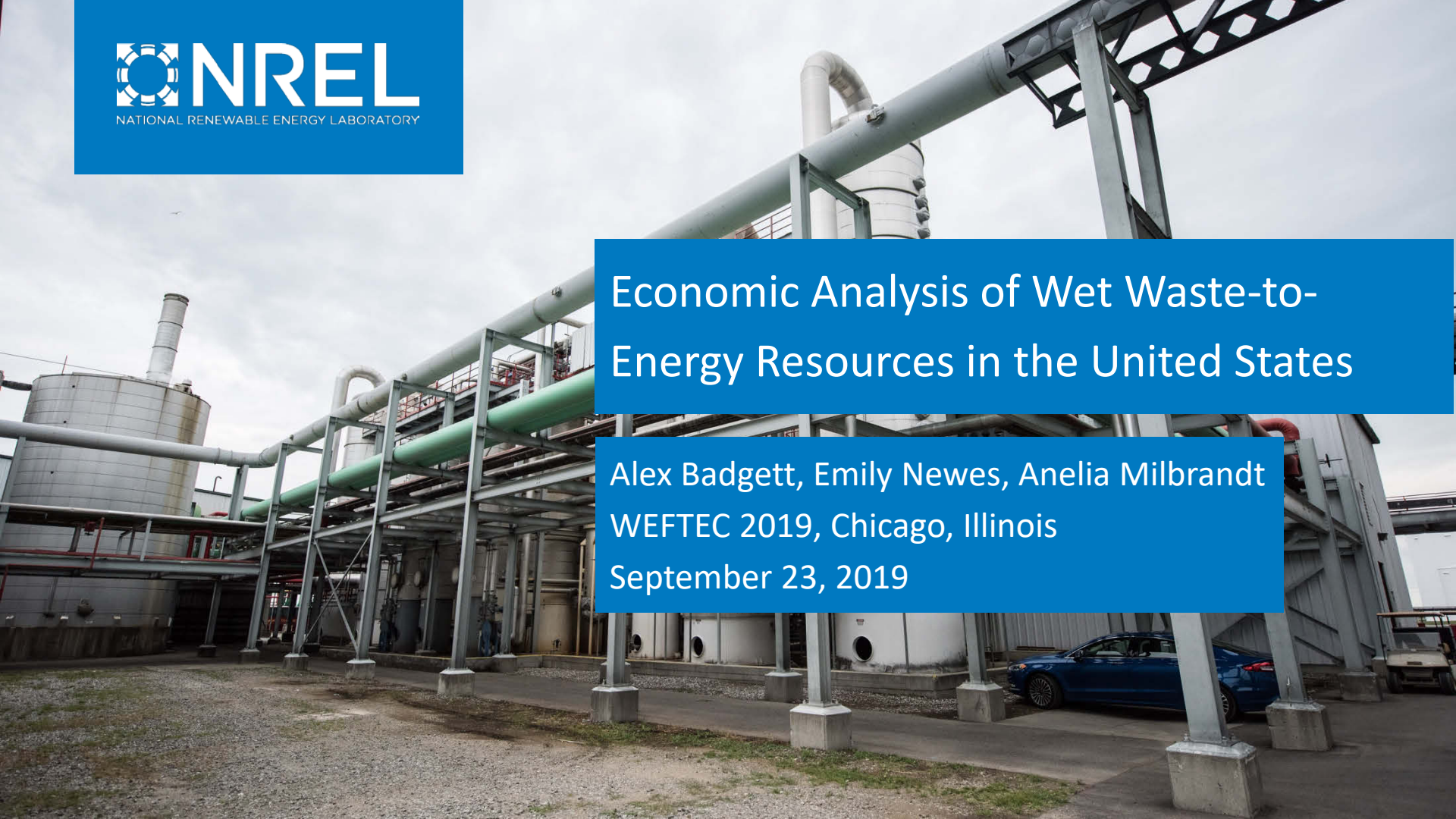

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Economic Analysis of Wet Waste-to-Energy Resources in the United States

Alex Badgett, Emily Newes, Anelia Milbrandt

WEFTEC 2019, Chicago, Illinois

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Defining Waste-to-Energy (WTE)

Conventional Processes:

- Anaerobic digestion
- Incineration

Advanced Processes:

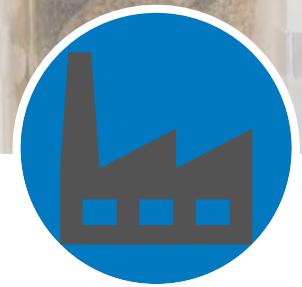
- Gasification
- Pyrolysis
- Hydrothermal Liquefaction

Photo by Beth Baird, NREL 43898

Wet Waste-to-Energy (WTE) Feedstocks

Food Waste

Discarded food from residential, commercial, institutional, and industrial sources



Sewage Sludge

Residuals from publicly owned treatment works (POTWs) after wastewater treatment

Animal Manure

Manure from concentrated animal feed operations (CAFOs) including dairy, livestock, and swine (poultry excluded)

Fats, Oils & Greases

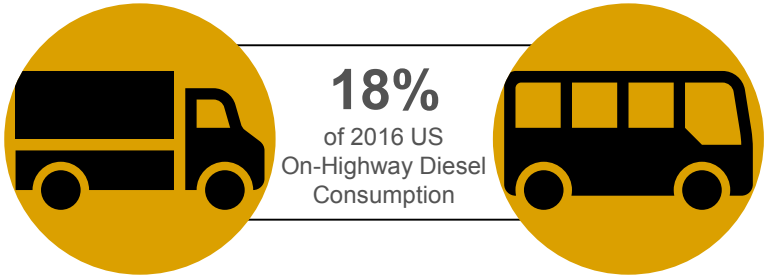
Yellow grease (filtered used cooking oil), brown grease (processed trap grease), and inedible animal fats

Photo by Dennis Schroeder, NREL 51862

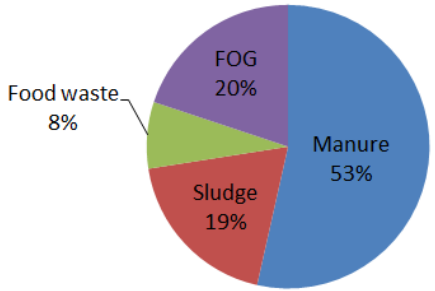
Resource Assessment

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

- About half of this potential is generated by animal manure
- Geographic distribution of these resources is driven by relevant activities – agricultural, industrial, and urban.



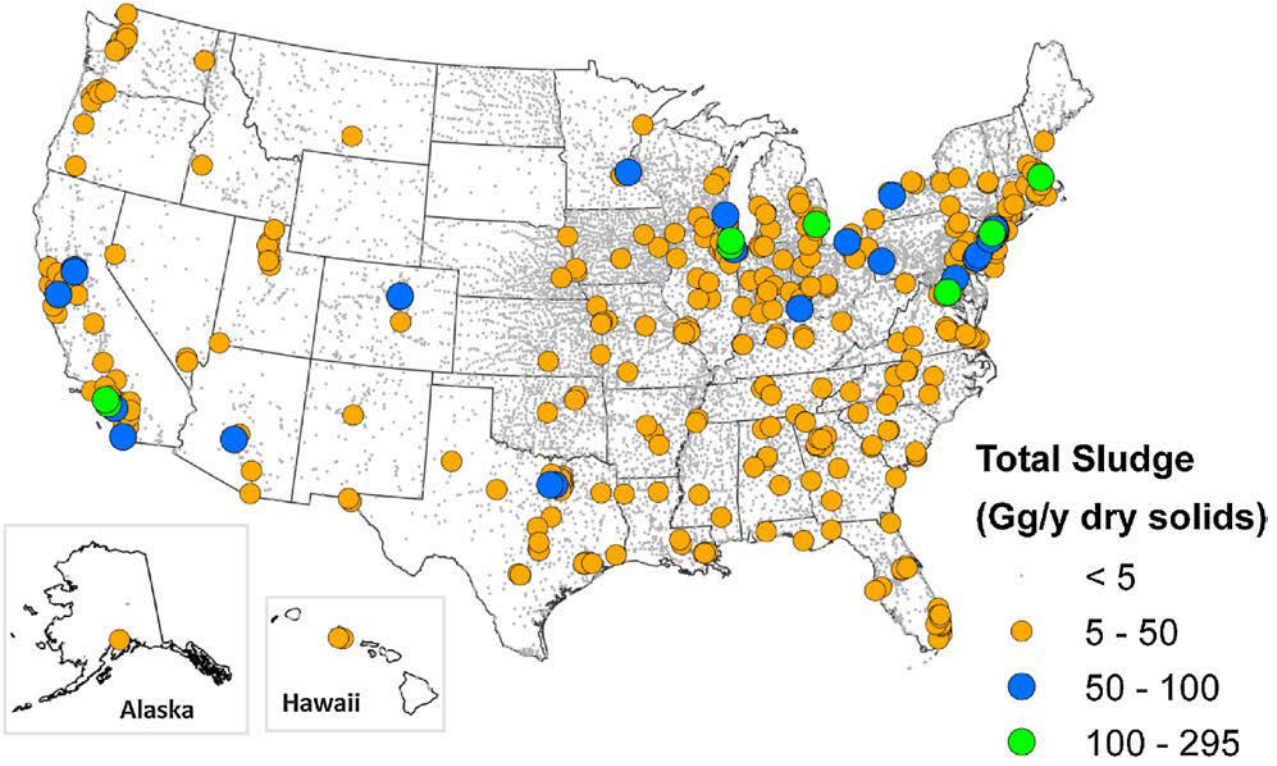
Wet WTE Resource Potential



Milbrandt et al. 2018. "Wet Waste-to-Energy Resources in the United States". *Resources, Conservation & Recycling.*

Sewage Sludge Resource

- About 15,000 publicly owned treatment works produce 14.7 MdT of sludge per year, equivalent to about **1.4 billion DGE**
- Approximately 52% of total sludge has no direct competitive use
- Production follows population dynamics.



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What's Different About Wet WTE Feedstock Economics?

- Most of these materials are not treated like commodities-they often hold little to no value to those managing them
- Low value and undeveloped markets suggest feedstocks could be available to WTE facilities at low prices
- Since there are not typically agreed upon market prices for feedstocks, an alternate approach to estimating their prices was developed

Photo by Dennis Schroeder, NREL 47096

Waste Feedstock Price Model

- The price a WTE facility might be asked to pay for non-commodity WTE feedstocks is the difference between any necessary pre-processing costs and disposal costs
- In other words, if you currently pay $50 per ton to send your waste to a landfill, you would pay anything less than that to a WTE facility to take the waste
- If the added cost to dewater the waste is $10 per ton, the net feedstock price is: -$40 = **$10** - **$50**

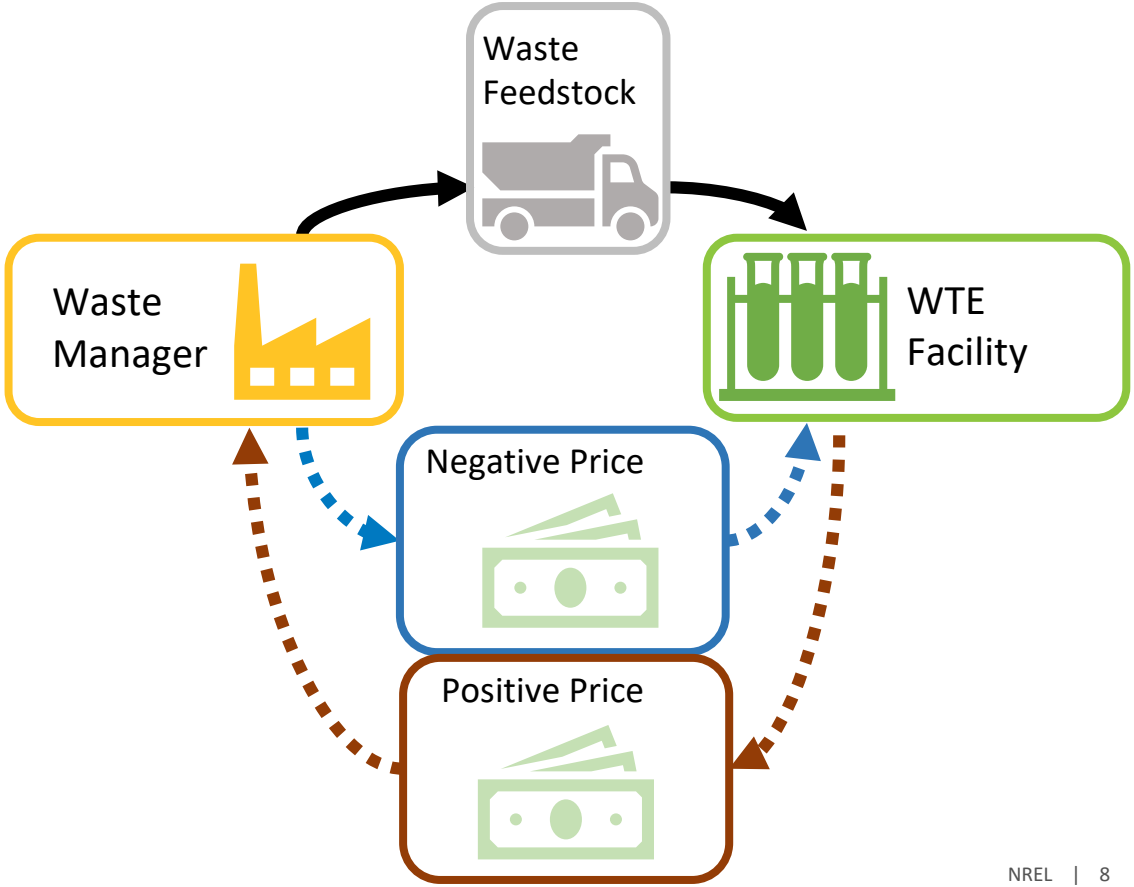
Feedstock Price = ***Added Costs*** – ***Avoided Costs***

The cost of any treatment required before using the feedstock in WTE (dewatering, long term storage, etc.)

The cost to dispose of the feedstock at a waste management facility (landfill, incineration, etc.)

Feedstock Price Evaluation

- **Positive price:**
  WTE facility must pay to acquire feedstock (typical when exchanging commodities)
- **Negative price:**
  WTE facility is paid to take a feedstock (i.e. tipping fee)



Modeling Framework

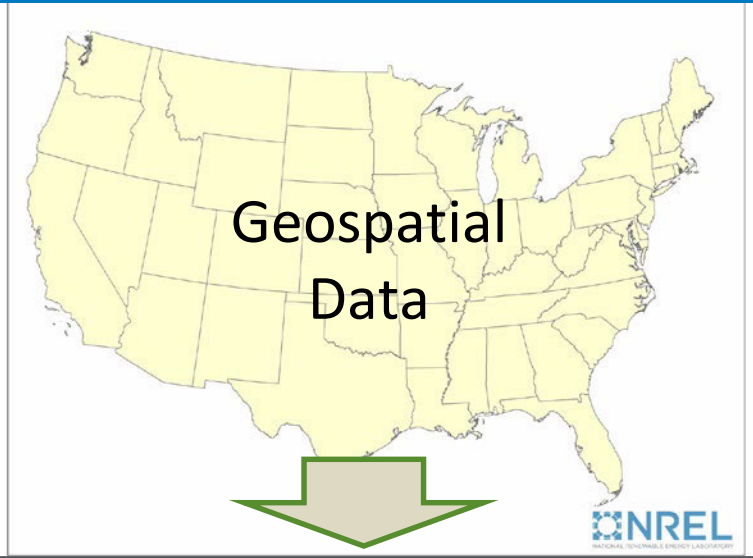
Cost functions & waste disposal datasets

Electricity, fuel prices & wages

Feedstock generation

Waste facility location, capacity, fees

Organic waste disposal policies and regulations



WTE Economic Model

- Developed in Python
- Incorporates published costs of waste disposal
- Finds avoided & additional cost for the feedstock

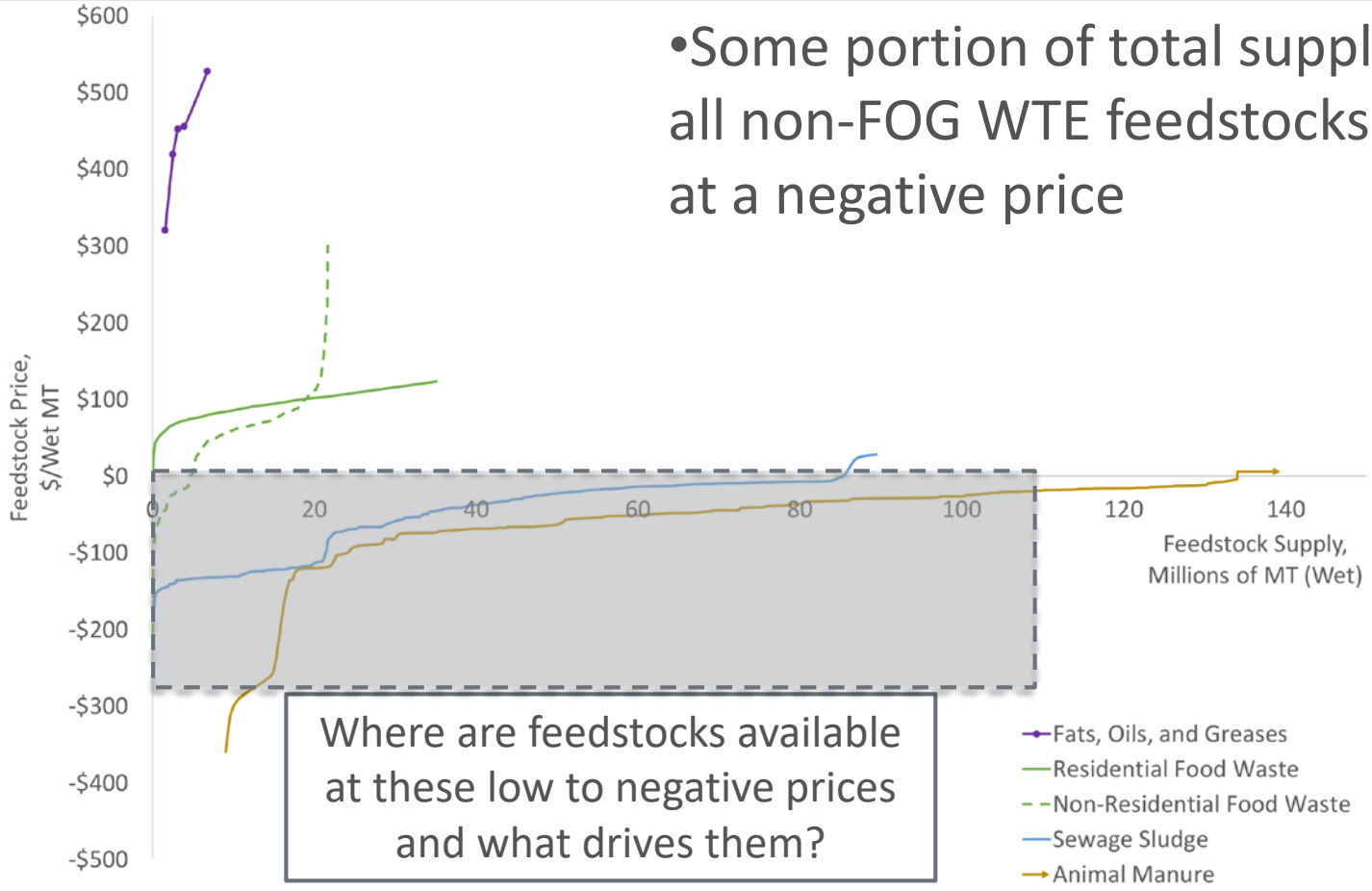
Feedstock Price = Avoided Costs – Additional Costs

Results

Feedstock price in $/Wet Ton by county

- Dataset resolution allowed for price estimation at a county level
- Lack of public/reliable data on waste disposal required adaptations to model
- Model provides production and price points to aggregate into national supply curves for each feedstock

National Supply Curves



- Some portion of total supply for all non-FOG WTE feedstocks exists at a negative price

Where are feedstocks available at these low to negative prices and what drives them?

Badgett, A., Newes, E. & Milbrandt, A. Economic analysis of wet waste-to-energy resources in the United States. *Energy* **176**, (2019).

Waste Feedstock Price Drivers

Population Centers

High supply of waste feedstock drives economies of scale

Disposal Costs

High disposal costs decrease feedstock prices

Organic Waste Bans

Standards for waste disposal can drive feedstock prices lower

Agricultural Centers

Areas with high manure volumes result in low feedstock prices

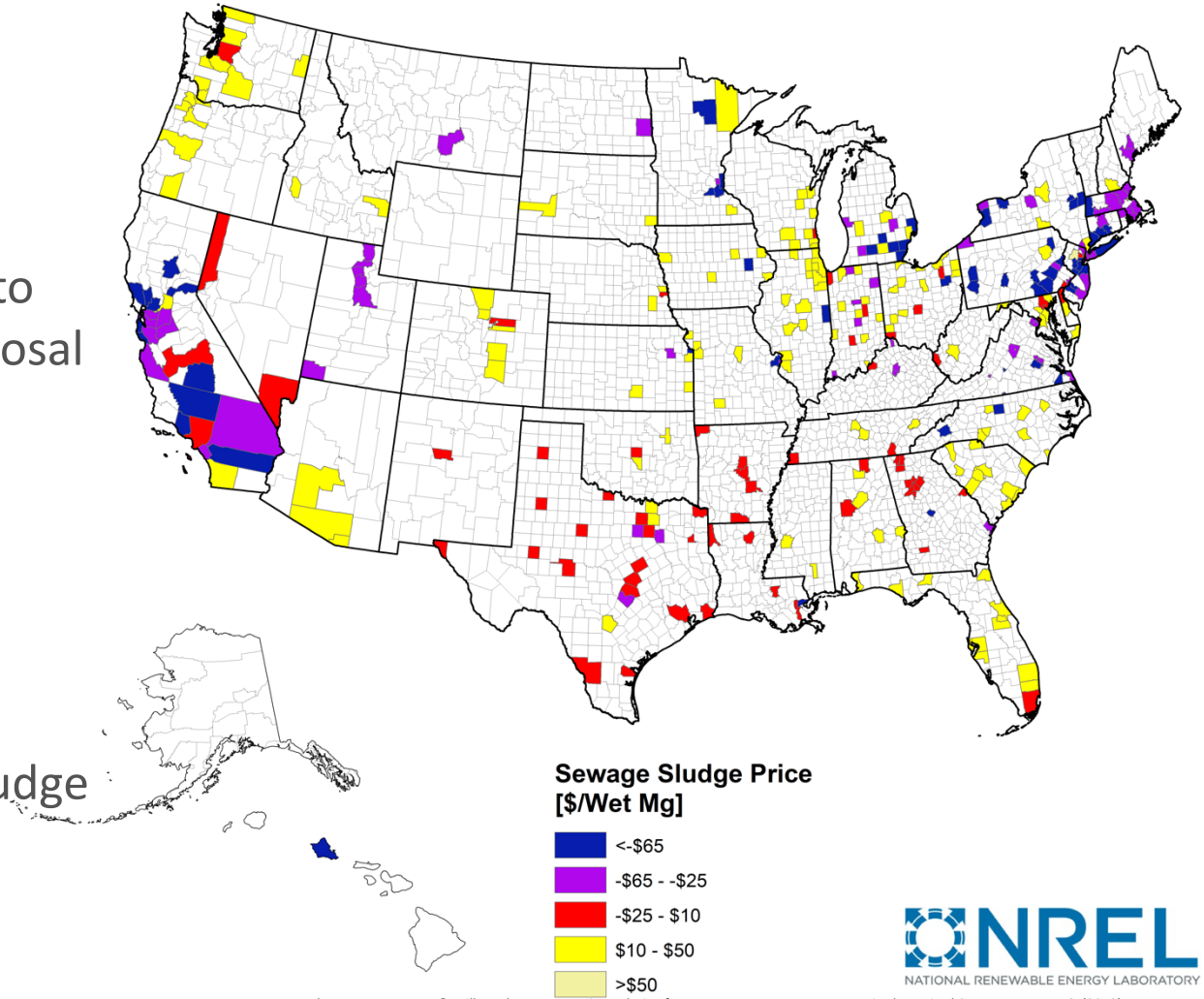
Local Markets

Formal or informal local markets can drive prices in a given area

Photo by Dennis Schroeder, NREL 56240

Sewage Sludge

- Sludge disposal varies by facility-EPA data was used to find most likely sludge disposal alternative among:
  - Incineration
  - Composting - Class A biosolids
  - Land Application
  - Landfilling
- Disposal alternative and sludge volume control prices
- Urban areas exhibit lowest prices



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Key Takeaways

Policy

Regulatory standards for organic waste disposal control availability and price of WTE feedstocks

Location

Low feedstock prices tend to occur in more populous areas where demand for bioenergy would also be high

Feedstock Prices

Results provide insight into feedstock prices to inform future TEAs and location/technology specific studies

Disposal

Feedstock prices are low where waste disposal is difficult and expensive, incentivizing sustainable waste disposal via WTE

WTE Development

This work provides a baseline context for WTE feedstock markets as they develop & evolve

Photo by Dennis Schroeder, NREL 51862

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Alex.Badgett@NREL.gov

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