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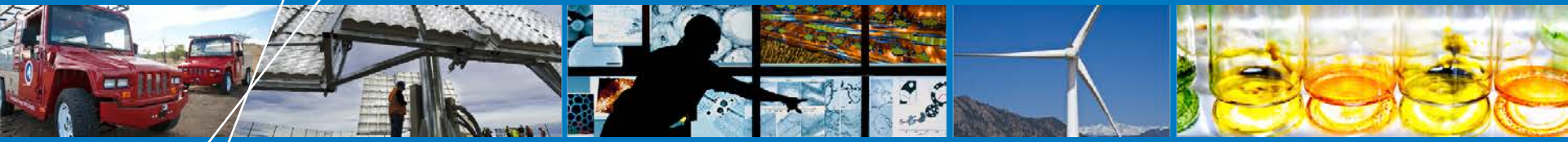
Biomass Resources Overview and Perspectives on Best Fits for Fuel Cells



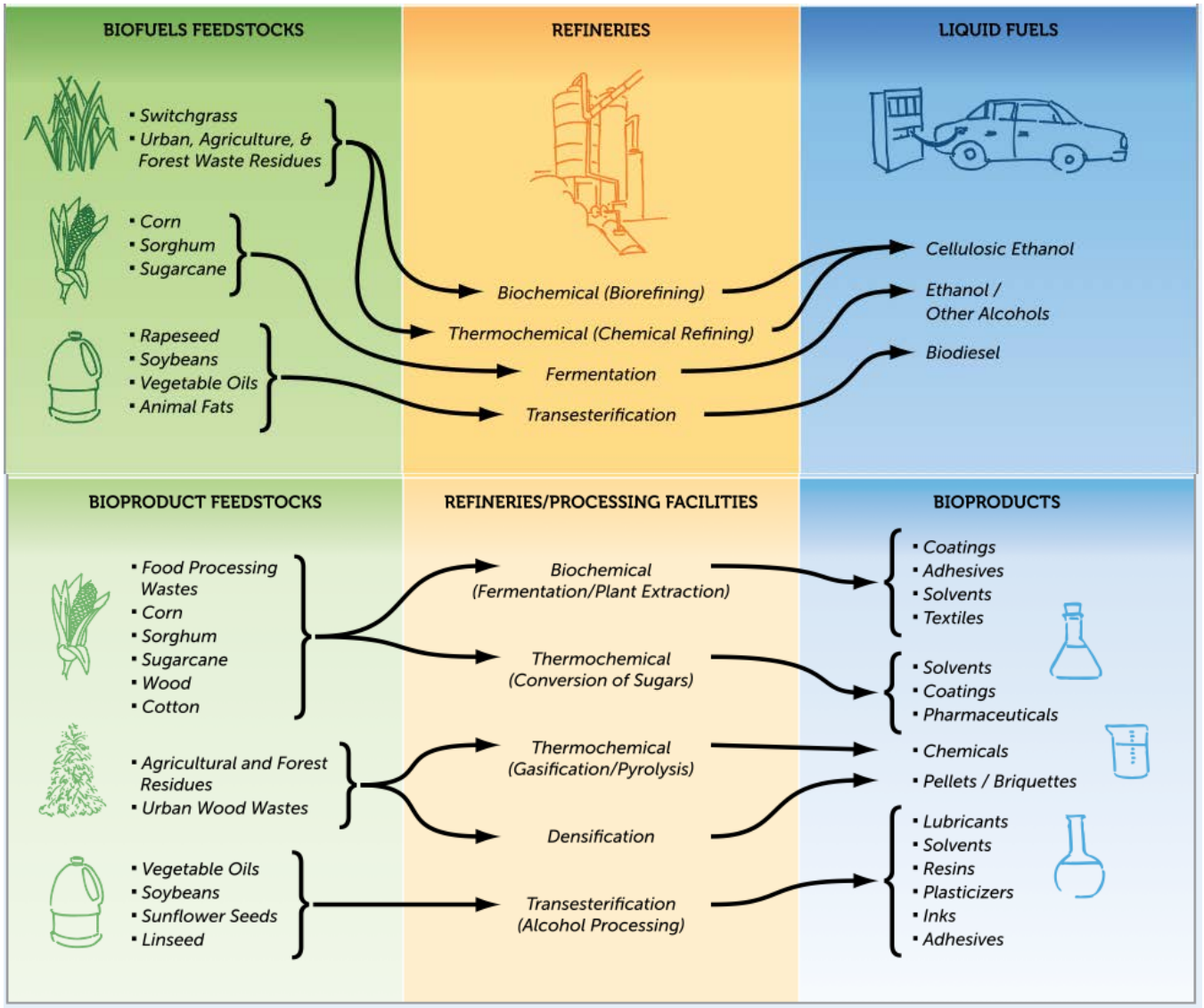
Darlene Steward, NREL

Biogas and Fuel Cells Workshop
Golden, CO June 11–13, 2012

Objective

- **Identify the primary opportunities and challenges for producing and utilizing methane from renewable resources**
  - Biogas from digestion of:
    - Manure Management
    - Wastewater Treatment
    - Food Processing
  - Landfill gas

Bio-energy Pathways; Three Broad Categories of Products

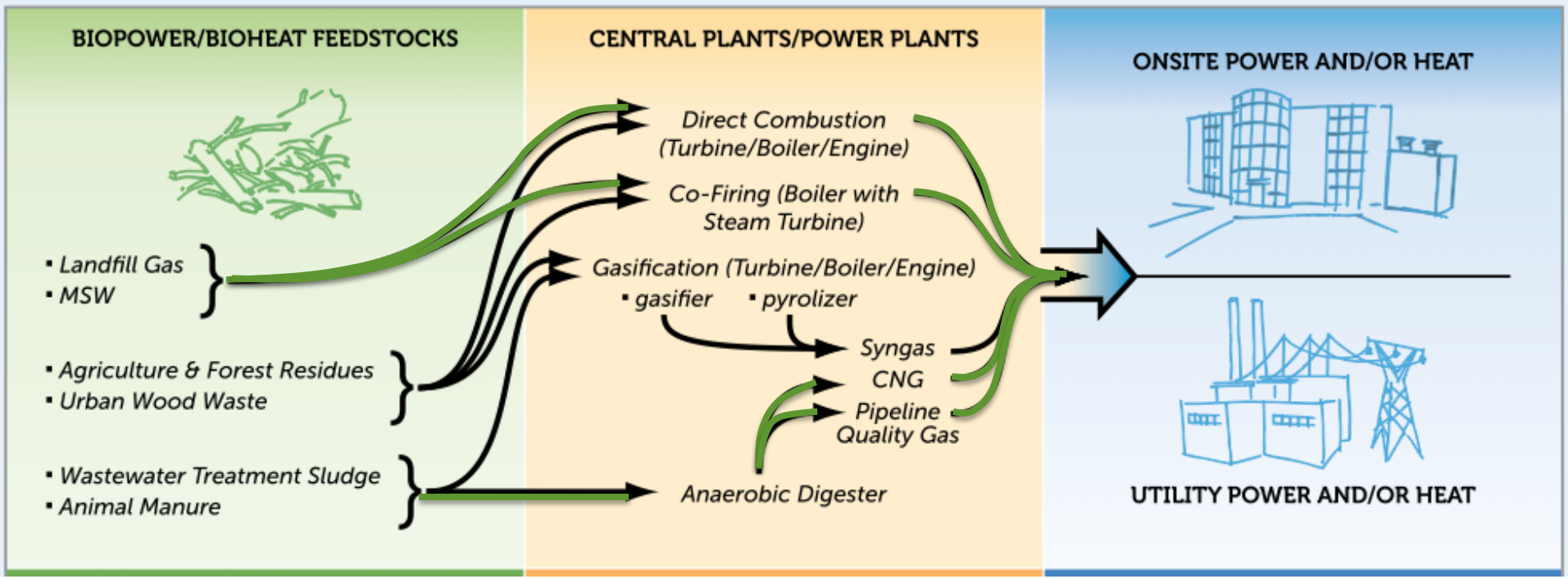


Biomass to liquid fuels pathways

Biomass to bioproducts pathways

Source; EPA, NREL, State Bioenergy Primer, Sept. 15, 2009

Energy Product Pathway is the Focus of this Workshop



Biomass to electricity and/or heat pathways

Focus on

- **Landfill gas**
- **Wastewater treatment sludge**
- **Animal manure**
- **Food processing**

Source; EPA, NREL, State Bioenergy Primer, Sept. 15, 2009

Geographic Distribution of Conventional Energy Sources

Electricity

- GHG emissions per kWh
- Price

Natural Gas

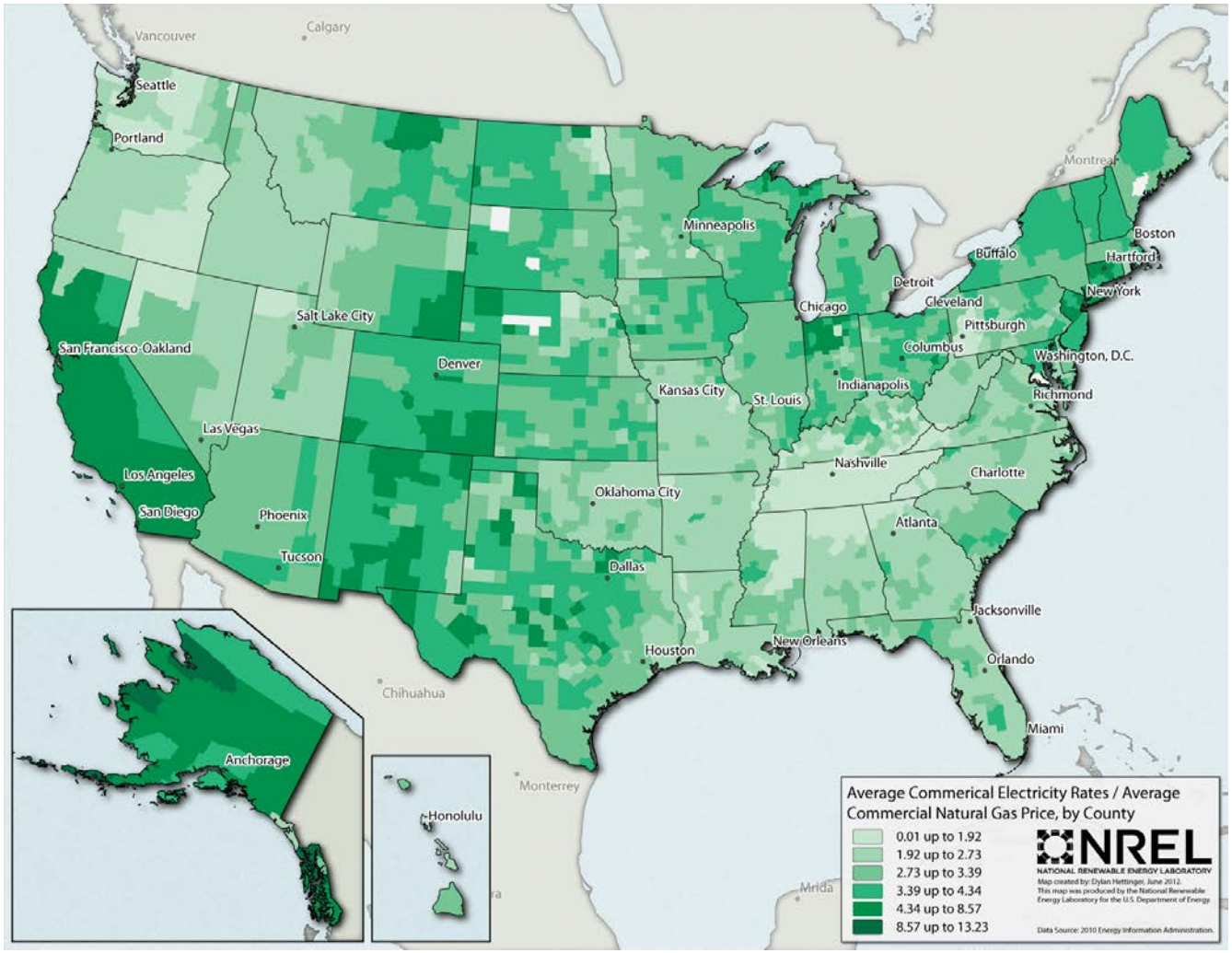
- Price

"Spark Spread" is the ratio of electricity to NG prices on an equivalent energy basis

Economics of Biogas for Generation of Electricity (and Heat) are Affected by Both Prices

High electricity price in relation to NG price:

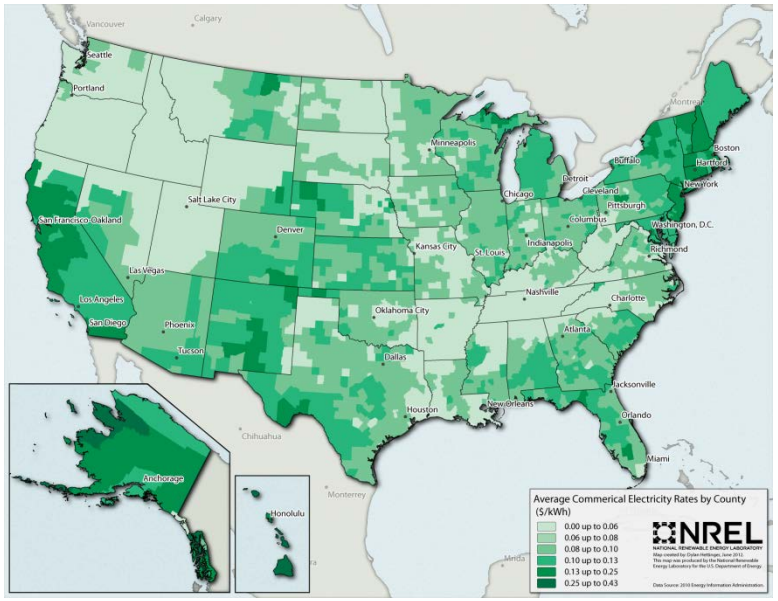
- Focus on maximizing benefits of high value products



Spark Spread: $\frac{\text{Commercial Electricity Rate}}{\text{Commercial Natural Gas Price}}$

High Prices for Either Competing Feedstock or Product Improves Biogas Economics

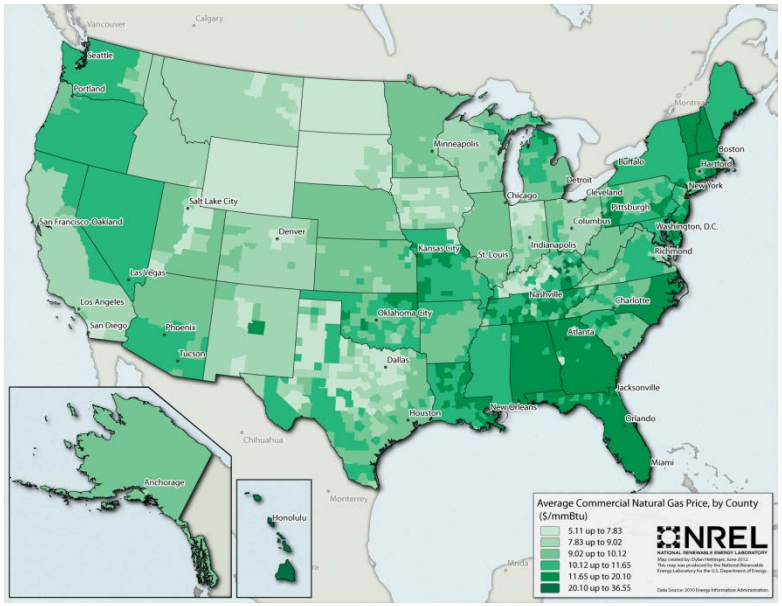
High prices for competing product (electricity) improves biogas economics



Electricity Prices range from:

< 6¢ – 43¢ /kWh

High prices for competing resource (natural gas) improves economics



Natural Gas Prices range from:

5 – 37 $/mmBtu

Biogas Resources and Geographic Distribution

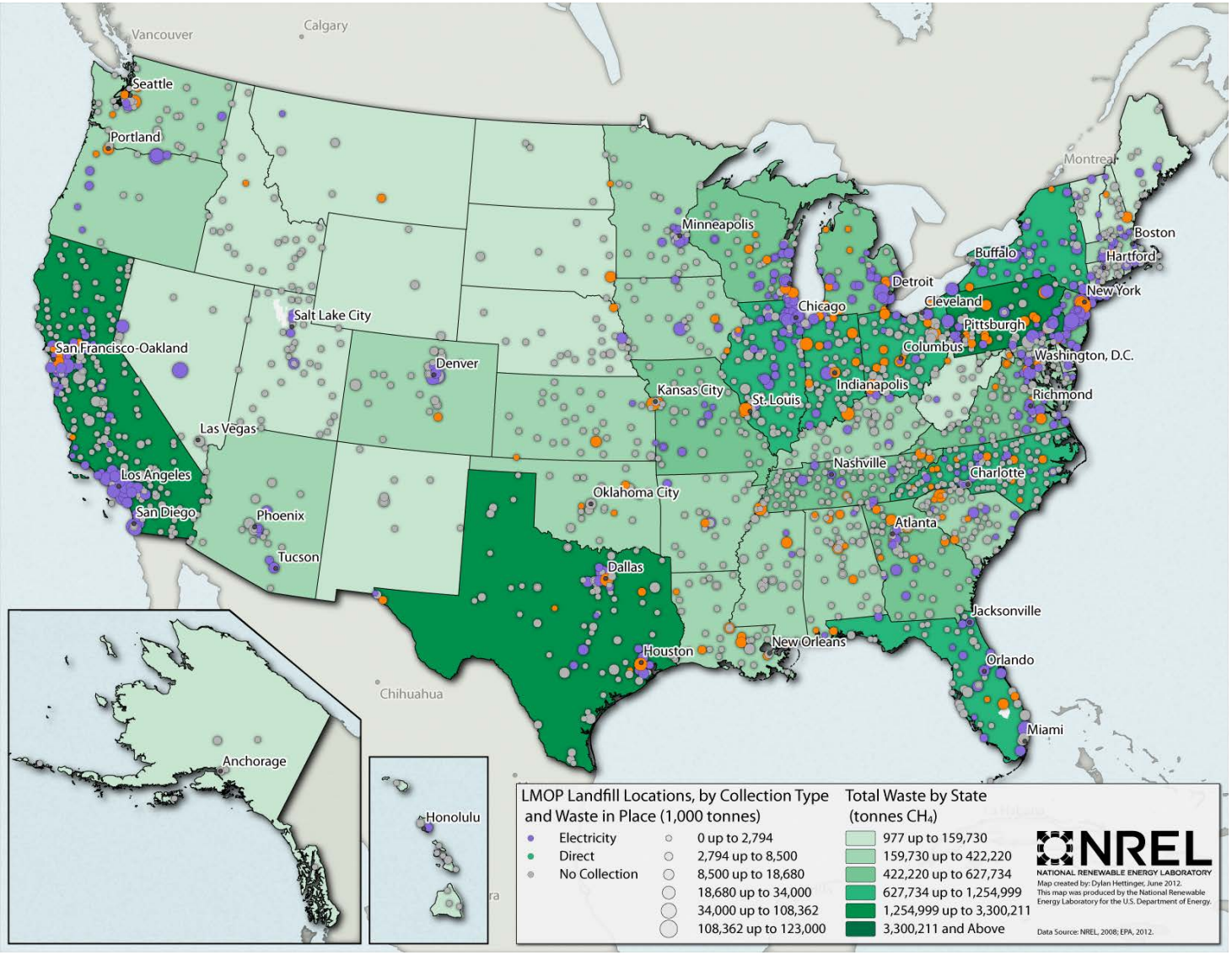
Opportunities

- Biogas from agricultural resources
  - Dairies/ Food Processing
  - Other Livestock
  - Agricultural and Forest Waste
- Biogas from Landfills
- Wastewater

Challenges

- Dis-economies of scale for distributed resource
- Regulations regarding mixing of biogas and natural gas in pipelines
- Clean-up
- Transport of biogas

Biogas Resources – Landfill Gas



Opportunities

- 16 million metric tonnes (MMtonnes)/ year

Challenges

- Siloxane removal
- Restricted from pipeline addition

Biogas Resources – Landfill Gas in Operating Landfills

Source:	2010 Tg CO2 eq.	2010 million metric tonnes
MSW Landfills	264.0	12.6
Industrial Landfills	15.9	0.8
Recovered		
Gas-to-Energy	(79.8)	(3.8)
Flared	(80.3)	(3.8)
Oxidized	(12.0)	(0.6)
Total Recovered	(172.1)	(8.2)

Source: EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2010, 430-R-12-001, U.S. Environmental Protection Agency 1200 Pennsylvania Ave., N.W. Washington, DC 20460 U.S.A., April 15, 2012

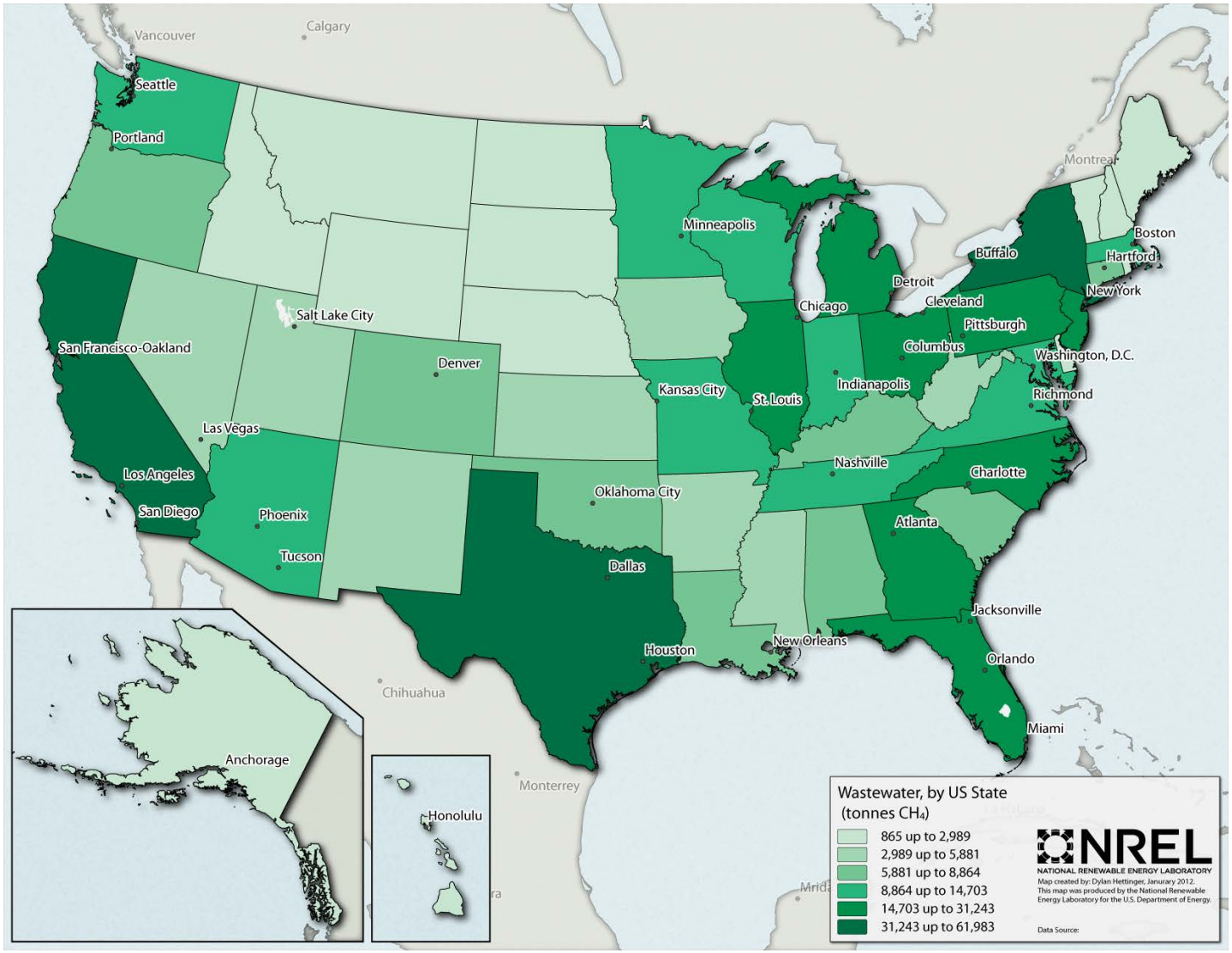
Opportunities

- 5.1 MMtonnes/year not captured
- 4.4 MMtonnes captured but not used for energy

Potential GHG Emissions Reduction

- 108 Tg CO2eq savings for converting un-captured CH4 to energy

Biogas Resources – Wastewater Treatment



Opportunities

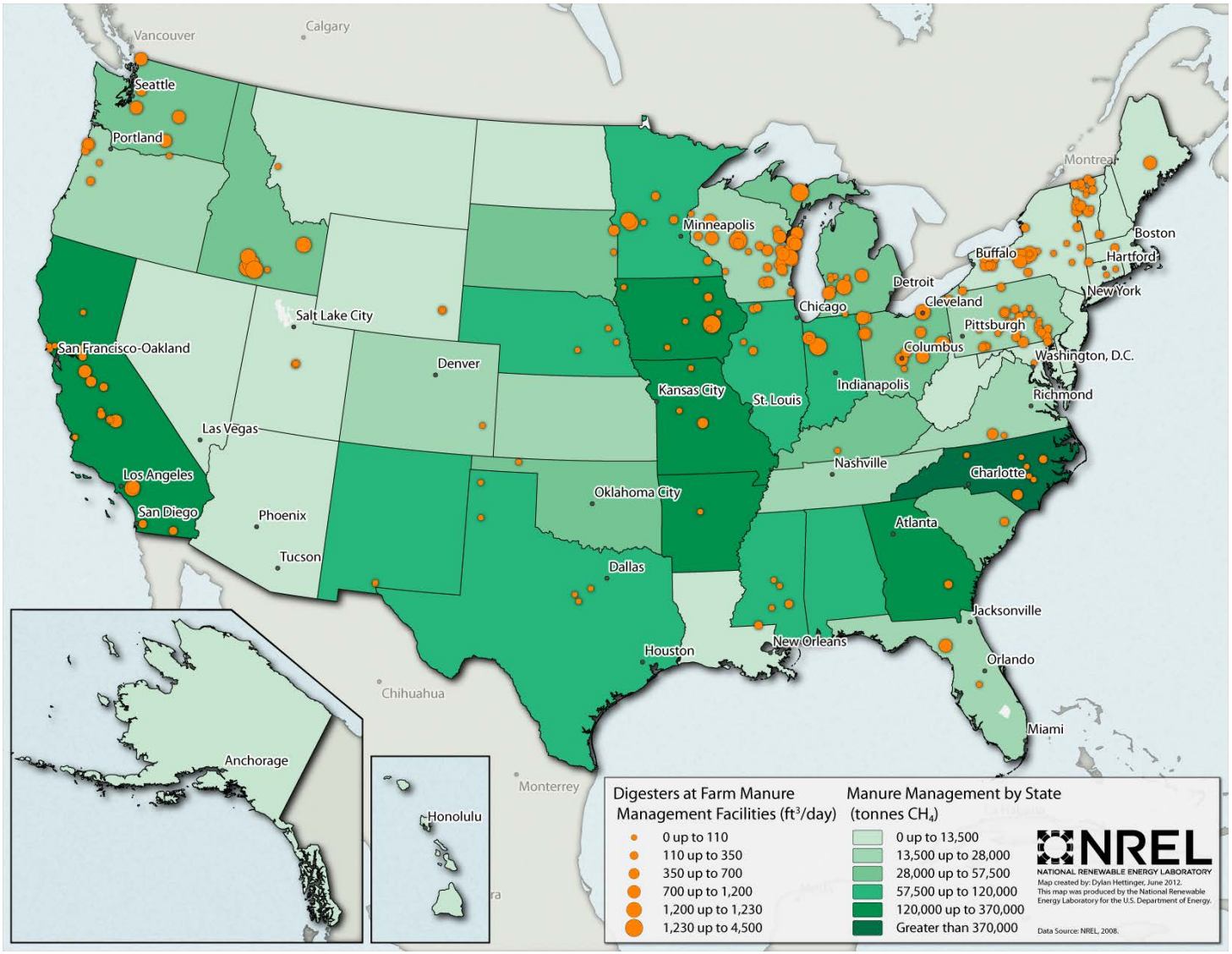
- 0.5 MMtonnes/ year

Challenges

- Small volumes

Units: Tonnes CH_4 from WWT plants by State

Biogas Resources – Manure Management



Opportunities

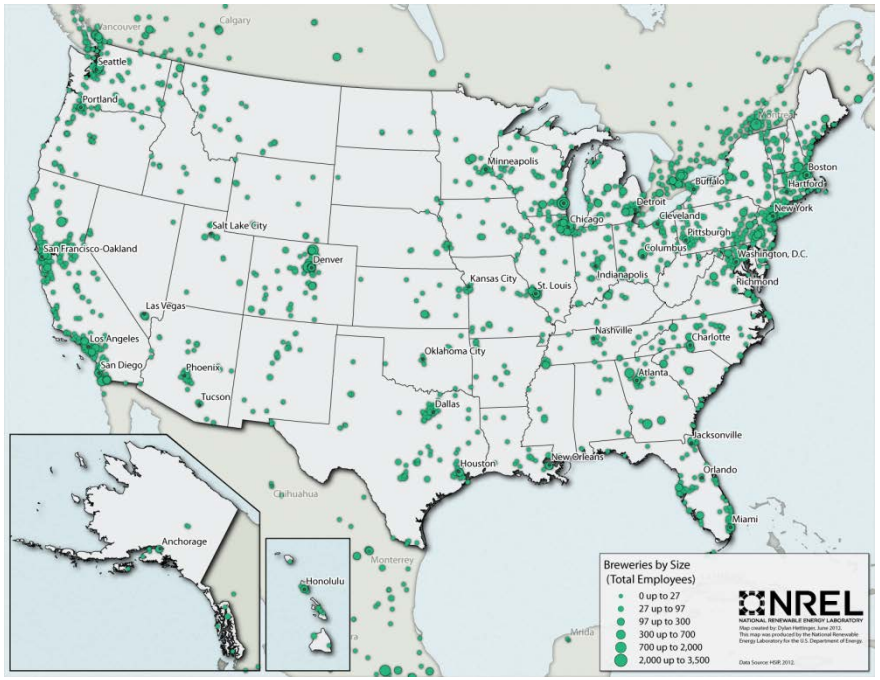
- 2.2 MMtonnes/ year

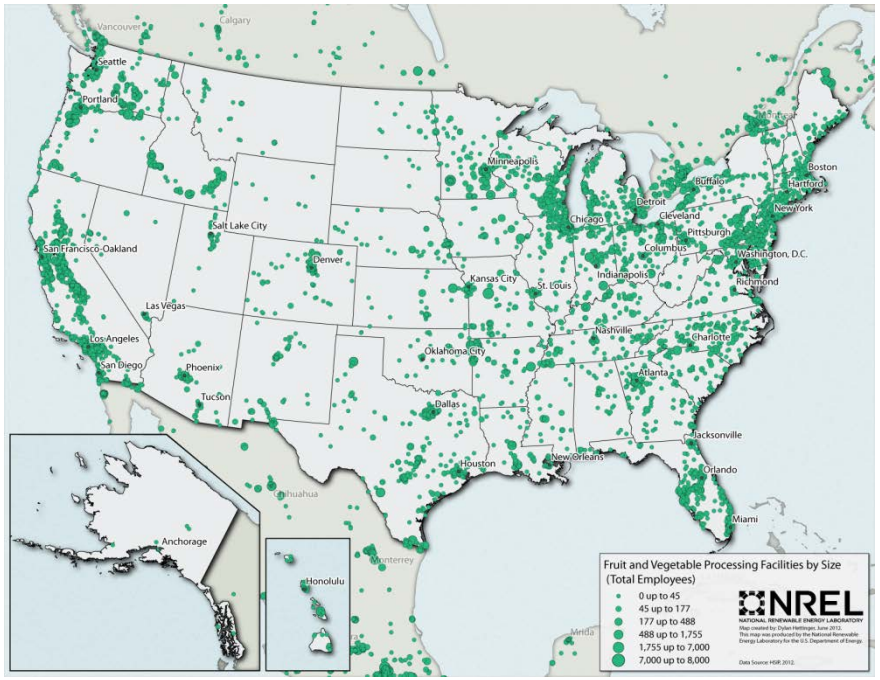
Challenges

- Small volumes
- Business case for farmers

- Tonnes CH_4 from manure management by State (Green)
- Digester farm manure management facilities in ft^3/day (Orange)

Biogas Resources – Food Processing Facilities



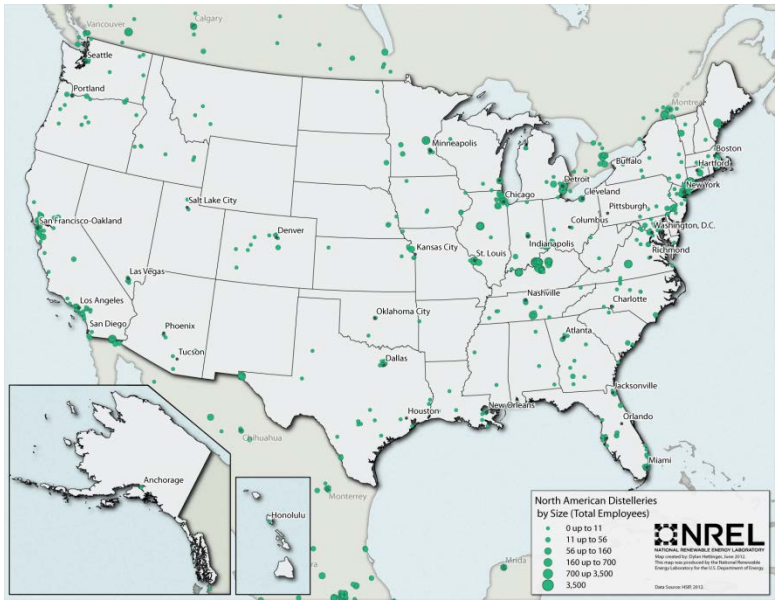


Breweries

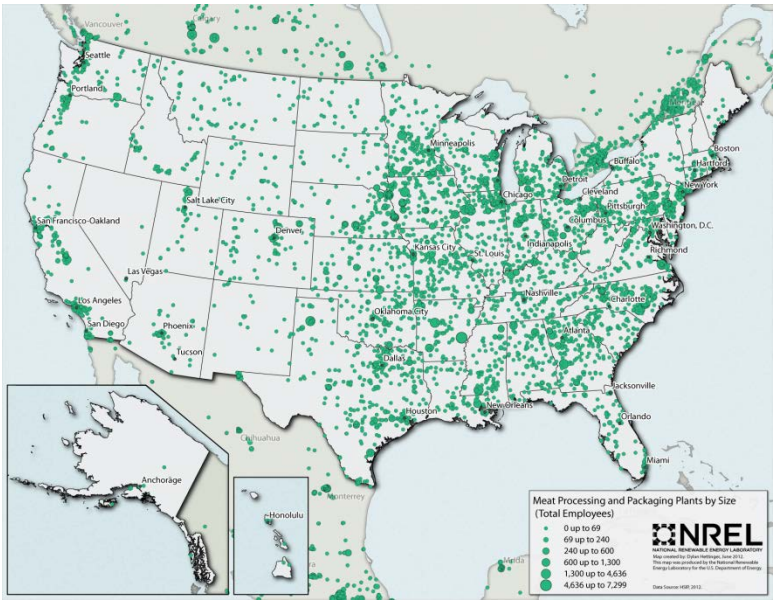
Fruit & Vegetable Processing

Note: Circle sizes based on the number of employees only, indicating relative size of facilities within each category

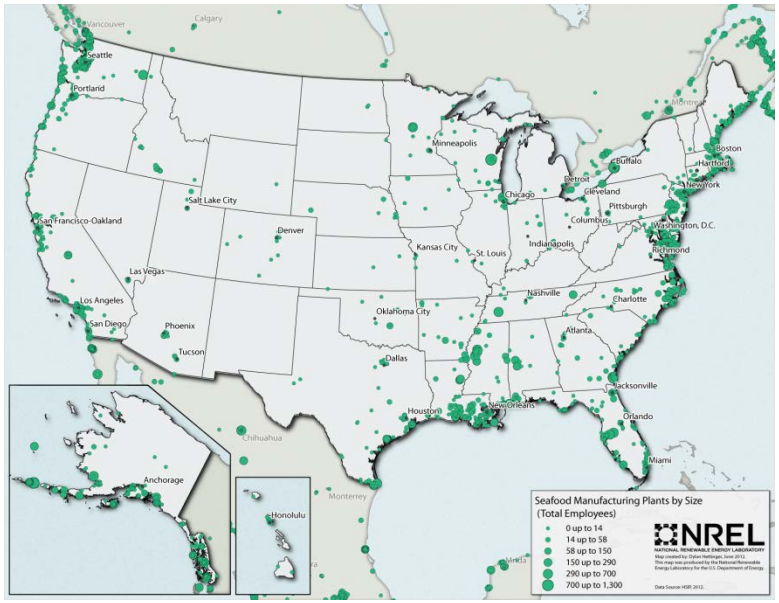
Biogas Resources – Food Processing Facilities



Distillers



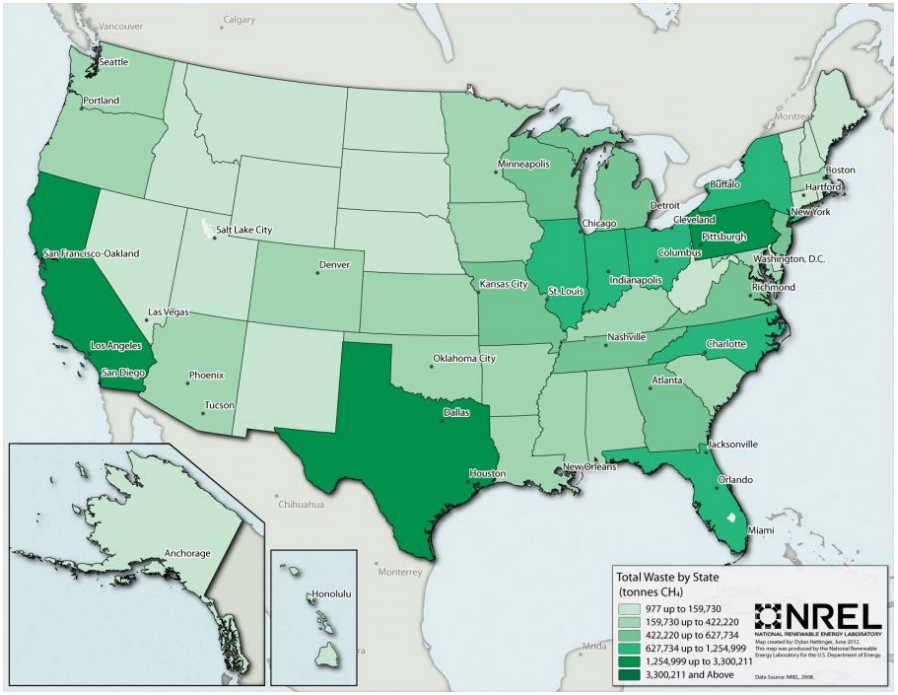
Meat Processing

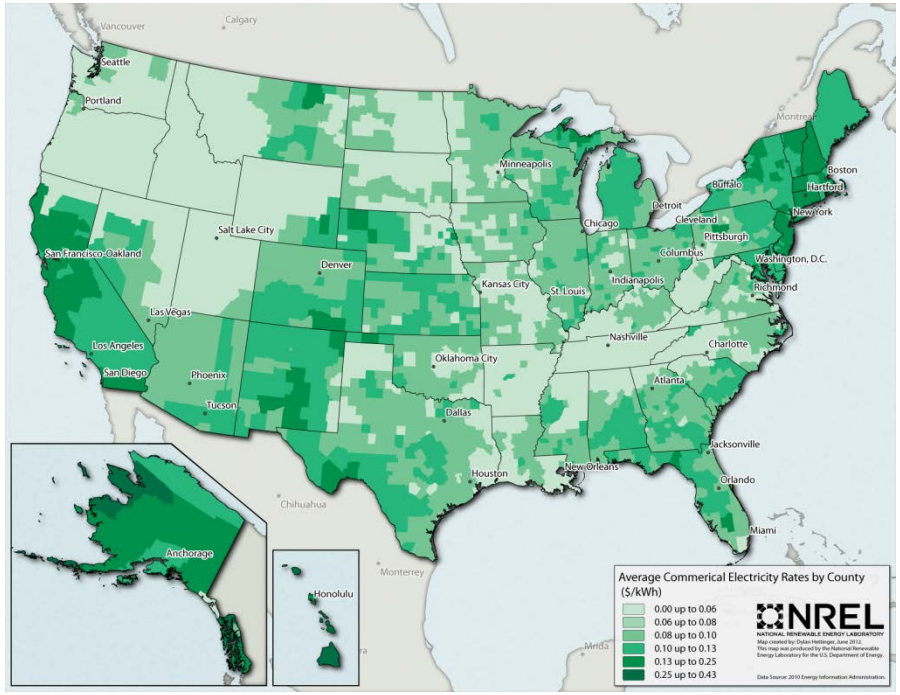


Seafood Processing

Note: Circle sizes based on the number of employees only, indicating relative size of facilities within each category

Biogas Combined Resources from Landfill Gas, Wastewater Treatment, Manure Management – Economic Opportunities





Opportunity

19 MMtonnes/year

- Of this, 16 Mmtonnes/year from landfills
- California has significant biogas resources and high electricity prices.

Biogas Combined Resources from Landfill Gas, Wastewater Treatment, Manure Management – GHG Reduction Opportunities

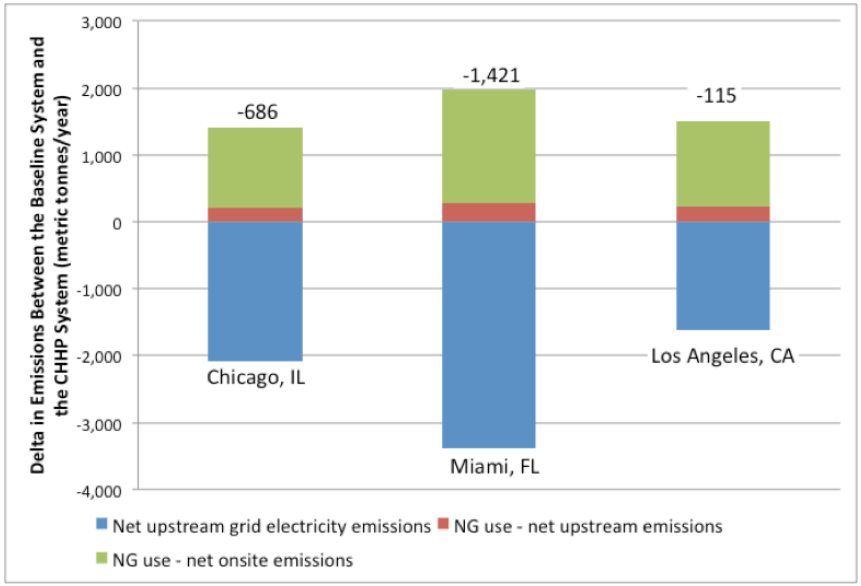
GHG Reduction Potential: High values indicate high potential to reduce GHG emissions with biogas use in a fuel cell

State	State GHG Ratio to Average	State Total Biogas Ratio to Average	Combined Ratios
Highest 5			
California	< 0.5	9	4
Pennsylvania	1	4	4
Texas	1	3	3
Indiana	> 1.5	2	3
Ohio	> 1	2	3
Lowest 5			
Maine	< 0.5	< 0.5	<< 0.5
North Dakota	2	<< 0.5	<< 0.5
Idaho	< 0.5	< 0.5	<< 0.5
District of Columbia	2	<< 0.5	<< 0.5
Vermont	<< 0.5	< 0.5	<<< 0.5

GHG Potential is based upon multiplying two metrics:

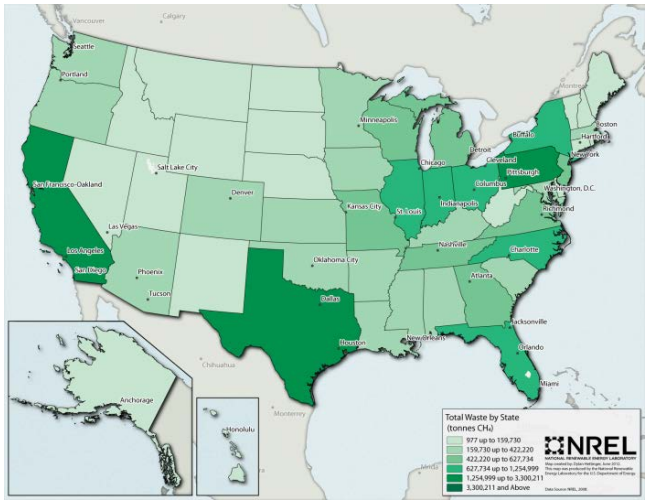
- Average GHG emissions (per state) = unity
- Average biogas resource (per state) = unity.

Example of a City Comparison: Net upstream and onsite GHG emissions for CHHP systems v. grid supply

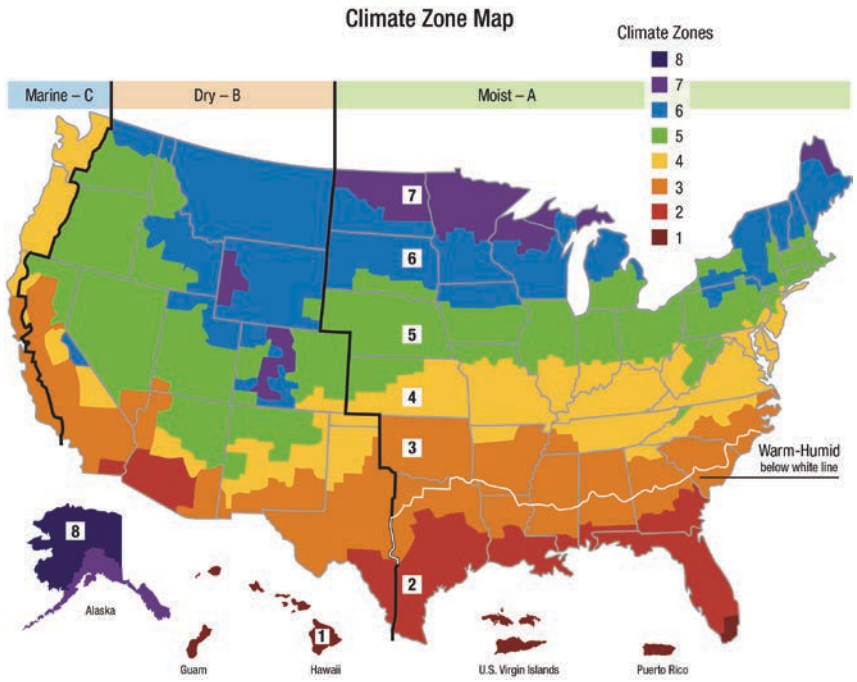


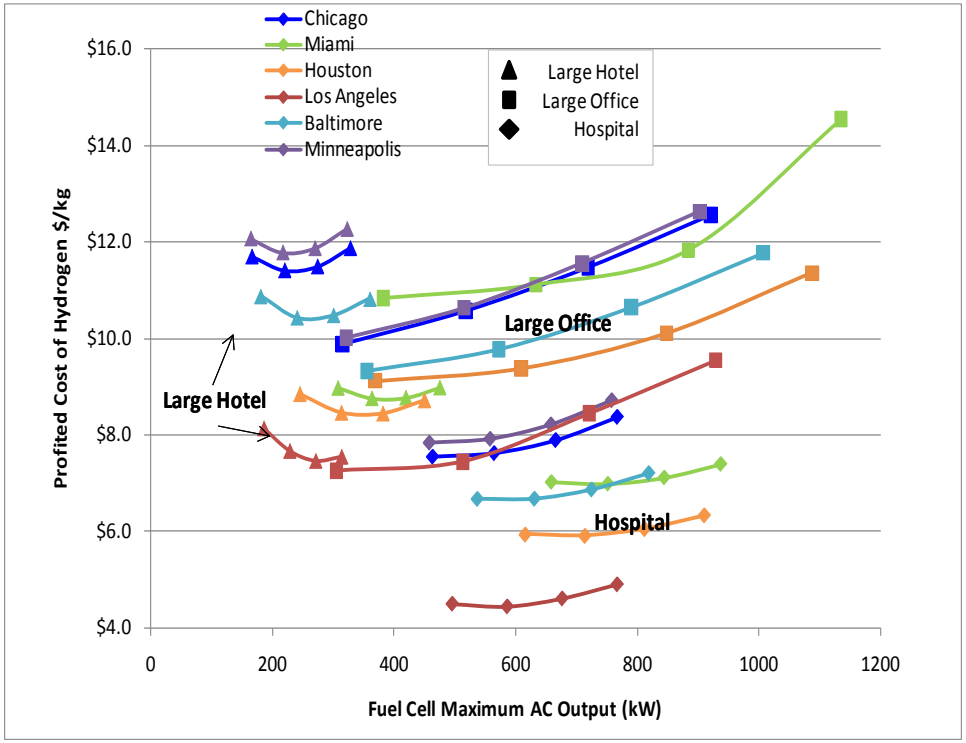
GHG potential varies state-by-state, and is higher for states with more coal-based electricity and more biogas resource

Effect of climate and building type on CHP/CHHP Opportunities



Total Biogas Resource by State





Cost of hydrogen produced in CHHP systems in commercial buildings in various climate zones

Houston and Los Angeles appear to have the best CHHP opportunities

Summary of Biogas Electricity & Hydrogen Production and GHG Reduction Potential

Nationally, 1.9 million tonnes H2 and 81,000 GWh electricity could be produced using CHHP systems.

Source	Tg CO2eq emissions (2010)	CH4 emissions (Gg CH4)	Emissions from Combustion (Tg CO2)	Avoided emissions for conversion to CO2
Landfills	279.9	13,332	37	243
Manure Management	52	2,478	7	45
Wastewater Treatment	16.3	779	2	14
Total	**348.2**	**16,589**	**46**	**303**

Nationally, 2,277 MMtonne CO2eq emissions from electricity generation in 2010.

Up to 300 MMtonne CO2eq emissions from CH4 could be avoided by converting to CO2 through electricity generation in fuel cells – equivalent to 13% of national CO2eq emissions from electricity generation

EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2010, 430-R-12-001, U.S. Environmental Protection Agency 1200 Pennsylvania Ave., N.W. Washington, DC 20460 U.S.A., April 15, 2012

Table values are based upon different data sources than shown in previous maps.

Summary of Benefits of Biogas Capture and Use

- Large GHG reduction potential for capture of biogas
- Opportunities for increased efficiency in CHP and CHHP distributed systems
- Federal and State Incentives.
  - Renewable portfolio standards
  - Distributed generation capacity purchase incentives
  - Tax credits based on production
- Capture of biogas satisfies other waste management mandates and goals (such as odor reduction for manure management)

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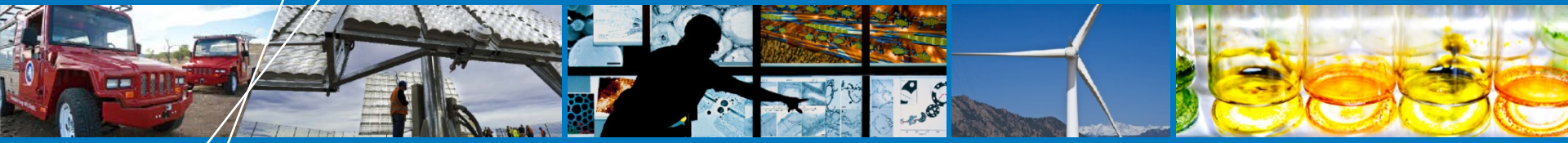

Questions?