NREL
NATIONAL RENEWABLE ENERGY LABORATORY

DOE Bioenergy Technologies Office (BETO) 2019 Project Peer Review

Waste-to-Energy (WTE): Feedstock Evaluation and Biofuels Production Potential - NREL

Waste-to-Energy

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Goal Statement

Goal: Provide foundational data, strategic analyses, and modeling to support further development of the WTE industry.

Outcome: Enable the industry to accurately assess the viability, scale, and sustainability of WTE potential through:

- Nationwide inventory of resource potential and associated feedstock costs
- Identifying areas with highest potential for advanced WTE development
- Understanding the costs and benefits of various food waste utilization options and provide a basis for comparing different applications.

Relevance: By providing relevant data and analysis, this project fills in knowledge gaps and supports decision making for BETO, the bioenergy industry, the waste management industry, investors, and researchers.

Quad Chart Overview

Timeline

- Start: July 2015
- Merit review cycle: FY2017-2019
- 75% complete of review cycle

	Total Costs Pre FY17	FY 17 Costs	FY 18 Costs	Total Planned Funding (FY 19-Project End Date)
DOE Funded	$375k	$300k	$375k	$600k

Partners/Collaborators: PNNL's resource and techno-economic analysis (TEA) teams, NREL's system dynamics and TEA teams.

Barriers addressed

- Ft-A. Feedstock Availability and Cost
- At-A. Analysis to Inform Strategic Direction
- At-E. Quantification of Economic, Environmental, and Other Benefits and Costs

Objective

Assess the availability and economic viability of waste streams for use in advanced WTE systems.

End of Project Goal

- Feedstock cost of wet WTE resources and cost-benefit analysis of food waste are complete and published.
- Resource assessment accounts for all fractions of municipal solid waste (MSW) that are convertible to biofuels and bioproducts and is published.

Project Overview

Context:

- Knowledge gaps regarding volume, availability, location, and price of WTE streams

History:

- Began as joint lab Q4 FY15 start (with PNNL)
- Builds on previous work during FY15 – FY16 which conducted a wet WTE resource assessment
- Builds on NREL's expertise in resource and economic modeling.

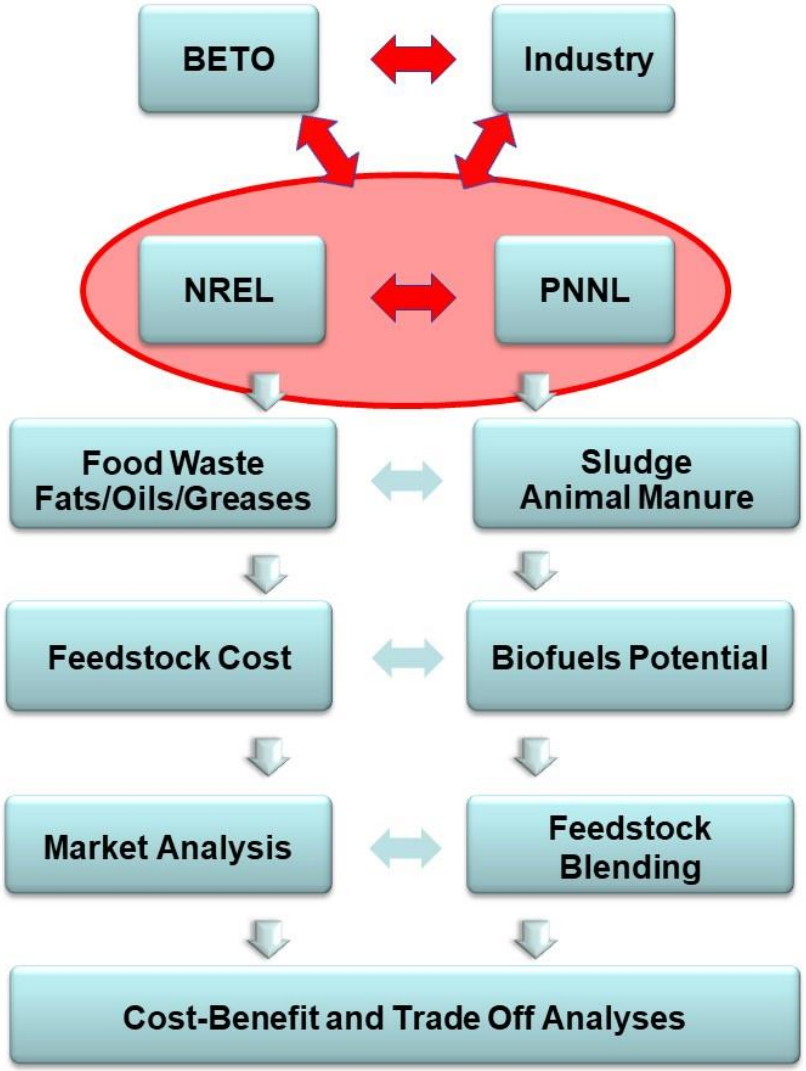
Goal: Provide foundational data, strategic analyses, and modeling to support further development of the WTE industry:

- Resource availability (volume, location, current use)
- Resource cost modeling (feedstock cost and supply curves)
- Resource opportunity analysis ("hot spot" analysis)
- Cost-benefit analyses.

Approach - Management

Strong communication between partners, BETO management, industry and other modeling/research teams.

- Annual NREL, PNNL and BETO team coordination meeting
- Quarterly progress reporting to BETO (in writing)
- Regularly scheduled BETO calls (monthly and as needed)
- NREL-PNNL team calls (as needed)
- Communication with industry members and other private/public institutions: e.g. *Waste Management Inc., Newtrient LLC, Baker Commodities Inc., North Carolina State University, Iowa State University, California Association of Sanitation Agencies, USDA, EPA, East Bay Municipal Utility District, Great Lakes Water Authority.*
- Communication with NREL/PNNL TEA teams and NREL system dynamics modeling team.



Approach - Technical

Unique aspects

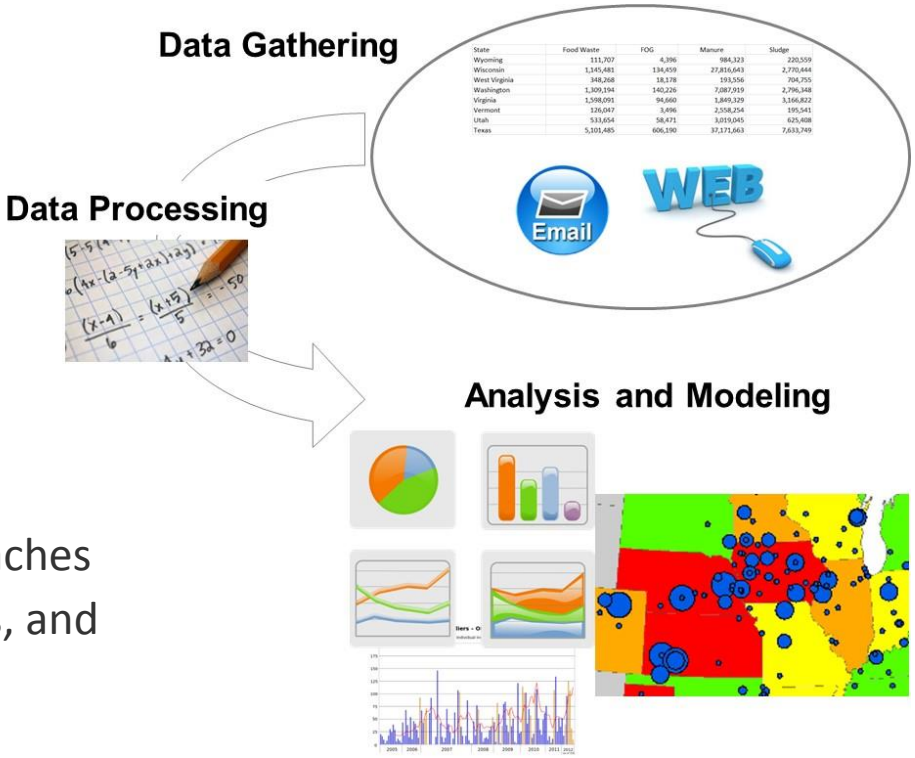
- Rigor in data collection/transformation
- Geospatial analysis and modeling to achieve results at finest resolution (previous estimates at national level).

Challenges

- Data availability (lack of data or gaps)
- Data quality (inaccurate/dated records, time intensive verification process).

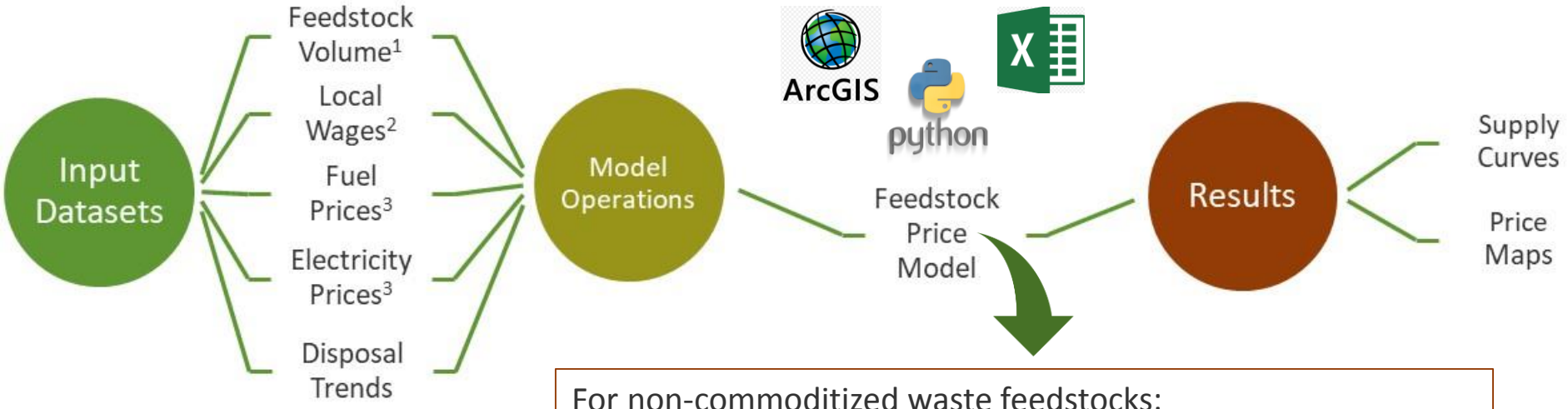
Critical Success Factors

- Industry engagement
- High-quality data
- Retain realism in analytic and model approaches
- Ongoing engagement with TEA, conversions, and system dynamics modeling teams.



Approach – Technical: Wet WTE Resource Prices and Supply Curves

- Wet WTE Resources:
  - Animal manure
  - Sewage sludge
  - Fats, oils and greases (FOG)
  - Food waste



For non-commoditized waste feedstocks:
Price = (Added Pretreatment Costs) – (Avoided Disposal Costs)

For commoditized feedstocks (FOG):
Price = Reported Market Prices

[1] Milbrandt, A., Seiple, T., Heimiller, D., Skaggs, R., Coleman, A., 2018. Wet waste-to-energy resources in the United States. *Resources, Conservation and Recycling* 137, 32–47.
[2] Bureau of Labor Statistics (BLS)
[3] Energy Information Administration (EIA)

Approach – Technical: Wet WTE Resources Opportunity Analysis

- "Hot spot" analysis identifies areas with the best potential for developing advanced WTE technologies
- We developed a set of geospatial models that overlay spatial data to identify "hot spots" or areas with optimal values between the input data
- Geospatial models developed for each wet WTE resource: manure, sludge, FOG, and food waste
- Prior to overlaying the individual datasets, values were ranked, classified and assigned a value used in a weighted overlay function
- The above process is followed by kernel density function that determines the density of points within a defined radius.

Model Input Data

Fuel Demand[1]

Feedstock Supply[2]

Feedstock Price[3]

Relevant Policy[4]

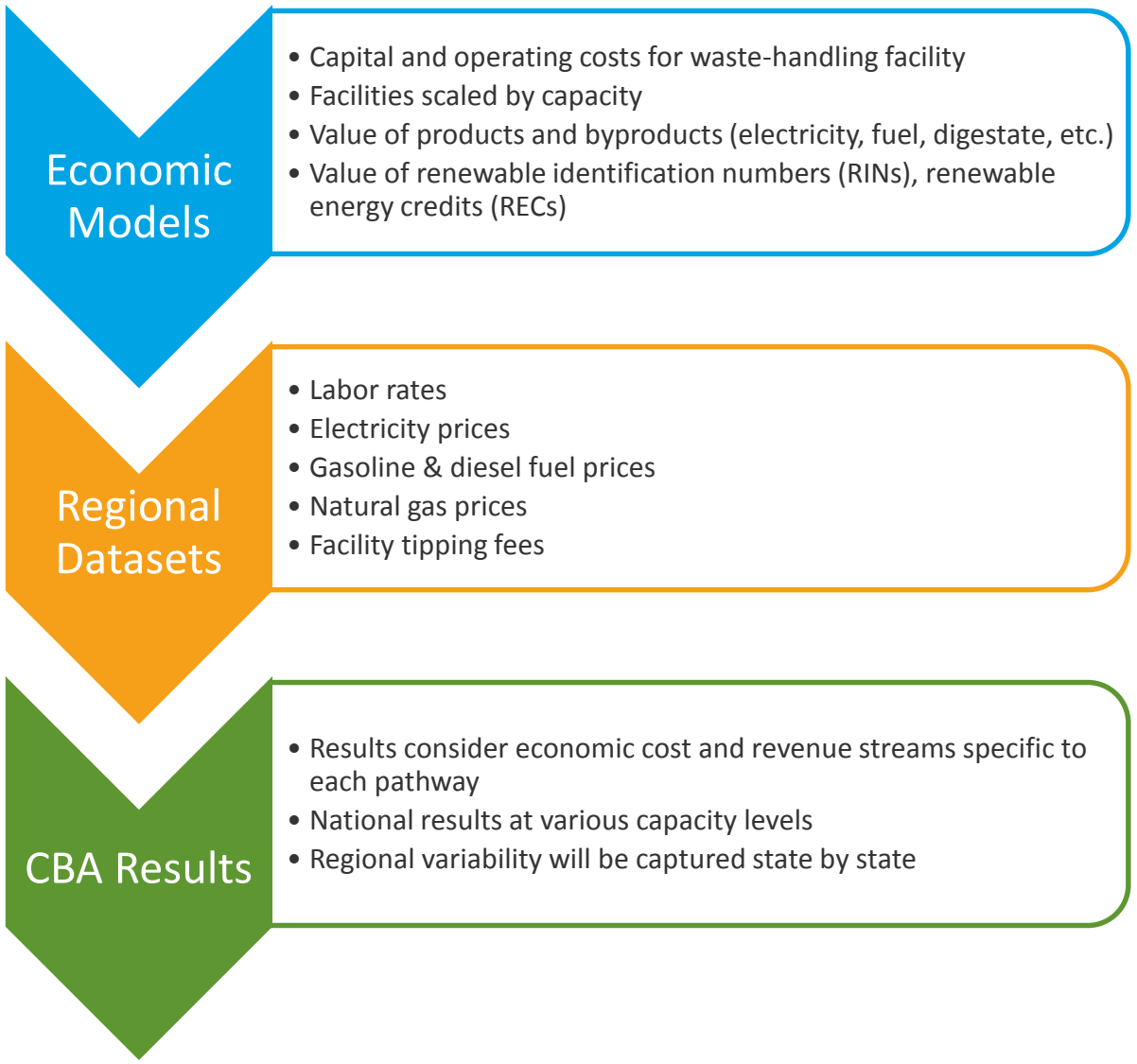
Hot Spots

[1] EIA
[2] NREL, PNNL
[3] NREL
[4] ReFED, USDA, EPA, etc.

Approach – Technical: Cost-Benefit Analysis (CBA) of Food Waste

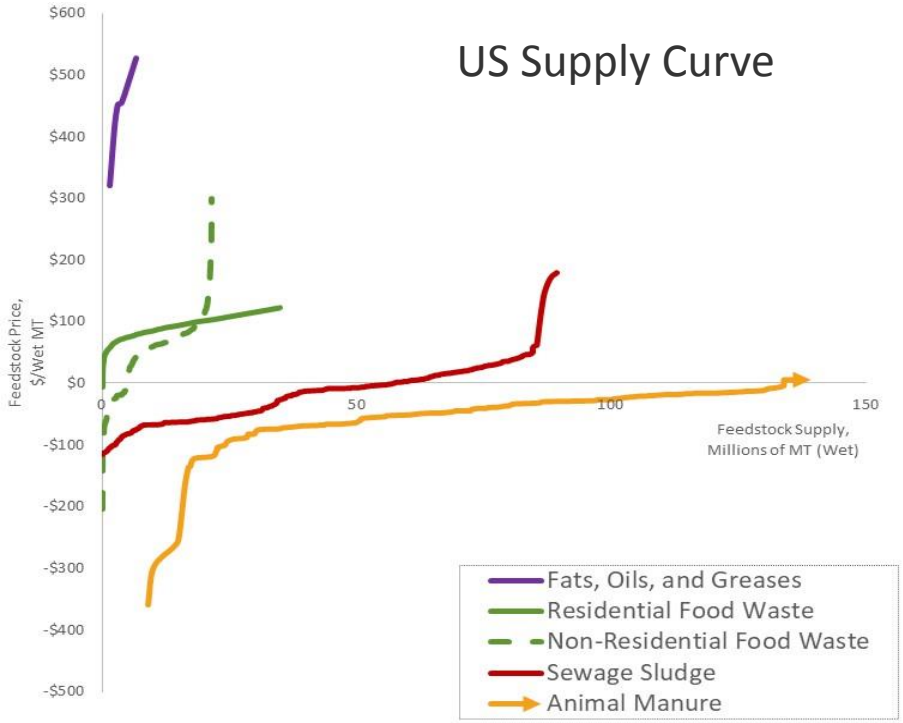
CBA pathways:

- Landfilling (baseline)
- Composting
- Anaerobic digestion
- Incineration
- Biofuels



Accomplishments: Wet WTE Resource Supply Curves

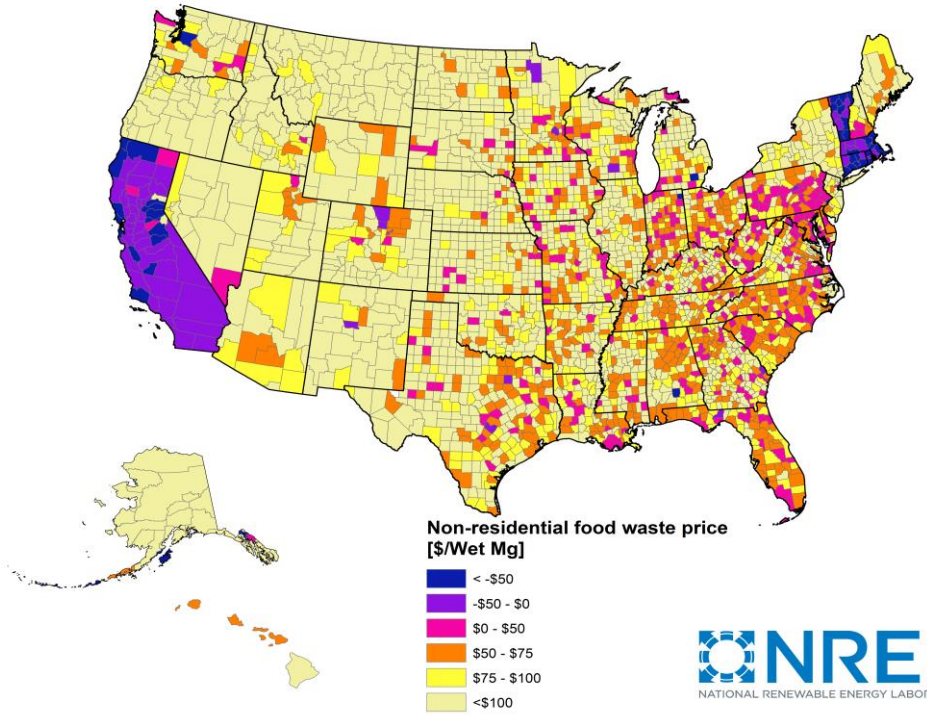
- Resource supply curves developed for the United States and individual states
- Some portion of non-FOG wet WTE feedstock exists at a negative price:
  - ~ 64% of sludge
  - ~ 27% of manure
  - ~ 7% of food waste
- Negative prices indicate:
  - Resource is free
  - A biorefinery could be paid to receive the material because it represents a disposal liability to the producer
- FOG are commoditized thus their prices are determined by market
- FOG (namely brown grease) may have lower or negative prices in certain geographic areas.



Badgett, A., Newes, E., Milbrandt, A. "Economic Analysis of Wet Waste-to-Energy Resources in the United States." Submitted to *Energy*.

Accomplishments: Wet WTE Resource Prices

- Price maps developed for each feedstock, except FOG
- If a resource has been commoditized (e.g. FOG), its price is determined by market demand
- If a resource is regarded as waste, its price is driven by the cost of its disposal
- With the exception of animal manure, negative prices occur in areas with:
  - Organic waste disposal bans
  - High landfill tipping fees
  - Population centers with high waste volume and disposal costs

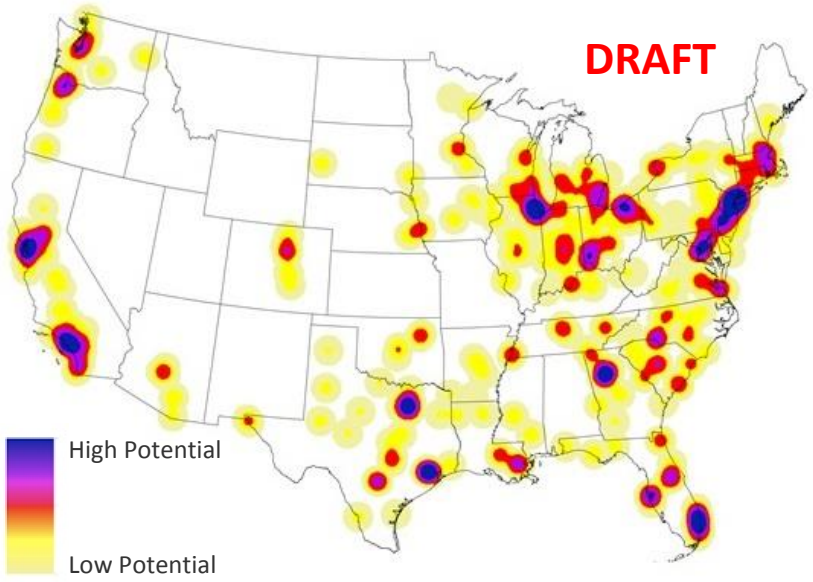


Badgett, A., Newes, E., Milbrandt, A. "Economic Analysis of Wet Waste-to-Energy Resources in the United States." Submitted to *Energy*.

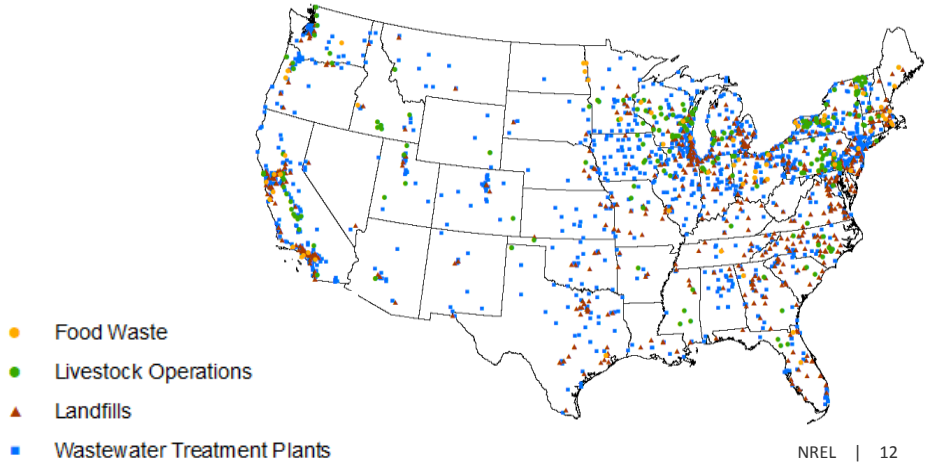
Accomplishments: Wet WTE Resources Opportunity Analysis

- "Hot spot" analysis maps for advanced WTE development are created for each resource
- Combined map with all resources illustrates blending opportunities
- High and very high potential is present in many states
- High and very high potential follows population dynamics where fuel consumption is also high
- Competing uses of wet WTE resources (e.g. biogas production) is also considered
- Final analysis results illustrate locations with high and very high potential and low resource competition.

Example: Sludge Opportunity Analysis



Competition: Existing Biogas Plants



Milbrandt, A., Badgett, A., Seiple, T., Skaggs, R. "Wet Waste-to-Energy Resources Opportunity Analysis". In preparation.

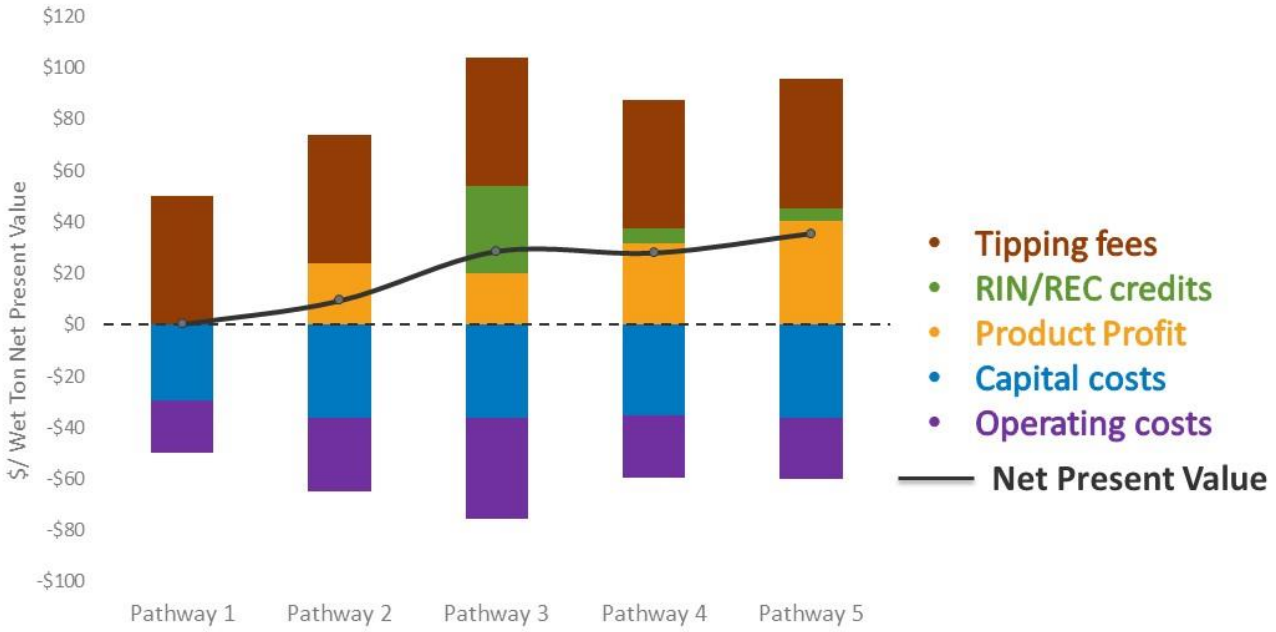
Accomplishments: Cost-Benefit Analysis of Food Waste

- Completed baseline, anaerobic digestion and composting models
- Provided BETO with preliminary results at a national and state level
- Preliminary results:
  - For a pathway to break even, it requires: 1) tipping fee, 2) a facility of particular scale [larger facilities are able to offset their costs easier] and 3) value of products
  - Geographic variances in pathways stem from differences in tipping fees, fuel/energy prices, and local wages.

Conceptual Results for a Facility with 100,000 t/yr Capacity

➢ Product sales increase the net present value of projects

➢ Results at various capacity and geographic levels.



Relevance

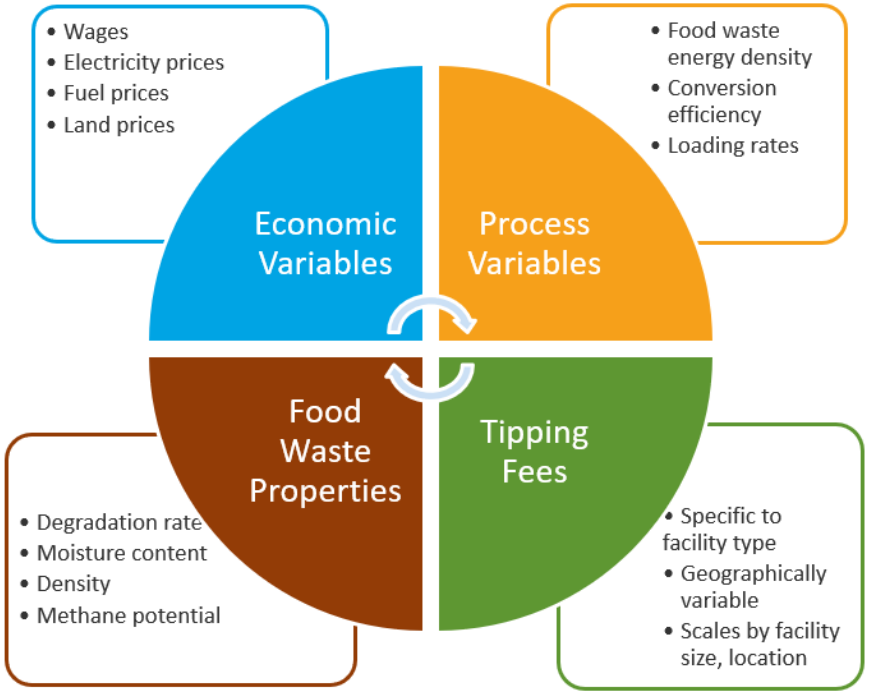
- **Filling gaps** that exist both in the knowledge of BETO as well as the industry
- To **enable the development of new technologies**, there is a need to understand the potential volume, availability, location, and price associated with WTE streams
- Getting this information out to the public is critical to further **enable the growth of these underutilized sources** and to support their conversion into clean energy alternatives
- Support the **bioenergy industry**:
  - Resource evaluation (first step in any feasibility study)
  - Feedstock cost information that is currently unavailable
  - Relevant data and analyses to support decision-making.
- Support the **waste management** industry as it explores opportunities to treat waste streams as energy sources (by providing information on biofuels production potential)
- WTE feedstock volume and price data **informs other BETO modeling and research activities** (e.g. NREL and PNNL TEA teams, NREL system dynamics modeling team, ANL's bioprocessing group, Co-Optima project, etc.).

Relevance (cont.)

- Support **BETO's strategic R&D decisions**:
  - Understanding of WTE resource potential and economic viability
- BETO's Strategic Plan:
  - Includes wet WTE resources as an element of a strong bioeconomy and states that "**Bioenergy provides value for otherwise problematic waste streams"**
  - Further development of WTE technologies are among the substrategies to reduce cost, improve performance and incorporate sustainability as a market enabler.
- Data and analyses **address the biorefineries' technology uncertainties and risks** related to feedstock availability and cost of production (consistent and affordable feedstock supply), outlined in the 2018 multi-year program plan (MYPP).
- **Stakeholder Outreach and Engagement:**
  - Publish papers and present at relevant conferences/meetings
  - Publish data and analysis results in Bioenergy KDF, Bioenergy Atlas, AFDC, etc.
  - Regular contact with industry and public/private institutions to seek their feedback on our analyses approach and results.

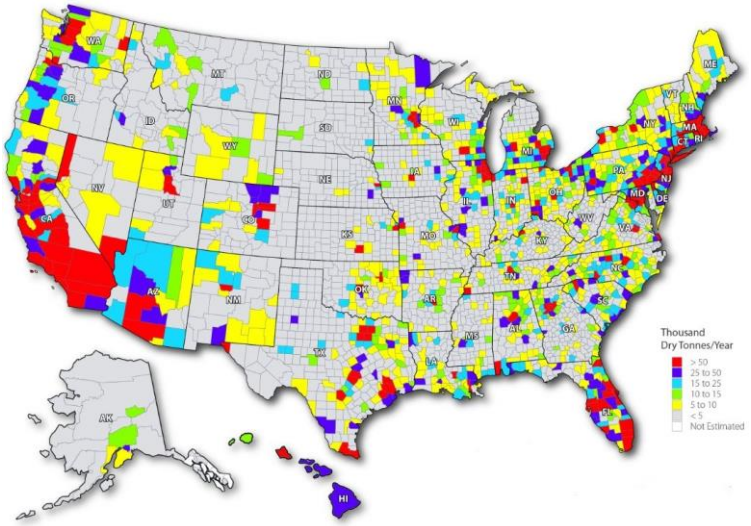
Future Work (FY19 Q2 and Q3)

- Finalize the wet WTE resources “hot spot” analysis
- Develop biofuels and incineration models for the CBA of food waste to achieve a comprehensive understanding of all pathways potential
- Complete sensitivity analyses of key CBA parameters to identify variables that affect the results most and analyze their degree of impact.
- **Stakeholder Dissemination**: Present work to date at the Water Environment Federation's Technical Exhibition and Conference in Chicago September 21-25, 2019



Future Work (FY19 Q4)

- Begin work towards additional WTE resource assessments to provide a comprehensive understanding of the MSW streams available for bioenergy conversions:
  - Woody portion of MSW:
    - Chips, pallets, construction and demolition wood, etc.
    - Update to our 2012 analysis.
  - Plastics:
    - Non-recycled portion
    - About 75% of plastic waste is landfilled (EPA 2015)
    - Assess type and location.
  - Paper:
    - Non-recycled portion
    - About 27% of paper and paperboard is landfilled (EPA 2015)
    - Assess type and location.



Summary

- **Overview**: Provide foundational data, strategic analyses, and modeling to support further development of the WTE industry
- **Approach**: Rigorous resource, economic, and geospatial analyses and modeling with input from key stakeholders
- **Technical Accomplishments/Progress**:
  - Comprehensive estimate of wet WTE resource prices at county level and national/state supply curves
  - Preliminary results of the wet WTE resources "hot spot" analysis
  - Baseline, anaerobic digestion and composting pathway models for CBA of food waste (preliminary results provided to BETO).
- **Relevance**: By providing relevant data and analysis, this project fills in knowledge gaps and supports decision making for BETO, the bioenergy industry, the waste management industry, investors, and researchers
- **Future work**: Finalize wet WTE resources "hot spot" analysis, complete CBA of food waste, update estimates of woody MSW, estimate the availability of non-recyclable plastics and paper.

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David Bielen (former)

PNNL Team

Richard Skaggs (former)
Timothy Seiple
Lesley Snowden-Swan

Public and Private Institutions

Waste Management Inc.
Newtrient LLC
Great Lakes Water Authority
North Carolina State University
EPA
Baker Commodities Inc.
California Association of Sanitation Agencies
East Bay Municipal Utility District
Iowa State University
USDA

Thank You

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Response to Reviewers' Comments 2017

- This needs feedstock costs for TEA relevance (currently unavailable). It would be good to have a clearer methodology for getting that information.
- *Response*: We agree with the reviewers that feedstock cost is very important for TEA. The results of our feedstock cost analysis will be provided not only to the TEA team at Pacific Northwest National Laboratory, but also to the WTE system dynamics modeling team at the National Renewable Energy Laboratory and any other entity requiring that information. Given the time constraints during the Peer Review, we were unable to discuss the details of this task.

Response to Reviewers' Comments 2017

- The specific role of the "system dynamic modeling team" (including their contribution, engagement in the project to date, and plans for future contributions to the project) was not adequately clear.
- *Response*: Our collaboration with the system dynamic modeling team includes data sharing (e.g. the WESyS model includes our resource assessment data) and it will use the feedstock cost data developed by our team. The model will also utilize the results of our opportunities and barriers report, as well as the results of our WTE standards and practices analysis.
- The current reliance on personal communications (including emails and phone calls) is a resource intensive and unreliable method for gathering data. To the degree possible, data gathering should be automated and leverage existing databases, etc.
- *Response:* Our project uses existing databases for the most part. We resorted to personal communication in cases where there were data gaps, no data available (e.g., specifically for rendering plants), or need for site-specific information for validation purposes.

Publications and Presentations

- Skaggs, R., A. Coleman, T. Seiple, A Milbrandt, ”Waste-to-Energy Biofuel Production Potential for Selected Feedstocks in the United States”. *Renewable and Sustainable Energy Reviews*. Volume 82, Part 3, February 2018, Pages 2640-2651.
- Badgett, A., Newes, E., Milbrandt, A. “Economic Analysis of Wet WTE Resources in the United States”. Presentation at BETO Conversion Technologies Laboratory Call. August 13, 2018.
- Milbrandt, A. Seiple, T., Heimiller, D., Coleman, A., Skaggs, R. “Wet Waste-to-Energy Resources in the United States”. *Resources, Conservation & Recycling.* Volume 137, October 2018, Pages 32-47.
- Badgett, A., Newes, E., Milbrandt, A. “Economic Analysis of Wet Waste-to-Energy Resources in the United States.” Submitted to *Energy*.

Abbreviations and Acronyms

AFDC: Alternative Fuels Data Center
AS&T: Allegheny Science and Technology
BETO: Bioenergy Technologies Office
CBA: Cost-benefit analysis
C&D: Construction and demolition
EPA: U.S. Environmental Protection Agency
FOG: Fats, oils and greases
HTL: Hydrothermal liquefaction
KDF: Knowledge Development Framework
MSW: Municipal solid waste
MYPP: Multi-year program plan
NREL: National Renewable Energy Laboratory
PNNL: Pacific Northwest National Laboratory
REC: Renewable energy credit/certificate
RIN: Renewable identification number
TEA: Techno-economic analysis
USDA: U.S. Department of Agriculture
WTE: Waste-to-Energy