



BETO 2021 Peer Review
Waste-to-Energy (WTE): Feedstock
Evaluation and Biofuels Production
Potential - NREL

March 9, 2021
Waste-to-Energy
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Project Overview

Context: Knowledge gaps regarding volume, availability, location, and value of waste resources

History:

- Builds on previous project outcomes, e.g., estimates of quantity, geographic distribution, and prices of wet waste resources (food waste, sludge, manure, waste fats and oils)
- Need for additional waste resource assessments to provide comprehensive understanding of the MSW streams available for bioenergy conversions
- BETO seeks mobilization of gathered data, knowledge, and information

Goal: Provide foundational data, strategic analyses, and outreach related to waste resources to support further development of the WTE industry

State of the Art: Existing data and analyses at national level

Relevance: Filling knowledge gaps and support decision-making

Market Trends

Product

-  Anticipated decrease in gasoline/ethanol demand; 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 H₂
-  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

Better understanding of the waste resources potential and economic viability enables development of new technologies and supports strategic decisions

Key Differentiators

- First-of-a-kind resource analyses
- Comprehensive data at fine geographic resolution
- Overlaying various factors, e.g., resource availability, management cost, policy structures, etc.
- Industry participation ensures analysis and model fidelity leading to credible results

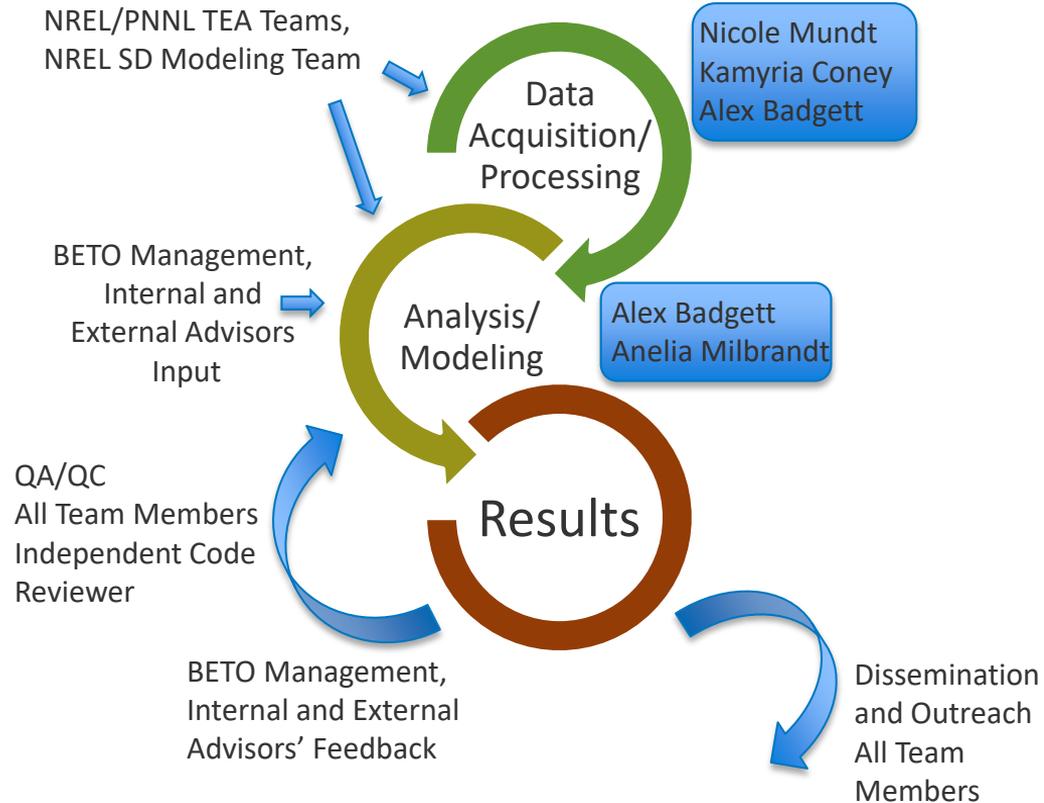
1. Management

Strong communication between team members, BETO management, stakeholders, and other modeling/research teams:

- Weekly team meetings
- Monthly meetings with BETO management
- Periodic communication with PNNL resource and TEA teams, and NREL system dynamics (SD) and TEA teams
- Regular communication with internal (*NREL engineers and economists*) and external advisors (*e.g., Waste Management Inc., The Recycling Partnership, Covanta, EPA, etc.*)

Risks: a) Lack of raw data, b) Data processing taking longer than anticipated

Risk-mitigation strategies: Planning sufficient time for rigorous data collection and processing, close monitoring of schedule, making changes as necessary.



2. Approach

Technical work since last Peer Review

- Cost-benefit analysis (CBA) of food waste disposal and utilization pathways (FY18-FY19, midway during last review)
- Assessment of select MSW materials: plastic, paper/cardboard, and wood (FY19-FY20)
- WTE technical assistance (TA) for local governments (FY21)

Key Challenges

- Data availability (e.g., gaps in MSW composition data)
- Data quality (e.g., inconsistent MSW composition definitions)
- First-of-a-kind data (no point of comparison, industry input instrumental)

Go/No-Go

- Analysis rigor meets BETO and the stakeholder community expectations to ensure comprehensive methodology and reliable results

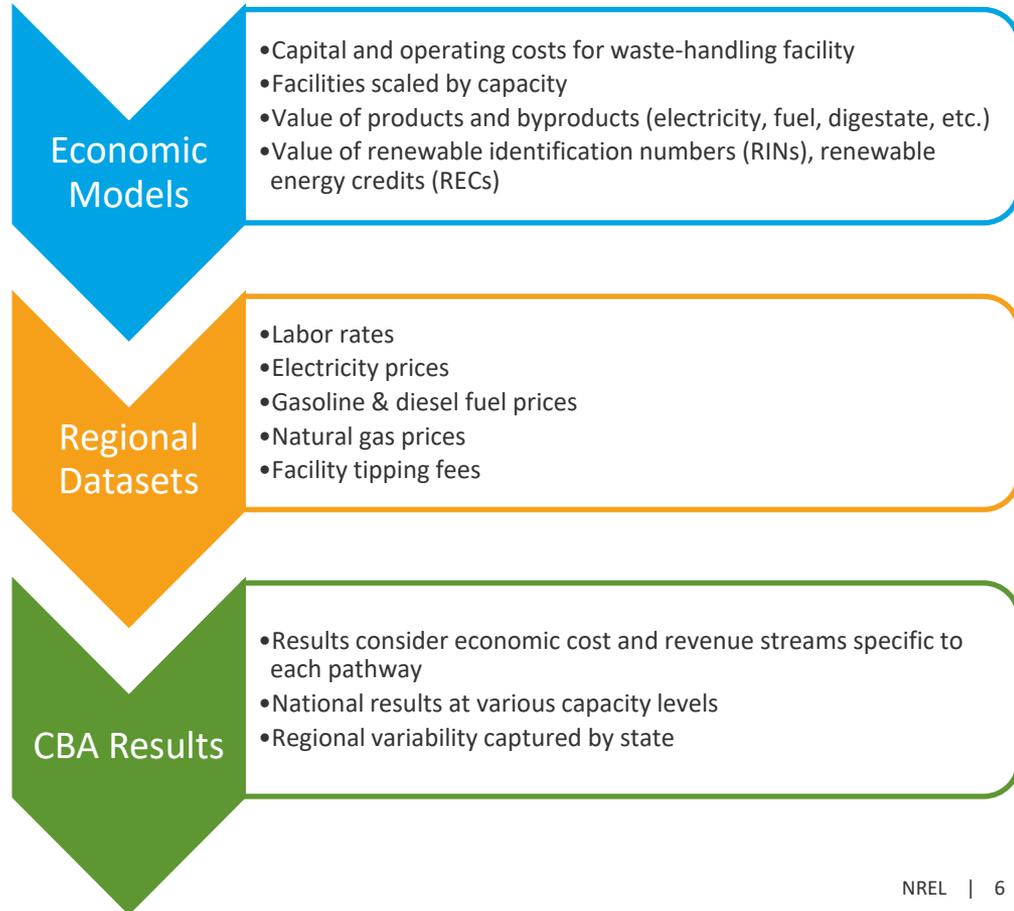
2. Approach: CBA of Food Waste Management Pathways

Advances State-of-the-Art

First study to analyze spatial variability of food waste pathway economics below national level

Project Objectives

- Evaluate the costs and benefits associated with disposal and utilization pathways for food waste:
 - Landfilling, baseline: 5 sub-pathways
 - Composting: 3 sub-pathways
 - Anaerobic digestion (AD): 10 sub-pathways split between dry and wet AD
 - Incineration: 2 sub-pathways
 - Biofuels via Hydrothermal Liquefaction (HTL)
- Identify economically favorable pathways
- Understand driving market factors



2. Approach: Assessment of Plastic, Paper/Cardboard, and Wood Waste

Advances State-of-the-Art

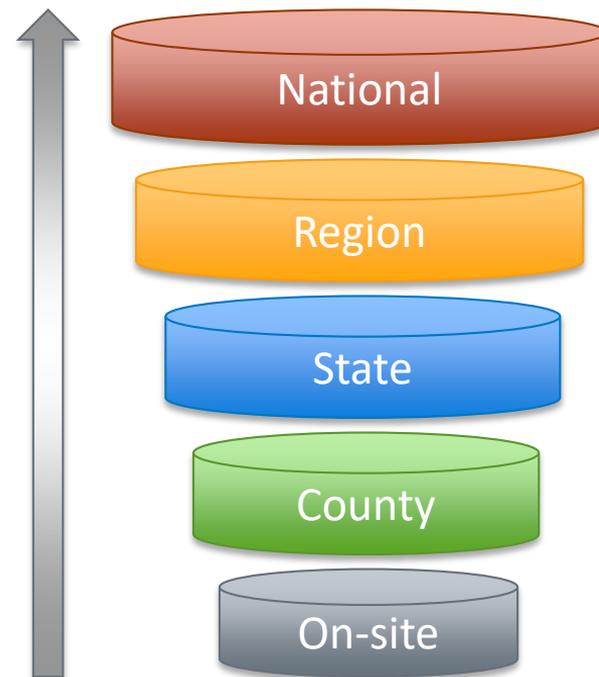
First study to analyze spatial variability of landfilled plastic, paper/cardboard, and wood waste below national level

Project Objectives

- Estimate the total plastic, paper/cardboard, and wood waste managed in the US
- Map the landfilled material below national level to illustrate opportunities for diversion and reuse geographically
- Estimate the market and energy value of landfilled waste
- Conduct sensitivity analysis

Statistical and geospatial methods applied; key model inputs include:

- State and local waste composition data
- Tonnage of MSW received by waste managing facilities in 2019
- Market price of post-consumer materials
- Embodied energy, HHV



Bottom-up Approach

2. Approach: WTE TA for Local Governments

Unique Aspects

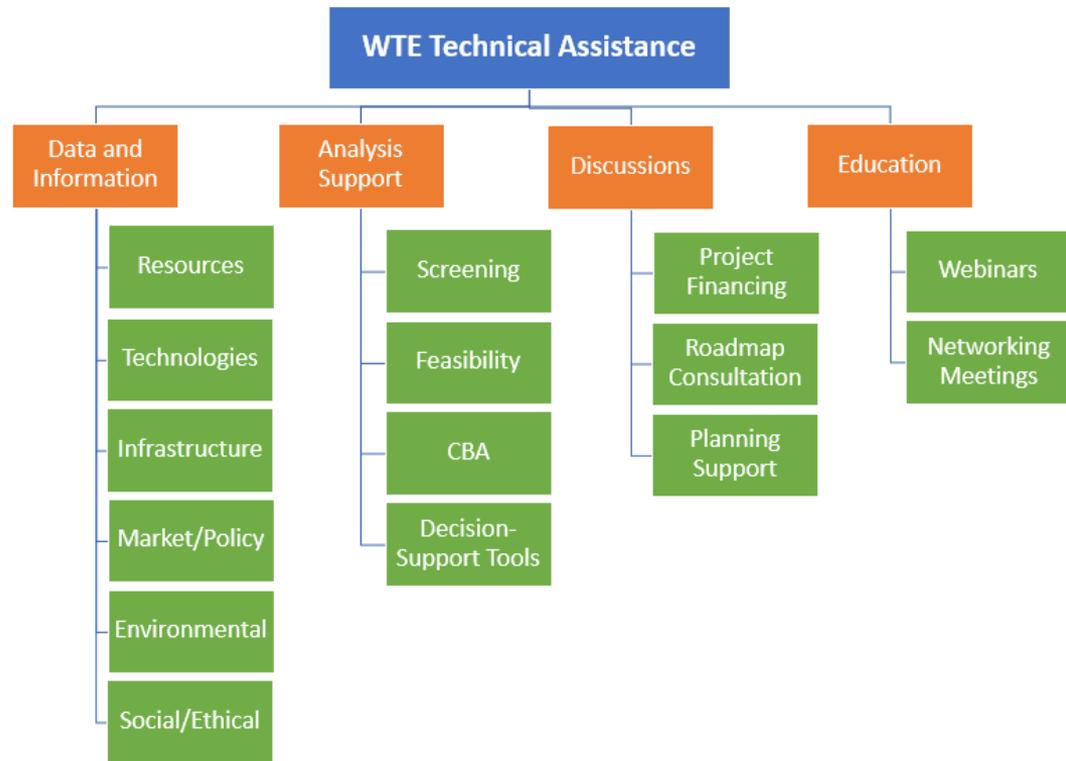
First dedicated WTE TA for local governments to address knowledge gaps, specific challenges, decision-making considerations, and planning

Program Goal

Mobilize data generated on waste resources and provide this data to local decision makers

Program Objectives

- Develop a project web site describing the types of TA available and provide an online application form
- Complete TA for as many awardees as budget allows
- Summarize key results of the TA (e.g., most frequent requests, biggest issues faced by municipalities, participants feedback, etc.).



3. Impact

CBA and Resource Assessment

- Filling data gaps and **advancing state-of-the-art**, e.g., data at subnational level
- Enabling **development of new waste-based fuels and chemicals industries** that can reduce GHG, create employment, and add to GDP, and lead to **commercialization of waste resources**
- Support decision-making and investment strategies, e.g., siting of new conversion facilities
- Help prioritize cost-effective pathways for waste management



Source: University of California- Santa Cruz

WTE TA

- Enable energy and/or resource recovery at the municipal level
- Deploy developed analyses and **test applications in real world**
- Foster public-private **partnerships**

3. Impact (cont.)

- Waste resource data **inform other BETO research activities** (e.g., BOTTLE Consortium, Feedstock-Conversion Interface Consortium, etc.)
- Support **BETO's strategic R&D decisions**:
 - Providing better understanding of the resource, market, and economic potential of waste streams
 - Providing better understanding of urban challenges and priorities related to waste management

Stakeholder Outreach and Engagement

- Publish papers and present at relevant conferences/meetings
- Publish data in Bioenergy KDF, Bioenergy Atlas, AFDC, etc.
- **Regular contact with industry**, public institutions, and NGOs to seek feedback on our analysis approach and results
- The WTE TA will involve **direct work with municipalities**

4. Progress and Outcomes

All FY2019 and FY2020 milestones in the PMP have been completed. Key milestones include:

- ✓ Prepare a draft manuscript on the CBA of food waste management pathways
- ✓ Prepare a draft manuscript on plastic waste assessment
- ✓ Develop a WTE TA web site mockup

Major Accomplishments

- ✓ Conducted a CBA for 21 food waste disposal and utilization pathways
- ✓ Developed a detailed assessment of select MSW resources at a fine geographic level
- ✓ WTE TA is underway

New Data and Knowledge

- Detailed economic data for 21 food waste management pathways
- Apple-to-apple comparison of 21 food waste management pathways
- Database of landfilled plastic, paper/cardboard, and wood waste on-site, by county, and state
- Estimates of the market and energy value of select landfilled waste streams

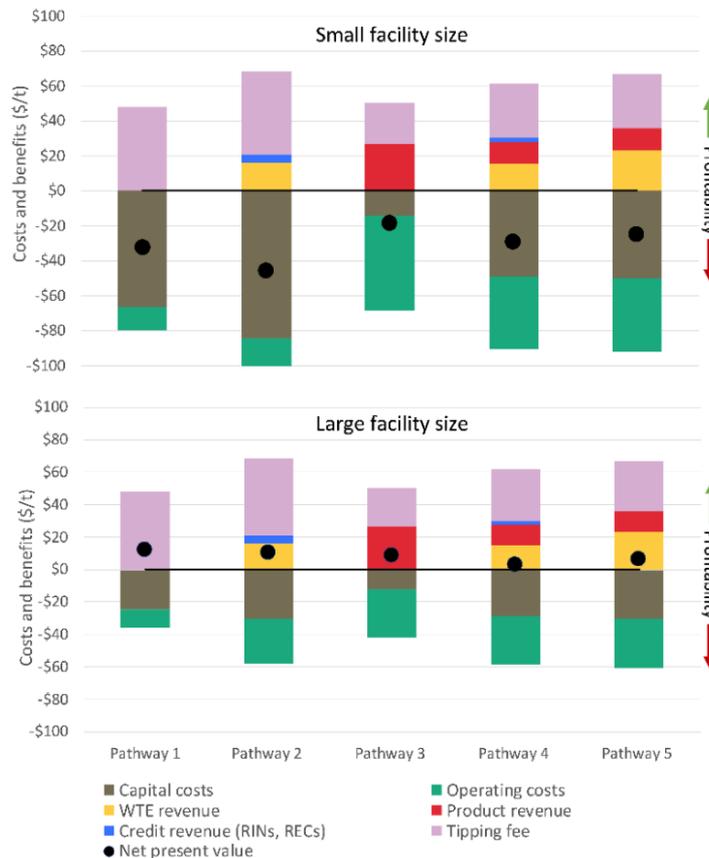
4. Progress and Outcomes: CBA of Food Waste Management Pathways

Results for 21 pathways at national and state level at various capacity

- Landfilling: flare, electricity, CHP, CNG, and pipeline injection
- Compost: windrow, in-vessel, and aerated static pile
- AD (dry and wet): flare, electricity, CHP, CNG, and pipeline injection
- Incineration: electricity, CHP
- HTL: biocrude

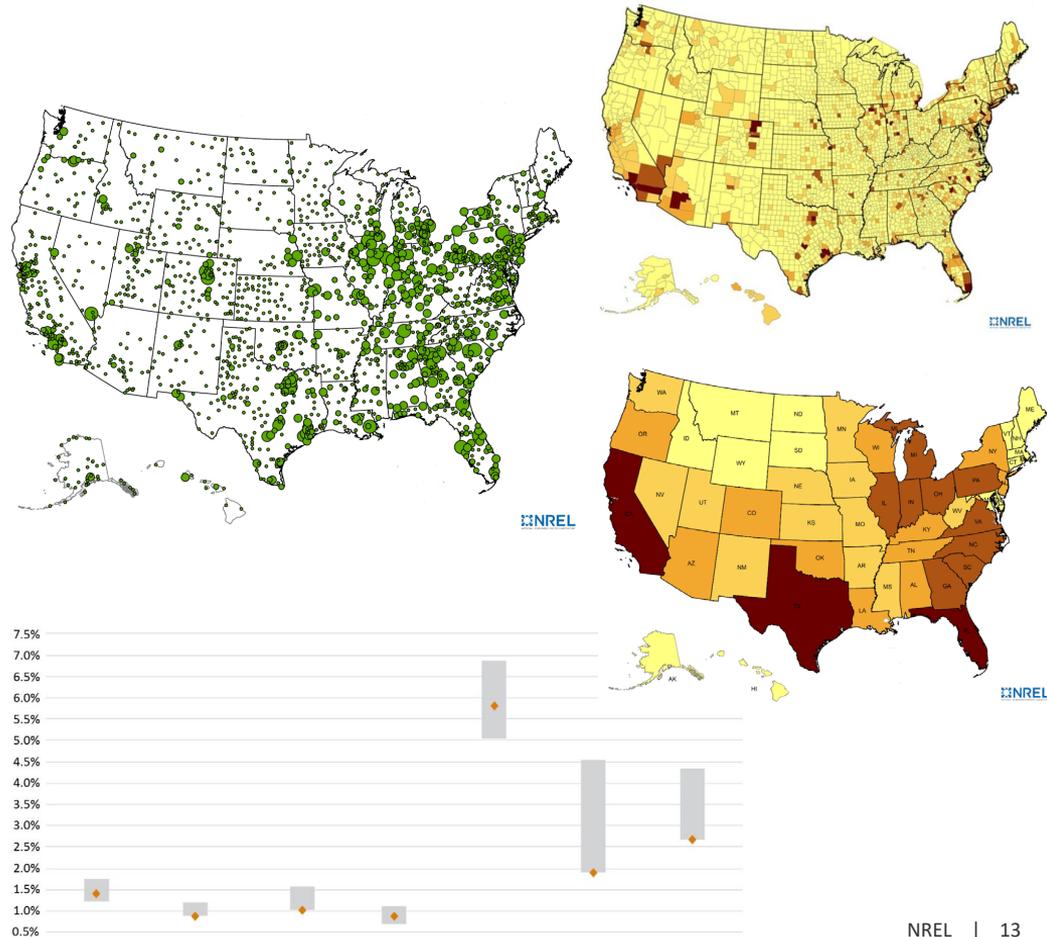
Key results

- For a pathway to break even it requires: 1) Tipping fee, 2) A facility of particular scale (larger facilities are able to offset costs easier), and 3) Revenue streams from product sales
- Results vary by capacity and geographic location (geographic variance stems from differences in tipping fees, fuel/energy prices, and local wages)



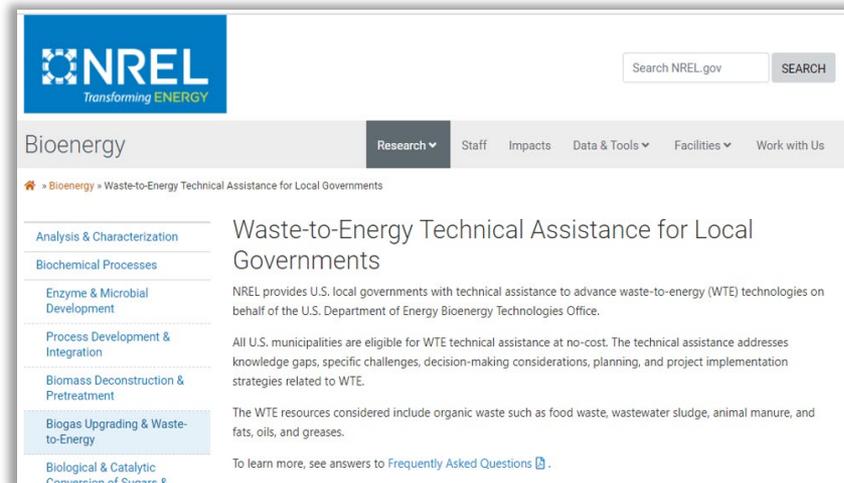
4. Progress and Outcomes: Assessment of Plastic, Paper/Cardboard, and Wood Waste

- Results at various geographic level
- Large amount of these materials are landfilled, larger than EPA national estimates
- Recycling rate is smaller than reported by the EPA (using the same data sources)
- Geographic distribution follows population patterns (with some exceptions)
- The landfilled materials evaluated here represent a notable resource lost to the economy: its market and energy value can't be recovered
- Sensitivity analysis results:  estimates close to actual values for some material, a range for other materials

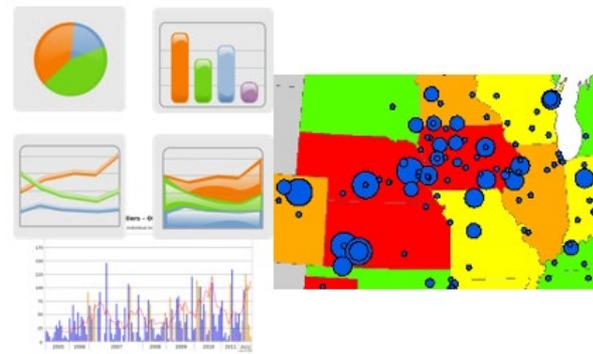


4. Progress and Outcomes: WTE TA for Local Governments

- Developed the WTE TA web site and application form
- Prepared detailed FAQ document
- Set up an informational webinar
- Defined selection criteria for applications, e.g., merit, impact, diversity in geography, size, etc.
- Coordinated efforts with other DOE programs, the Weatherization and Intergovernmental Programs (WIP) Office and the Office of Indian Energy Policy and Programs
- Launching the Program
- Next steps:
 - Work with municipalities to address their challenges and priorities related to waste management
 - Solicit feedback to evaluate the program and inform future research



The screenshot shows the NREL website interface. At the top left is the NREL logo with the tagline "Transforming ENERGY". To the right is a search bar with the text "Search NREL.gov" and a "SEARCH" button. Below the logo is a navigation menu with "Bioenergy" selected, and other options like "Research", "Staff", "Impacts", "Data & Tools", "Facilities", and "Work with Us". The main content area is titled "Waste-to-Energy Technical Assistance for Local Governments" and includes a sidebar with categories like "Analysis & Characterization", "Biochemical Processes", "Enzyme & Microbial Development", "Process Development & Integration", "Biomass Deconstruction & Pretreatment", "Biogas Upgrading & Waste-to-Energy", and "Biological & Catalytic Conversion of Sugars &". The main text describes the program's purpose and eligibility criteria.



Summary

Management: Strong communication, solid PMP including risk identification and mitigation strategies, close monitoring of budget and schedule

Approach: Advancing state-of-the-art by providing data and analyses at a fine geographic resolution

Impact:

- Enable development of new waste-based industries which leads to commercialization of waste resources
- Support BETO and industry strategic decisions
- Direct work with municipalities supports work on the ground for real world impact

Progress and Outcomes:

- All milestones completed
- Meeting our goal: developed foundational data, strategic analyses, and outreach related to WTE resources to support further development of the WTE industry
- First dedicated WTE TA for local governments is underway

Quad Chart Overview

Timeline

- Project start date: 2015 (Q4)
- Project end date: 9/30/2021

	FY20	Active Project
DOE Funding	\$300k	\$2,060k

External Project Advisors: Waste Management Inc., The Recycling Partnership, Covanta, EPA, Eastern Research Group, BioCycle Magazine

Project Collaborators: PNNL's resource and TEA teams, NREL's system dynamics and TEA teams

Barriers addressed

Ft-A. Feedstock Availability and Cost

At-A. Analysis to Inform Strategic Direction

Project Goal

Provide foundational data, strategic analyses, and outreach related to WTE resources to support further development of the WTE industry

End of Project Milestone

- CBA and MSW assessments completed and published
- WTE TA completed and a summary of key results prepared

Funding Mechanism

Seed project, FY15

Full project, FY16-FY17

Lab call, FY18-FY20

Lab call, FY21

Thank you!

www.nrel.gov

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 the DOE 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. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.



Additional Slides

Responses to Previous Reviewers' Comments

- It would be helpful to see a specific list of tasks, milestones, and schedule for this project, which would allow one to get a better feel for whether the team has achieved its initial goals and whether there is sufficient time to complete the remaining work. *Response: Apologies for not including more information on milestones and schedule. The project is scheduled to continue through year 2020, which will allow us to complete all planned work.*
- It would be useful to overlay these maps to regional landfill locations, capacities, and trends and provide at least a qualitative direction on landfill disposition. *Response: We agree with the reviewers' recommendation to analyze landfill locations, capacities, and trends; it is currently ongoing under the cost-benefit analysis task.*
- **Go/No-Go Review:** Analysis rigor meets BETO and the stakeholder community expectations. BETO decision: Proceed.

Milestones and Metrics

Milestone	Title/Description	Due Date	Completed
FY19 Q2	Summarize data findings to analyze the cost and benefit streams for biofuels pathway (HTL)	3/31/2019	On time
FY19 Q3	Summarize data findings to analyze the cost and benefit streams for incineration pathway	6/30/2019	On time
FY19 Q4	Draft estimates of total available woody MSW, paper and plastic resources are compiled at a county level. Partial net availability analysis (few regions) is able to differentiate types of plastics and papers that are currently disposed of at landfills and recycled.	9/30/2019	On time
FY20 Q1	Draft manuscript titled "Cost-Benefit Analysis of Food Waste" which will summarize the results from the 5 pathways analyzed under this project: landfilling, AD, composting, incineration and biofuels (HTL).	12/31/2019	On time
FY20 Q2	Summarize data findings related to the total and net availability of woody MSW, paper, and plastics	3/31/2020	6/4/2020 (delay due to staff's schedule adjustments related to COVID-19)
FY20 Q3	Summarize data findings related to woody MSW, paper and plastics market prices	6/30/2020	On time
FY20 Q4	Draft manuscript titled "Assessment of Plastics in the United States: Generation, Recycling Rates, Disposal, Value, and Availability for Advanced Conversion Technologies"	9/30/2020	11/15/2020 (delay due to staff's schedule adjustments related to COVID-19)
FY21 Q1	Mockup of the technical assistance (TA) web site which will include information about the program, description of assistance types, and an online application form.	12/31/2020	On time
FY21 Q2	Launch of the TA web site and summarize initial responses (e.g. number of requests, type of requests, etc.).	3/31/2021	
FY21 Q3	Summarize information about applications received in Q2 and Q3 such as location, size of community, request type, etc.	6/30/2021	
FY21 Q4	Complete TA for as many awardees as budget allows (between 10 and 20) and summarize key results (e.g., most frequent requests, biggest issues faced by municipalities, participants feedback, etc.).	9/30/2021	

Publications, Patents, Presentations, Awards, and Commercialization

- Badgett, A., Milbrandt, A. “Food Waste Disposal and Utilization in the United States: A Spatial Cost Benefit Analysis”. Submitted to *Journal of Cleaner Production*.
- Milbrandt, A., Badgett, A. “Waste Resources Availability and Economic Analysis in the United States”. Presentation at the American Chemical Society’s Green Chemistry Institute 24th Annual Green Chemistry & Engineering (ACS-GCI-GC&E) Virtual Conference, June 16, 2020.
- Badgett, A., Milbrandt, A. “A Summary of Standards and Practices for Wet Waste Streams Used in Waste-to-Energy Technologies in the United States”. *Renewable & Sustainable Energy Reviews*. Vol. 117, January 2020.
- Badgett, A., Newes, E., Milbrandt, A. “Economic Analysis of Wet Waste-to-Energy Resources in the United States”. Presentation at the Water Environment Federation's Technical Exhibition and Conference (WEFTEC) in Chicago, IL. September 23, 2019.
- Badgett, A., Newes, E., Milbrandt, A. “Economic Analysis of Wet Waste-to-Energy Resources in the United States”. *Energy*. Vol. 176, June 2019.
- Milbrandt, A., Coney, K., Badgett, A., Beckham, G. T. “Plastic Waste in the United States: Quantity, Geographic Distribution, Marker and Energy Value”. Manuscript in preparation.
- Milbrandt, A., Badgett, A., Seiple, T. “Market Analysis of Wet Waste-to-Energy Resources in the United States”, Manuscript in preparation.
- Milbrandt, A., Coney, K., Badgett, A. “Wood, Paper, and Cardboard Waste in the United States: Quantity, Geographic Distribution, Market and Energy Value”. Manuscript in preparation.

Abbreviations and Acronyms

AD: Anaerobic digestion
AFDC: Alternative Fuels Data Center
ASP: Aerated static pile (composting)
BETO: Bioenergy Technologies Office
BOTTLE: Bio-Optimized Technologies to keep Thermoplastics out of Landfills and the Environment
CBA: Cost-benefit analysis
CHP: Combined heat and power
CNG: Compressed natural gas
GDP: Gross domestic product
HHV: Higher heating value
HTL: Hydrothermal liquefaction
KDF: (Bioenergy) Knowledge Development Framework
MSW: Municipal solid waste
NPV: Net present value
NGOs: Non-government organizations
NREL: National Renewable Energy Laboratory
PMP: Project management plan
PNNL: Pacific Northwest National Laboratory
QA/QC: Quality assurance/quality control
REC: Renewable energy credit/certificate
RIN: Renewable identification number
SD: System Dynamics
TA: Technical assistance
TEA: Techno-economic analysis
WTE: Waste-to-Energy