U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

U.S. Department of Energy (DOE) Bioenergy Technologies Office (BETO) 2017 Project Peer Review

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

March 7, 2017
Waste-to-Energy

Anelia Milbrandt
National Renewable Energy Laboratory (NREL)

Richard Skaggs
Pacific Northwest National Laboratory (PNNL)

Project Goal

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

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

Relevance: Considerable stockpile of underutilized organic wastes requiring alternative, cheaper, and sustainable solutions to disposal.

Quad Chart

Timeline

- Project start date: 2015 (Q4, seed project); 2016 (full project)
- Project end date: 2018
- Percent complete: 36%

Budget

	Total Costs FY12–FY14	FY15 Costs	FY16 Costs	Total Planned Funding (FY17-Project End Date
DOE Funded	$0k	$75k	$640k	$1.38M

Budget for both labs

Barriers

Rigorous resource assessment of wet WTE feedstocks to address the following:

- Ft A. Feedstock Availability and Cost
- Ft-B. Production
- At-A. Comparable, Transparent, and Reproducible Analyses

Results provide critical information for:

- Ft-E. Feedstock Quality, Monitoring and Impact on Conversion Performance
- Ft-I. Overall Integration and Scale-Up

Partners

- Partners: **NREL, PNNL**
- Other interactions/collaborations: **EPA; USDA; Genifuel; Water, Environment & Reuse Foundation**
- **National Renderers Association**

1 – Project Overview

Context: BETO's objectives in WTE technologies

- Develop comprehensive resource evaluation
- Conduct economic and market assessments.

History: Joint lab Q4 FY15 start—builds on previous work at both labs

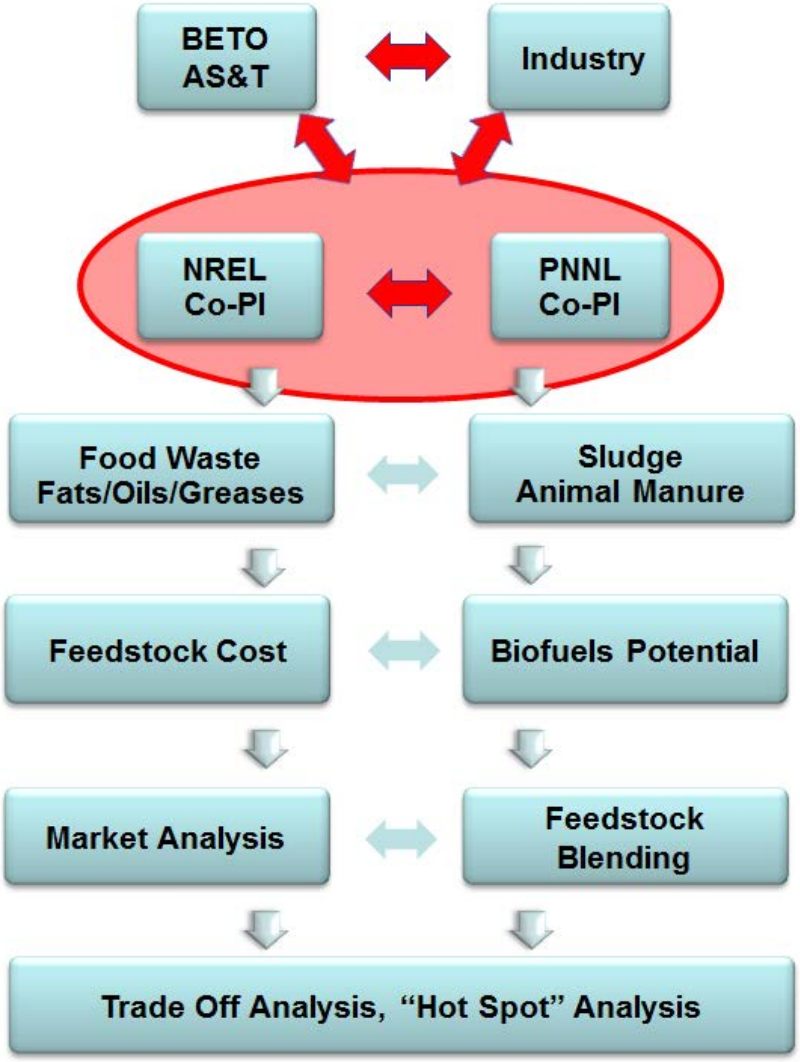
- NREL: Biogas and organic waste estimates
- PNNL: Resource assessment and geospatial analyses of algae and municipal solid waste.

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

- Resource availability (location, composition)
- Economic analysis (e.g., feedstock cost and supply curves)
- Multi-feedstock blending and biofuel production potential
- Market analysis (e.g., opportunities and barriers, "hot spot" analysis)
- Logistics and operations
- Trade-off analyses.

2 – Management Approach

- Annual operating plan and project management plan prepared prior to each fiscal year
- Go/no-go decision point to assess project value and direction
- Quarterly progress reporting to BETO (in writing)
- Regularly scheduled BETO calls (monthly and as needed)
- Regularly scheduled NREL-PNNL team calls (bi-weekly and as needed)
- Bi-annual project team and BETO team coordination workshops
- Communication with industry members as needed.



2 – Technical Approach

Unique aspects

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

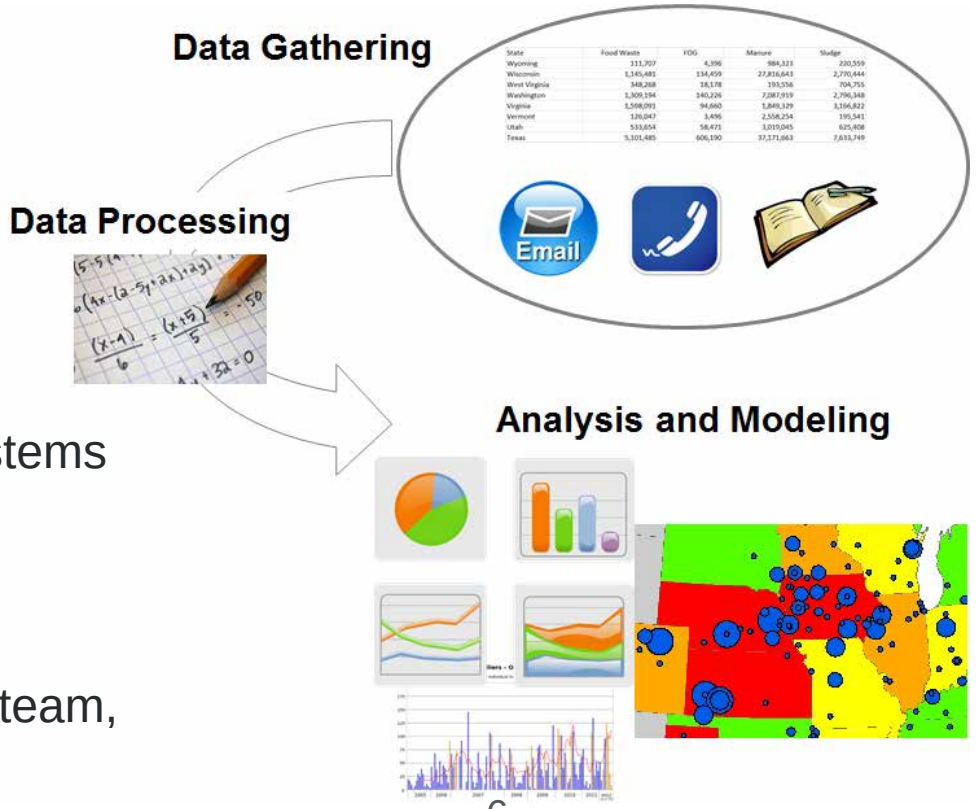
Challenges

- Data availability
- Data quality.

Critical Success Factors

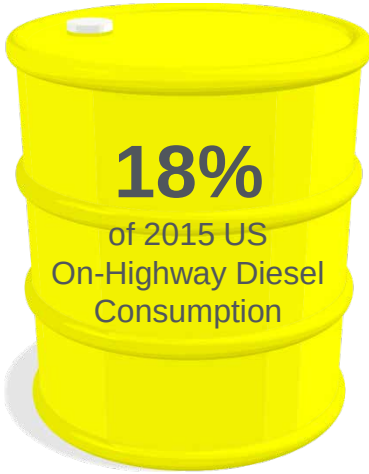
- Industry engagement
- High-quality data
- Advanced understanding of WTE systems
- Retain realism in analytic and model approaches
- Ongoing engagement with techno-economic analysis team, conversion team, and system dynamic modeling.

Original research based on industry input



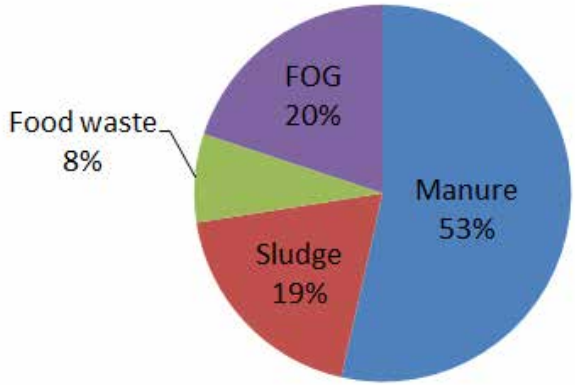
3 – Progress and Results

Wet WTE resources have the equivalent energy content of about one quad or 7 billion diesel gallon equivalent (DGE) per year.



- Wet WTE resources include:
  - Animal manure
  - Fats, oils, and greases (FOG)
  - Wastewater sludge
  - Food waste.
- About half of this potential is generated by animal manure
- Geographic distribution of these resources is driven by relevant activities – agricultural, industrial, and urban.

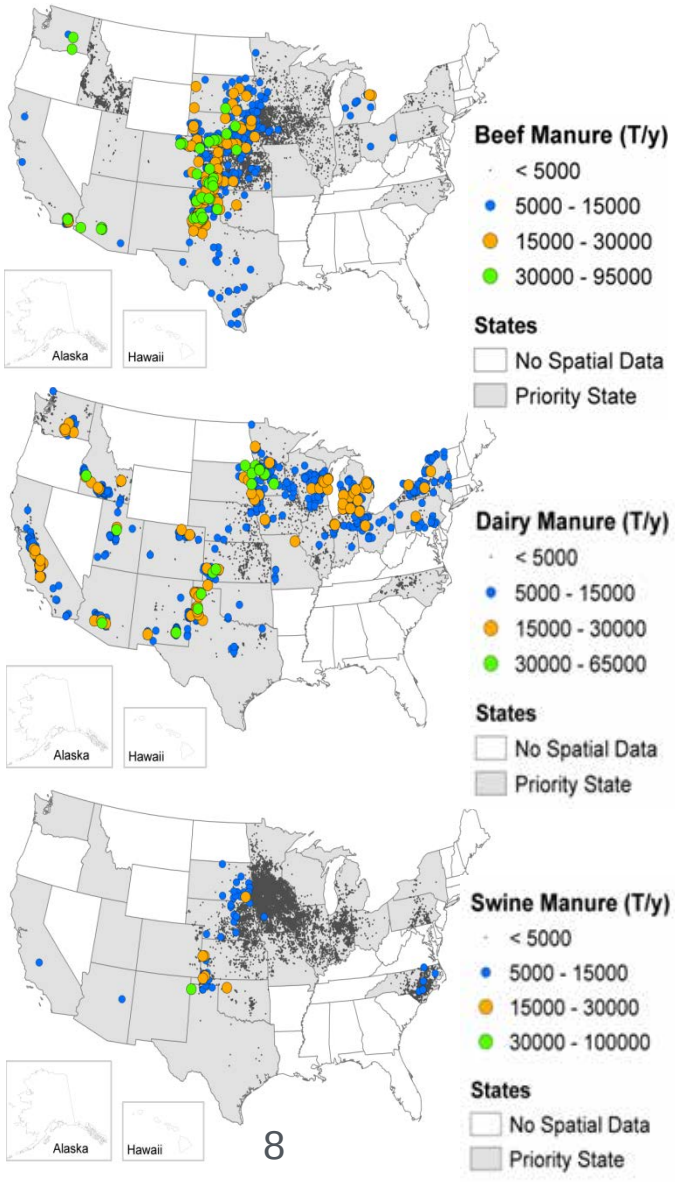
Wet WTE Resource Potential



Milbrandt et al. 2017. Pending publication. *Biomass and Bioenergy*.

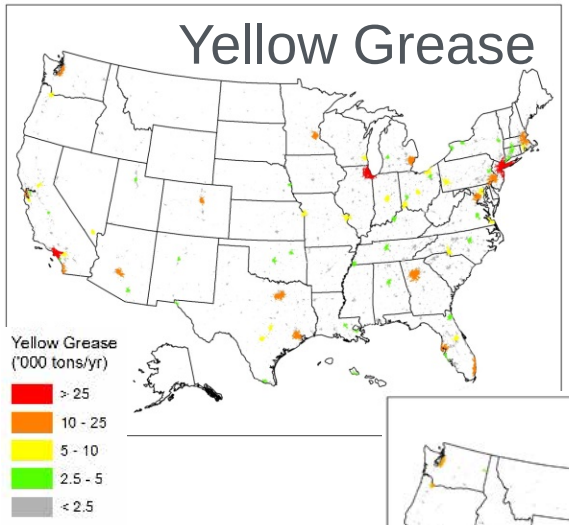
3 – Progress and Results: Completed Animal Manure Estimate

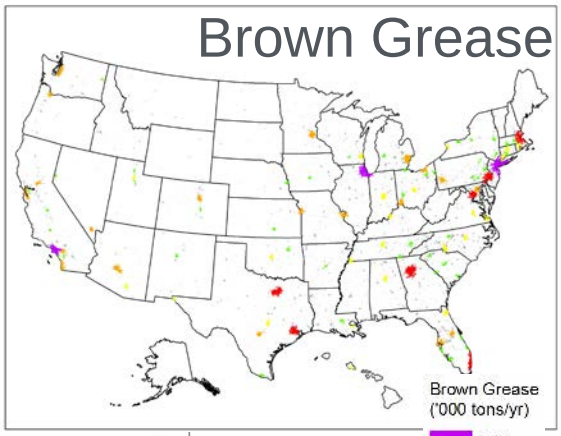
- Organic material containing nitrogen, phosphorus, potassium, and other nutrients
- Focus on feedlot beef, dairy cows, and swine
- Confined livestock produced 41.5 million dry tons per year (MdT/y) of recoverable manure in 2016, equivalent to about **3.8 billion DGE or half of total wet WTE** resource potential
- **First national siting** of manure at point scale (32,176 locations)
- Land application is the most common disposal pathway
- About 4.6% of confined recoverable manure is used for on-farm energy recovery (anaerobic digestion).

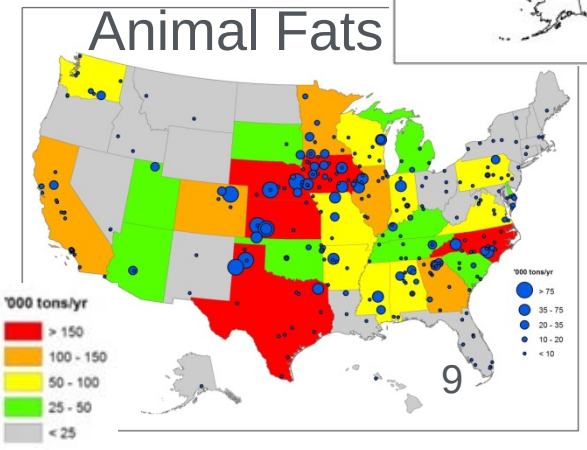


3 – Progress and Results: Completed FOG Estimate

- Generated during food preparation at food service establishments and at rendering plants
- This analysis includes yellow grease (refined used cooking oil), brown grease (trap/interceptor grease), and inedible animal fats
- About 5.9 million tons generated annually, equivalent to about **1.4 billion DGE or 20% of total wet WTE** resource potential
- **First estimate** of FOG below national level
- About 88% of yellow grease is already used by various industries and export
- About 65% of poultry fat is currently used (e.g., animal feed, small portion for biodiesel production and export)
- Brown grease is underutilized.

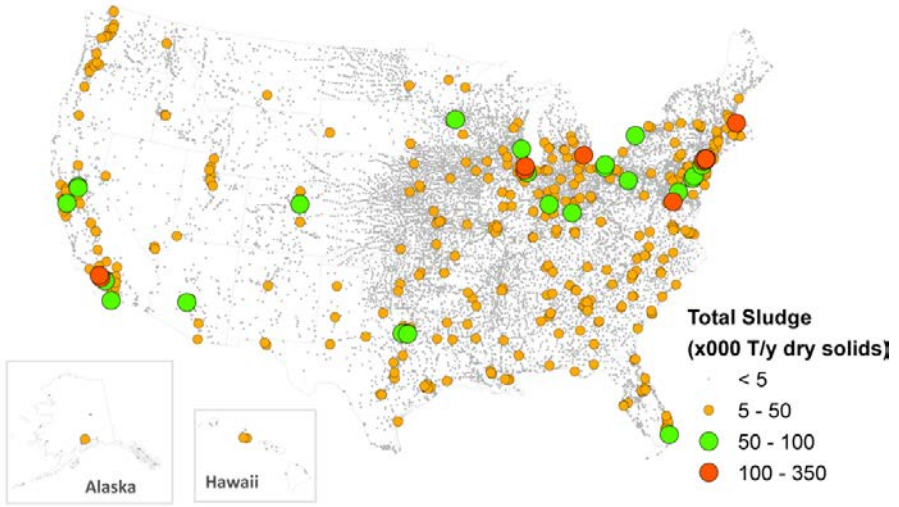




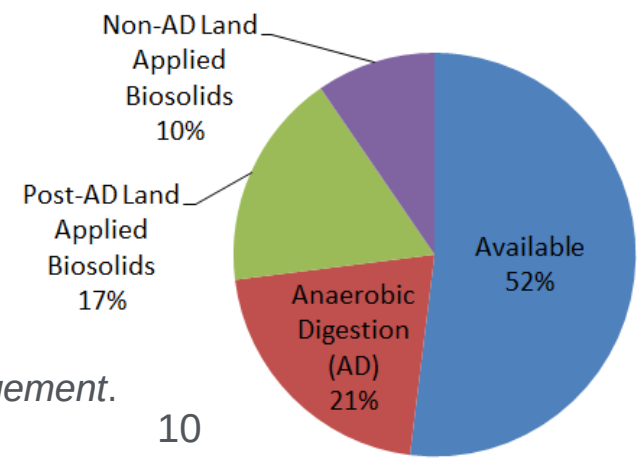


3 – Progress and Results: Completed Sludge Estimate

- Sewage sludge and biosolids are distinct material streams from a WTE perspective:
  - **Sewage sludge** includes untreated solids that remain after wastewater processing
  - **Biosolids** are treated sludge (to remove pathogens) that meet standards for beneficial use or disposal.
- About 15,000 publicly owned treatment works produce 14.7 MdT of sludge per year, equivalent to about **1.4 billion DGE or 19% of total wet WTE** resource potential
- Approximately 52% of total sludge has no direct competitive use.



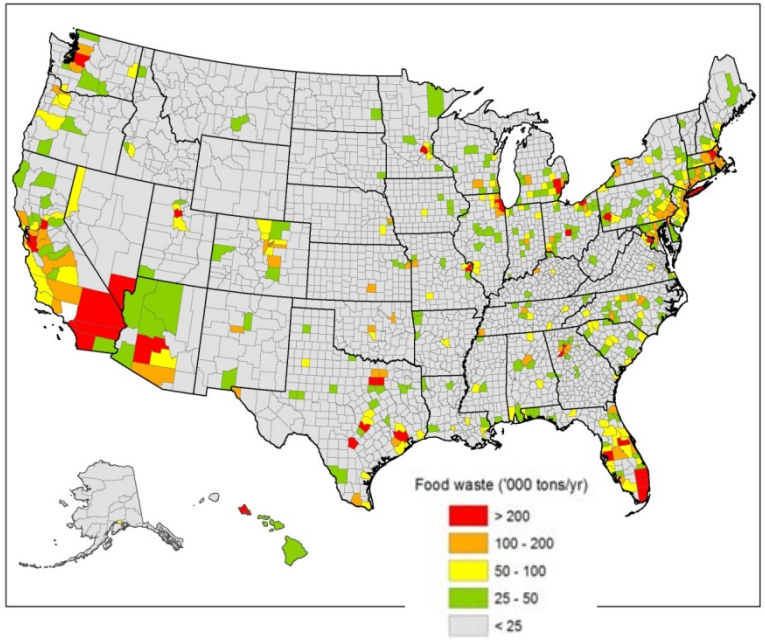
Current Uses for Sludge



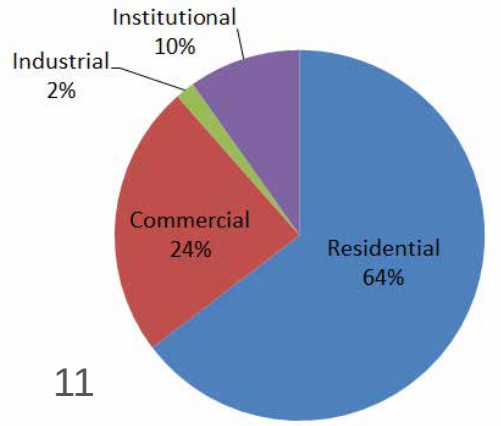
Seiple et al. 2017. Pending publication. *Journal of Environmental Management*.

3 – Progress and Results: Completed Food Waste Estimate

- Four primary sources—industrial, institutional, commercial, and residential
- About 61.2 million wet tons* of food waste is generated annually, equivalent to about **550 million DGE or 8% of total wet WTE** resource potential
- Residential food waste accounts for about two-thirds of all food waste
- About 57% of the estimated food waste is currently destined for landfills—this material is essentially available for alternative uses such as biofuels production.



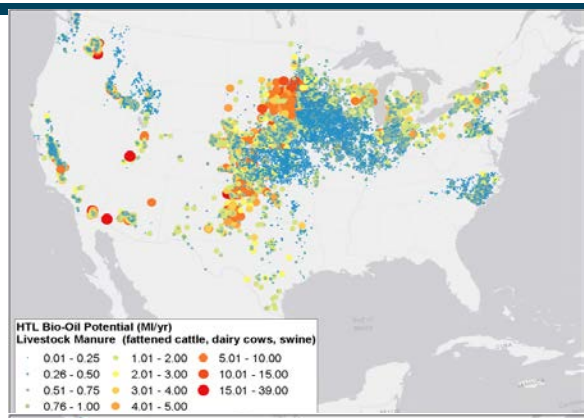
Food waste generated in the US by source

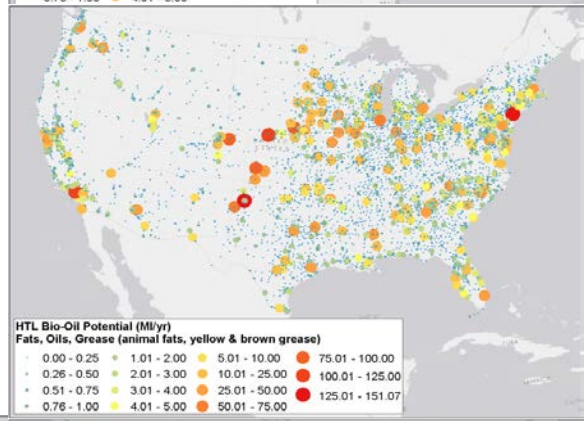


*About 15.3 MdT/y, assuming 75% moisture content.

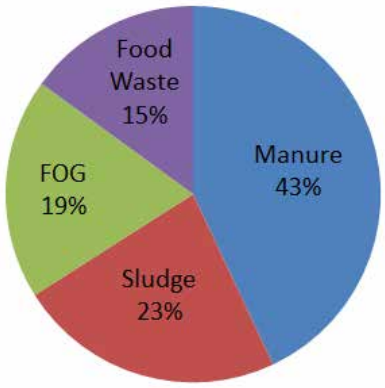
3 – Progress and Results: Completed Biofuels Potential Estimate

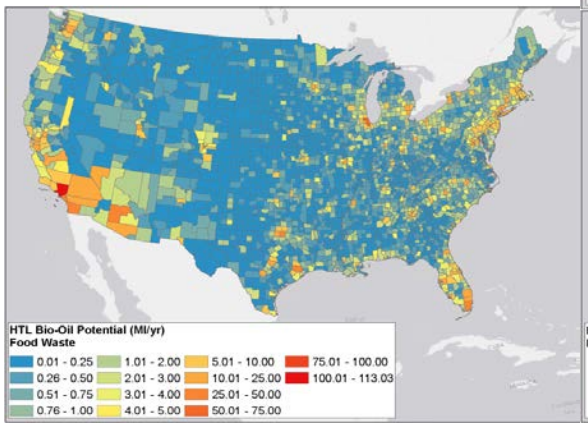
- Assumed hydrothermal liquefaction (HTL) as "baseline" conversion technology pathway
- Reduced form, regression-based conversion model: Yield = f (lipid, protein, carbohydrate)
- Annual average production potential: 6 billion gallons of biocrude or about **6 billion DGE**, equivalent to **15% of 2015 U.S. on-highway diesel fuel consumption.**

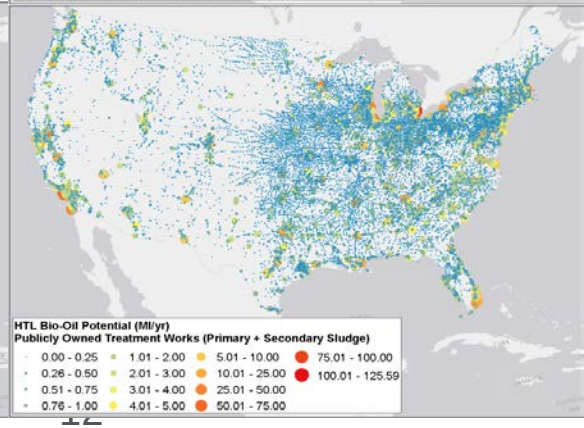




WTE HTL Bio-Oil Potential







Skaggs et al. 2017. Pending publication. *Renewable and Sustainable Energy Reviews*.

4 – Project Relevance

WTE = Reduce Waste Disposal + Energy Production

- Support the **bioenergy industry**:
  - Resource evaluation (first step in any feasibility study)
  - Feedstock cost information that is currently unavailable
  - Conversion technology development (enable focus on most promising feedstocks for biofuel production)
  - Relevant data and analysis to support decision-making.
- Support the **waste management** industry as it explores opportunities to treat waste streams as energy sources
- It is likely that these waste streams are cheaper than terrestrial feedstocks therefore may be candidates for early commercialization
- Advanced WTE technologies, such as HTL, give us access to diesel and jet fuel markets which are growing fuel markets in the country.

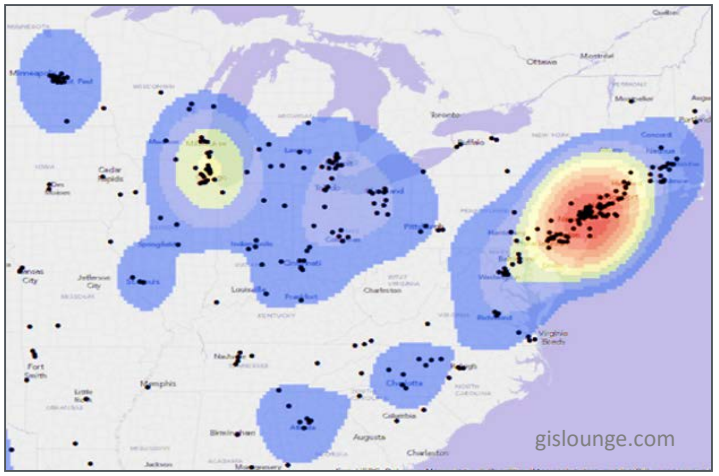
4 – Project Relevance (cont.)

- **Foundational study:**
  - Supports BETO's strategic R&D decisions
  - A building block of BETO's "Biofuels and Bioproducts from Wet and Gaseous Waste Streams: Challenges and Opportunities" report, January 2017.
- **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.
- The 2016 multi-year program plan (MYPP) categorizes wet WTE as an "**emerging area**" and states that "these materials may contribute significantly to bioenergy goals" and "may also prove to be **more amenable to conversion** processes than raw lignocellulosic materials."

5 – Future Work

FY17: Utilize knowledge gathered in FY16 to further our understanding of WTE viability for transportation fuels production:

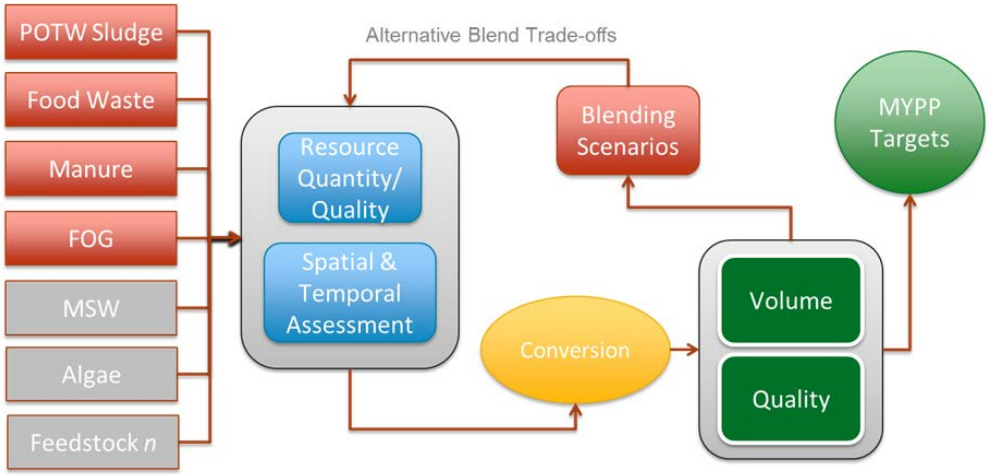
- Estimate wet WTE feedstock cost and develop supply curves
- Analyze opportunities and barriers associated with producing transportation fuels from waste
- Evaluate blending strategies
- Conduct scenario analysis of biofuels production potential at enterprise level relevant to BETO's MYPP target
- **Stakeholder Dissemination**: Present work to date at Water Environment Federation's Residuals and Biosolids Conference in Seattle April 8–11, 2017.

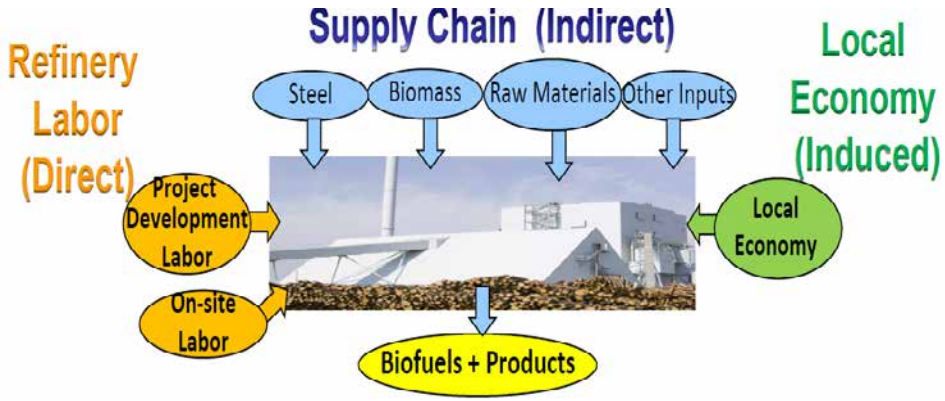


5 – Future Work (cont.)

FY18: Address emerging questions about WTE logistics, operations, and impacts:

- Evaluate supply chain logistics, handling, and pre-processing requirements
- Evaluate environmental sustainability trade-offs
- Evaluate socio-economic benefits (e.g., job development, rural development)
- Trade-off analyses to evaluate "**best sites**" to achieve targets and support decision-making.





Summary

- **Overview**: Provide foundational data, strategic analyses, and resource assessment modeling to support further development of the WTE industry
- **Approach**: Comprehensive and rigorous research with input from key stakeholders
- **Technical Accomplishments/Progress**:
  - Comprehensive wet WTE resource assessment (total and net potential)
  - Estimate of the biofuels potential from wet WTE sources via HTL conversion process.
- **Relevance**: By providing relevant data and analysis, this project supports decision making for BETO and the bioenergy industry
- **Future work**: Economic analysis, market analysis, blending opportunities analysis, logistics/operations analysis, trade-offs.

Acknowledgments

Bioenergy Technologies Office—Daniel Fishman, Brandon Hoffman, and David Babson

Allegheny Science & Technology (AS&T) – Mark Philbrick and Rafael Nieves

NREL Team

Donna Heimiller
Scott Nicholson
Emily Newes
Cindy Gerk
Alex Badgett, intern
Julian Abbott-Whitley, intern
Chris Amante, intern

PNNL Team

Timothy Seiple
Andre Coleman

Additional Slides

Milestones and Metrics

Title/Description	Due Date	Completed
WtE Resource Data inventory	Sep-15	On time
Progress report presented to BETO project lead	Dec-15	On time
White paper addressing the physical/chemical characteristic requirements for each waste resource (e.g. biosolids, manure) for effective HTL conversion.	Mar-16	On time
Draft comprehensive WtE feedstock database	Jun-16	On time
Draft manuscript describing the data sources, methodology and results of the WtE feedstock evaluation.	Sep-16	On time
Draft manuscript analyzing the relationship between feedstock availability and characteristics, HTL conversion efficiency, and biofuel production potential.	Sep-16	On time
Go/No Go. Demonstrate the viability of WtE feedstock: Assess potential for WtE feedstocks to generate 10% of BETO's MYPP FY22 target of 285 MDT/yr.	Dec-16	On time
Draft supply-cost algorithms and associated data sets to enable the generation of supply-cost curves for each of the current WtE feedstocks (sludge, manure, food waste and FOG).	Mar-17	
Analyze opportunities and barriers associated with producing transportation fuels from waste	Jun-17	
Assess and report on the market potential for producing transportation fuels from waste.	Sep-17	
Identify at least 2 scenarios indicating potential for production of biofuels from waste streams capable of supporting BETO MYPP FY22 target of 285 MDT/year at the enterprise scale.	Sep-17	
Harmonize resource, economic and market analyses with HTL processing TEA efforts to identify sustainable, integrated enterprises and work towards achieving BETO feedstock production target of 285 million dry tons	Sep-18	

Publications and Presentations

- “Waste-to-Energy Resource Assessment” (Preliminary Results). Presentation at the DOE Waste-to-Energy Workshop. June 22-23. Golden, CO.
- Seiple, T., Coleman, A., Skaggs, R. “Municipal Wastewater sludge as a Sustainable Bioresource in the United States”. Publication submitted to the Journal of Environmental Management.
- Milbrandt, A. Seiple, T., Heimiller, D., Coleman, A., Skaggs, R. “Wet Waste-to-Energy Resource Assessment”. Publication submitted to the Biomass and Bioenergy Journal.
- Skaggs, R., A. Coleman, T. Seiple, A Milbrandt, ”Waste-to-Energy Biofuel Production Potential for Selected Feedstocks in the United States”. Publication Submitted to Renewable and Sustainable Energy Reviews.

Abbreviations and Acronyms

AS&T: Allegheny Science and Technology
BETO: Bioenergy Technologies Office
DGE: Diesel gallon equivalent
EPA: U.S. Environmental Protection Agency
FOG: Fats, oils and greases
HTL: Hydrothermal liquefaction
MdT/y: million dry tons per year
MYPP: Multi-year program plan
NREL: National Renewable Energy Laboratory
PNNL: Pacific Northwest National Laboratory
quad: quadrillion Btu
USDA: U.S. Department of Agriculture
WTE: Waste-to-Energy