M., Johnsson, F., Junginger, M., Kline, K. L., Koponen, K., Koppejan, J., Kraxner, F., Lamers, P., Majer, S., Marland, E., Nabuurs, G.-J., Pelkmans, L., Sathre, R., Schaub, M., Smith Jr., C. T., Soimakallio, S., Van Der Hilst, F., Woods, J., and Ximenes, F. A. (2021) Applying a science-based systems perspective to dispel misconceptions about climate effects of forest bioenergy, ***GCB Bioenergy***, 13(8), 1210-1231. DOI: 10.1111/gcbb.12844

3. Tan, E. C. D., and Lamers, P. (2021). Circular Bioeconomy Concepts - A Perspective, ***Frontiers in Sustainability***, 2(53), 1-8. DOI: 10.3389/frsus.2021.701509

4. Lamers, P., Avelino, A., Zhang, Y., Tan, E., Young, B., Vendries, J. and Chum, E. (2021) Potential Socioeconomic and Environmental Effects of an Expanding U.S. Bioeconomy: An Assessment of Near-Commercial Cellulosic Biofuel Pathways, ***Environmental Science & Technology***, 55(8), 5496-5505. DOI: 10.1021/acs.est.0c08449

5. Avelino, A., Lamers, P., Zhang, Y., and Chum, H. (2021) Creating a Harmonized Time-Series of Environmentally-Extended Input-Output Tables to Assess the Evolution of the U.S. bioeconomy: A retrospective analysis of corn ethanol and soybean biodiesel, ***Journal of Cleaner Production***, 321, 128890. DOI: 10.1016/j.jclepro.2021.128890

6. Avelino, A., Lamers, P., Zhang, Y., Avery, G., and Li, M. (2021, Nov. 8). **BIOCAST: A Non-Linear Demo-Economic Forecasting Model for the U.S. Bioeconomy** [Conference session]. 68th North America Meetings of the Regional Science Association International, Denver, CO.

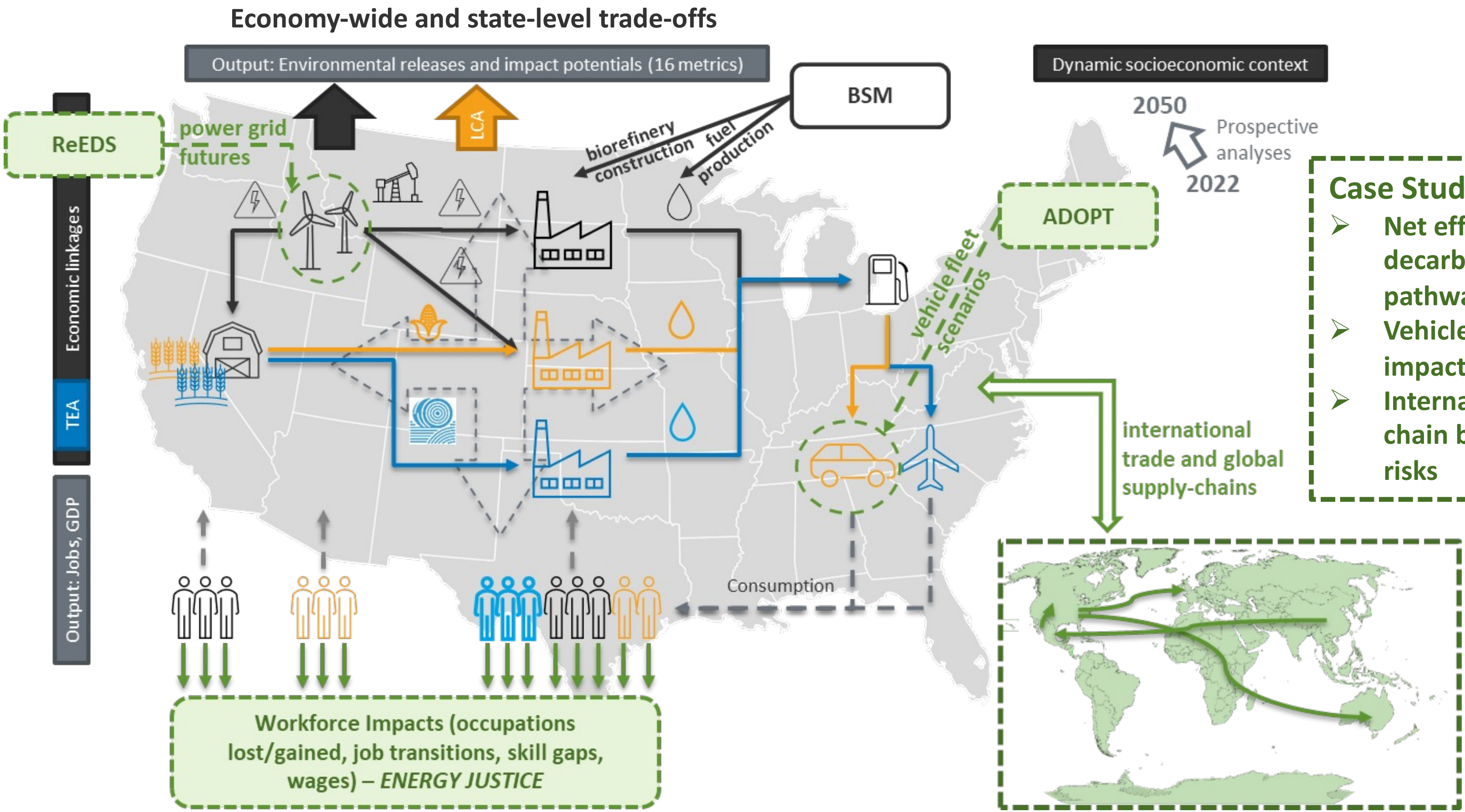
Publications and Presentations (Chronological Order)

7. Vera, I., Wicke, B., Lamers, P., Cowie, A., Repo, A., Heukels, B., Zumpf, C., Styles, D., Parish, E., Cherubini, F., Berndes, G., Jager, H., Schiesari, L. C., Junginger, M., Brandão, M. M. R., Bentsen, N. S., Hoefnagels, R., Daioglou, V., Harris, Z., and Hilst, F. v. d. (2022) Land use for bioenergy: synergies and trade-offs between Sustainable Development Goals (SDGs), ***Renewable & Sustainable Energy Reviews***, DOI: 10.1016/j.rser.2022.112409

8. Avelino, A., Lamers, P., and Zhang, Y. (2022, Feb. 23). **Bio-based circular carbon economy Environmentally-extended Input-Output Model (BEIOM)** [Presentation]. National Renewable Energy Laboratory, Golden, CO.

9. Avelino, A. (2022, Oct. 4). **Measuring the Bioeconomy: the BEIOM Model** [Presentation]. National Renewable Energy Laboratory, Golden, CO.

FY23-FY25 Planning



Case Studies:

- Net effects of different decarbonization pathways
- Vehicle electrification impacts
- International supply-chain bottlenecks and risks

ADOPT: Automotive Deployment Options Projection Tool
BSM: Bioenergy Scenario Model
LCA: Life Cycle Analysis
ReEDS: Regional Energy Deployment System
TEA: Techno-economic Analysis

Environmentally-extended Multi-regional Projection of Lifecycle and Occupational energY futures: EMPLOY / 4.2.1.31

Andre F. T. Avelino/NREL

WBS# 4.2.1.31 – 27593 Lab Call#: DE-LC-0000015

Project Objectives

Develop a state-level multi-regional model to quantify the net socio-economic, environmental and workforce effects of expanding the U.S. bioeconomy into 2050 within a global supply chain context. Support BETO in measuring Energy Justice and Equity impacts. Support IEA Bioenergy T45.

Technical Approach

- Expand the job datasets to include occupation data by sector and state to quantify job displacement, wage impacts, skill gaps and workforce development needs. Integrate the current model with ADOPT and ReEDS models to account for the effects of vehicle fleet and electric grid changes. (FY23)
- Analyze the net impacts (socioeconomic, environmental and workforce) of different decarbonization pathways and highlight state-level tradeoffs up to 2050. (FY24)
- Identify possible supply chain bottlenecks at local and international levels of different decarbonization pathways. (FY25)

Project Type: new start

Project Attributes

Project Dates	10/1/2022 – 9/30/2025	
FY23 Budget	$450,000	
Collaborations	EPA, Wes Ingwersen	ingwersen.wesley@epa.gov
DOE TM Lead	Michael Shell	michael.j.shell@ee.doe.gov

Project Milestones and Outcomes

- **FY23:** Occupational model extension at state level with ReEDS and ADOPT integration.
- **FY24:** Net impacts of different decarbonization pathways (to be determined with DOE) with detail on workforce development needs and state level tradeoffs.
- **FY25:** International model expansion and new insights on how international supply-chains can affect different decarbonization pathways in the U.S.
- **End of project goal/outcome:** Delivery of a prospective model able to quantify the net environmental and socioeconomic including workforce effects and regional tradeoffs for the U.S. economy with state-level detail. Application of the model for a series of sector and economy-wide decarbonization pathways aligning with DOE and U.S. government goals and ambitions, considering global supply chain dependencies.
- **Go/No-Go Decision (Q2FY24):** Successful application of the expanded occupational model to specify the net socioeconomic and environmental impacts with workforce detail and regional tradeoffs between states for at least one comprehensive DOE 2050 decarbonization scenario.

Decarbonization Pillars and EERE Emphasis Areas

This project quantifies the socioeconomic (value-added, employment), environmental (air and water quality, among others) and workforce (occupations, wages, skillsets) net effects and related state tradeoffs for decarbonizing the transportation sector and other industries. It assesses specific technologies or technology portfolios at industry-scale in a dynamic U.S. economy context (state-level), informing strategy decisions including process design changes or siting choices to reduce adverse effects and de-risk future commercial biofuel production, supporting the Administration's target of decarbonizing the economy and producing 35 billion gallons of Sustainable Aviation Fuels (SAF) annually by 2050. Workforce impacts including types of occupations, job transitions, median wages and skill gaps by state and sector allow the description of workforce development requirements for clean energy system transitions in specific regional contexts supporting the Administration's Energy Justice (EJ), Diversity, Equity and Inclusion (DEI) goals.

List of Acronyms

ADOPT: Automotive Deployment Options Projection Tool

BEA: Bureau of Economic Analysis (U.S. Department of Commerce)

BEIOM: Bio-based circular carbon economy Environmentally-extended Input-Output model

BETO: Bioenergy Technologies Office (DOE – EERE)

BIOCAST: Bioeconomy environmentally-extended Input-Output foreCASTing model

BSM: Bioenergy Scenario Model

CBO: Congressional Budget Office

DOT: Department of Transportation

EMPLOY: Environmentally-extended Multi-regional Projection of Lifecycle and Occupational energY futures

EPA: U.S. Environmental Protection Agency

GDP: Gross Domestic Product

LCA: Life-cycle Analysis

OEWS: Occupational Employment and Wage Statistics (U.S. Bureau of Labor Statistics)

ReEDS: Regional Energy Deployment System

SA: Strategic Analysis Office (DOE – EERE)

SAF: Sustainable Aviation Fuel

SOC: Standard Occupational Classification

TEA: Techno-Economic Analysis

USDA: U.S. Department of Agriculture

USEEIO: U.S. Environmentally-Extended Input-Output Model

VTO: Vehicle Technologies Office (DOE – EERE)