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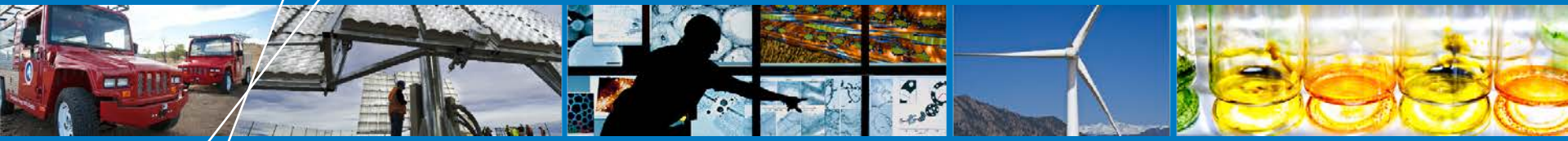
Hydrogen from Biogas: Resource Assessment



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National Renewable Energy Laboratory

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Project ID#: AN037

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Overview

Timeline

- Project start date: Sept. 2012
- Project end date: July 2013
- Percent Complete: 30%

Barriers

- A. Future Market Behavior
- C. Inconsistent Data, Assumptions and Guidelines

Budget

- Funding FY13: $45k

Data Sources

- Listed in presentation

Collaborations

- EPA

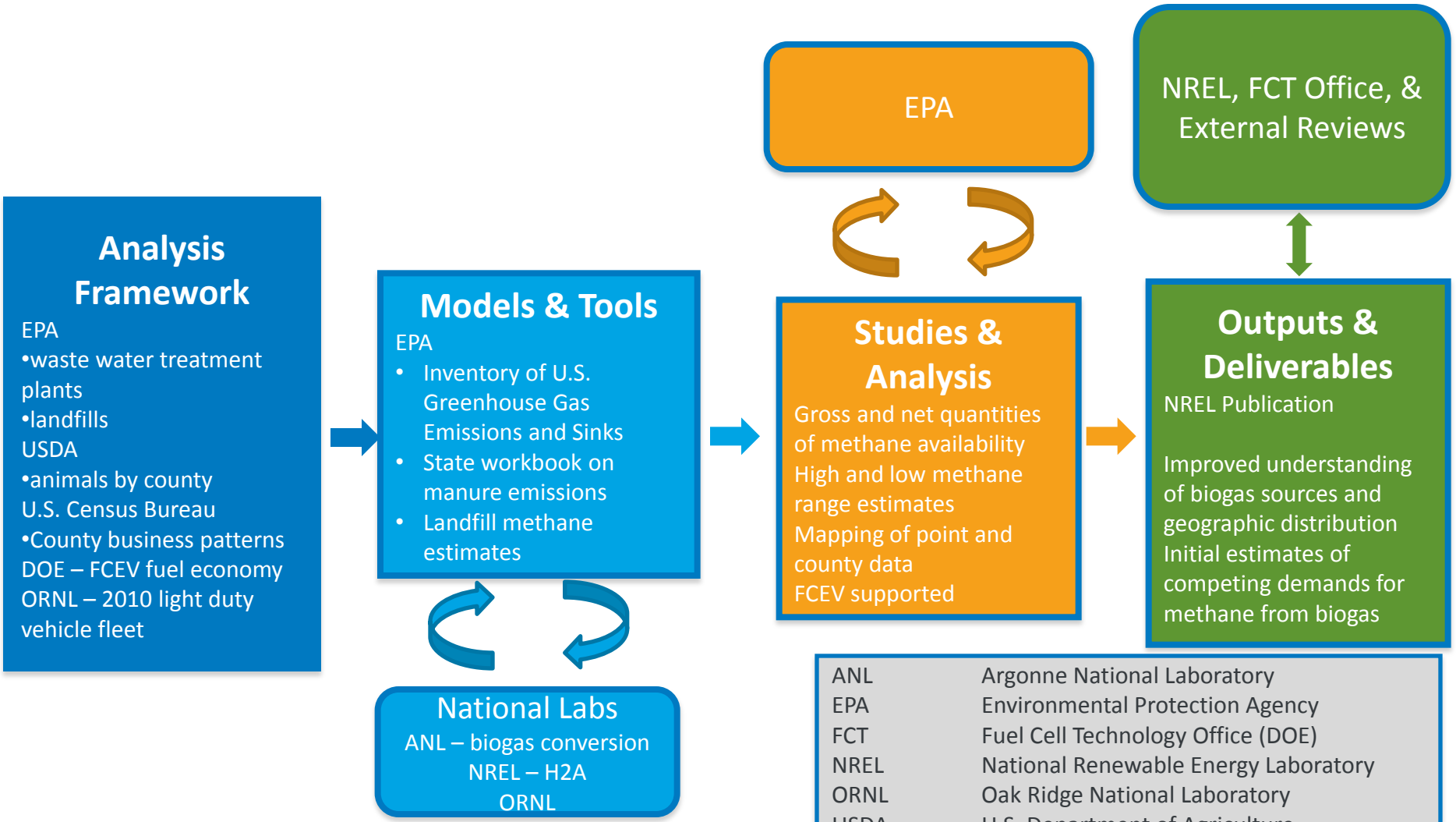
Relevance

- **Objectives**
  - Address resources availability for renewable hydrogen which provides alternatives to traditional sources of hydrogen, hedges again fluctuating costs and demand for fossil fuels, and aids compliance with state policies for renewable fuels.
  - Update prior study on methane from wastewater treatment, landfills, and manure management.
  - Expand analysis to include methane from industrial processes and organic food waste.
- **Barrier: Future Market Behavior**
  - Expand analysis to include current net availability by assessing sources currently in use.
- **Barrier: Inconsistent Data, Assumptions and Guidelines**
  - The resource assessment collects data from several sources into one place and uses consistent conversion methods to obtain the hydrogen potential.

Project Overview

Approach

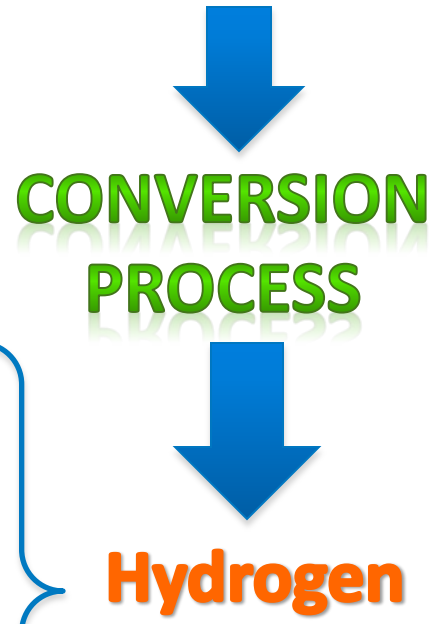
Effects of Technology Cost Parameters on Hydrogen Pathway Succession



ANL	Argonne National Laboratory
EPA	Environmental Protection Agency
FCT	Fuel Cell Technology Office (DOE)
NREL	National Renewable Energy Laboratory
ORNL	Oak Ridge National Laboratory
USDA	U.S. Department of Agriculture

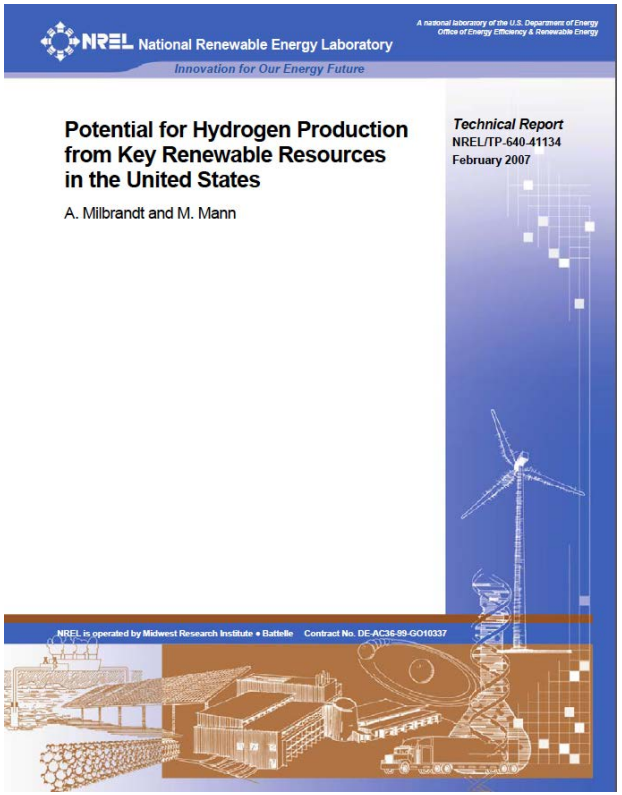
Approach - Overview

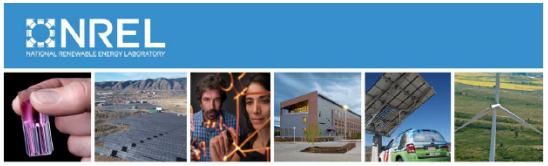
- **Biogas (methane) resource assessment**
  - Waste water treatment plants (WWTP)
  - Landfill gas (LFG)
  - Animal manure
  - Industrial sources and organic food waste
- **Net availability**
  - Estimated based on currently known applications
- **H_2 from biogas**
  - Conversion by steam methane reforming (SMR)
- **Vehicles Supported**
  - Use of 2020 medium case projection of fuel cell electric vehicles (FCEV) fuel efficiency
- **Final products**
  - US maps - national and regional
  - Tabular estimates – national, regional, top sources
  - FCEV supported
  - Final report



Approach – Previous Works

Milbrandt, A. and M. Mann (2006). Potential for Producing Hydrogen from Key Renewable Resources in the United States. Golden, CO, NREL: NREL/TP-640-41134.





H2A Biomethane Model Documentation and a Case Study for Biogas From Dairy Farms

Genevieve Saur and Ali Jalalzadeh-Azar

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Technical Report
NREL/TP-5600-49009
December 2010

Contract No. DE-AC36-08GO28308

Saur, G. and A. Jalalzadeh (2010). H2A Biomethane Model Documentation and a Case Study for Biogas From Dairy Farms. Golden, CO, NREL: NREL/TP-5600-49009.

Approach – Biogas Conversion

Wastewater Treatment (WWTP)

- 1 ft^3 biogas/100 gal wastewater [4]
- 65% CH_4*0.03 m^3 biogas/ft^3 biogas* .7 kg CH_4/m^3 CH_4 [5]

Landfill Gas (LFG)

- EPA Landfill Methane Outreach Program (LMOP): Candidate Landfills [6]

Animal Manure

- EPA State Workbook: Methodologies for Estimating Greenhouse Gas Emissions, Workbook 7 Methane Emissions from Manure Management. [7]

Industrial Process and Organic Food Waste

- US Census Bureau's County Business Patterns [8]

Methane to Hydrogen

- H2A Steam Methane Reforming (SMR) Central Case study : 3.3 kg CH_4/kg H_2 [9]

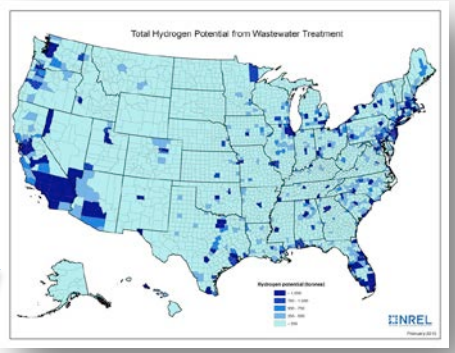
Vehicles Supported

- Total Costs of Ownership of Future Light-Duty Vehicles : Medium case 2020 : 57 miles/gge & 10,000 miles driven/yr [10]
- Transportation Energy Data Book [11] : 2010 car and two-axle, four-tire truck registrations : 230 million vehicles in 2011

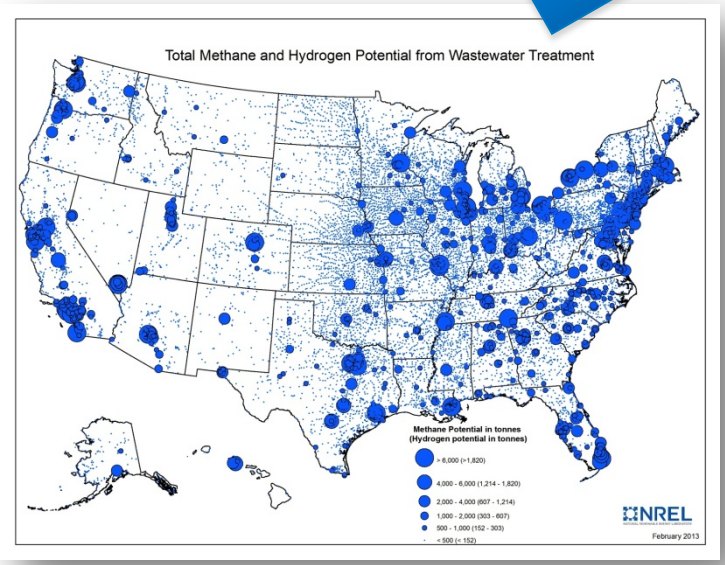
Accomplishments – Wastewater Treatment Plants (WWTP)

WWTP could support upwards of 2% of US vehicle fleet.

Gross CH_4 Potential	2,400 thousand tonnes
Gross H_2 Potential	716 thousand tonnes
Max FCEV Supported	4 million vehicles



Point source aggregated to county level



FCEV Supported

- 57 miles/gge *10,000 miles driven/yr [10]
- 230 million vehicles in US fleet 2011 [11]

Data Source: EPA's Clean Watersheds Needs Survey [1]

Data: ~18,000 records provide water flow

Methane Conversion: 1 ft^3 biogas/100 gal waterwater*0.03m^3 biogas/ft^3 biogas*65% CH_4*.7kg CH_4/m^3 CH_4 [4,5]

Hydrogen Conversion: 3.3 kg CH_4/kg H_2 [9]

Net Availability: cross reference to EPA database of Combined Heat and Power (CHP) plants

Methane range: 55%-70% methane by volume of biogas

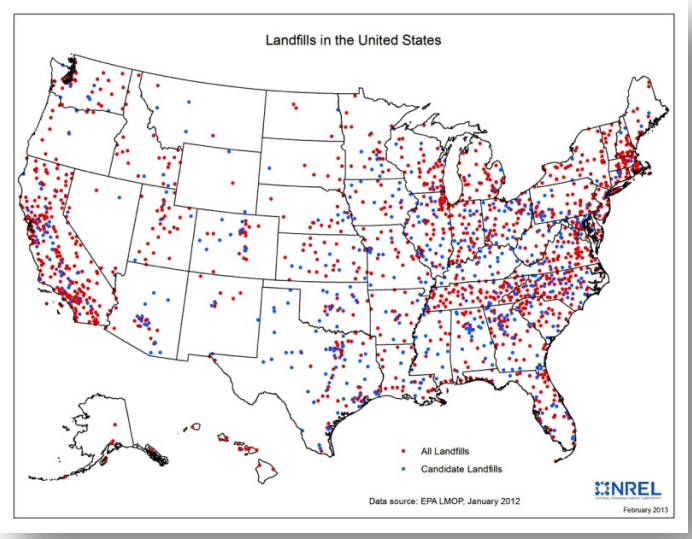
Accomplishments – Landfill Gas (LFG)

LFG could support upwards of 1% of US vehicle fleet.

Net CH_4 Potential	**1,600 thousand tonnes**
Net H_2 Potential	**493 thousand tonnes**
FCEV Supported	**2.8 million vehicles**

FCEV Supported

- 57 miles/gge *10,000 miles driven/yr [10]
- 230 million vehicles in US fleet 2011 [11]



Data Source: EPA's Landfill Methane Outreach Program (LMOP) [2]

Gross Availability: 10,500 thousand tonnes, ~2,000 records with waste data

Net Availability: 445 candidate* sites identified by EPA LMOP

Methane Conversion: EPA LMOP methodology

Hydrogen Conversion: 3.3 kg CH_4/kg H_2 [9]

Methane range: 40%-60% methane by volume of biogas

* Candidate sites must be accepting waste or been closed for 5 yr or less, contain at least 1 million tons of waste, and have no operational or under construction energy project

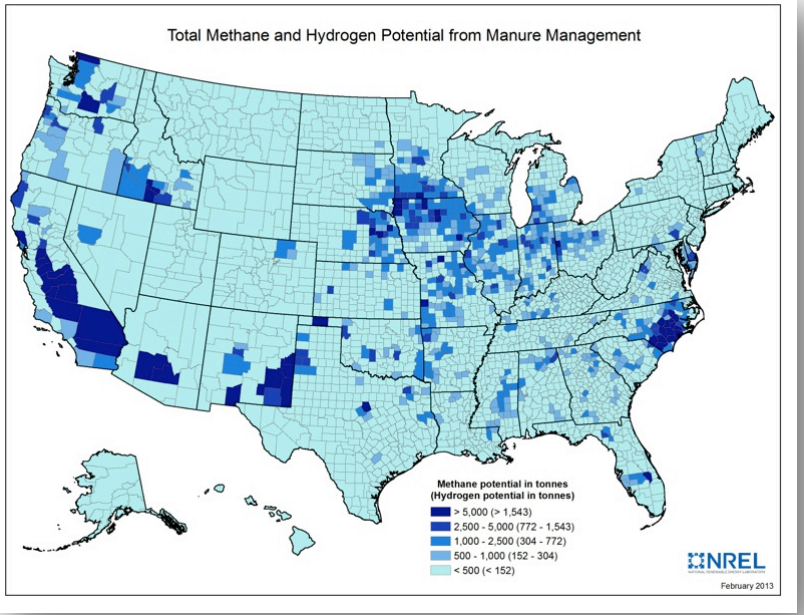
Accomplishments – Animal Manure (county level)

Animal manure could support upwards of 1% of US vehicle fleet.

Gross CH_4 Potential	1,900 thousand tonnes
Gross H_2 Potential	578 thousand tonnes
FCEV Supported	3.3 million vehicles

FCEV Supported

- 57 miles/gge *10,000 miles driven/yr [10]
- 230 million vehicles in US fleet 2011 [11]



Data Source: USDA 2007 Census [3]

Data: county level only

Animals: milk cows, hogs, broiler chickens

Methane Conversion: EPA State Workbook: Methodologies for Estimating Greenhouse Gas Emissions, Workbook 7 Methane Emissions from Manure Management

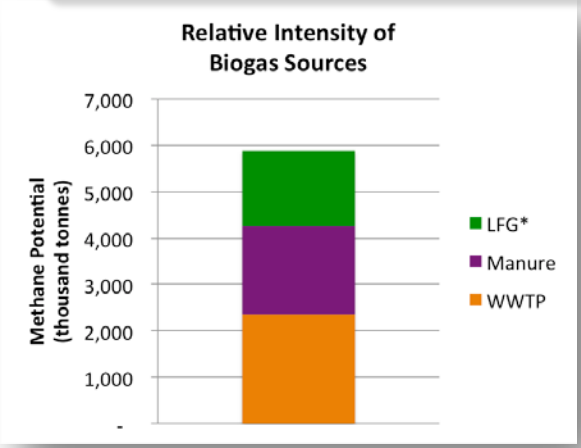
Hydrogen Conversion: 3.3 kg CH_4/kg H_2 [9]

Net Availability: Cross reference to EPA AgStar database of existing anaerobic digesters

Accomplishments – Methane Potential

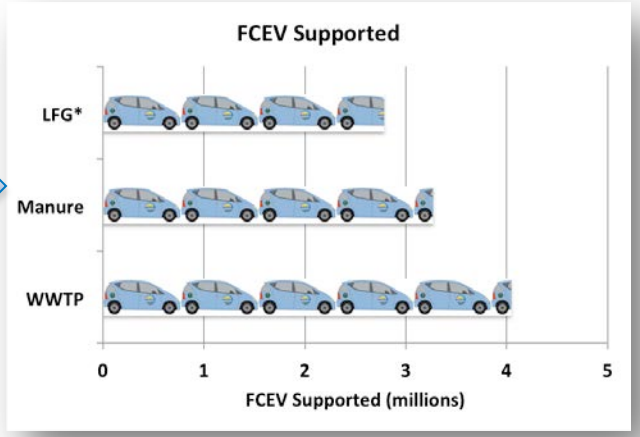
Methane from biogas could support 4% of US vehicle fleet and provide a renewable domestic fuel source for energy infrastructure.

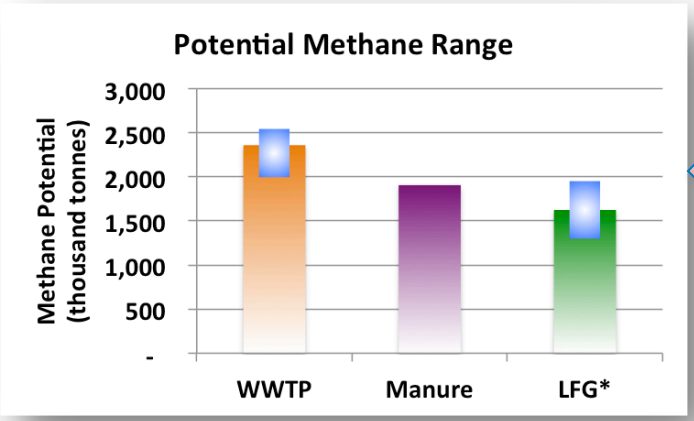
*LFG shows net availability, rather than gross potential for WWTP and animal manure



5,900 thousand tonnes methane*

10 million FCEV*





Biogas Methane Content

- WWTP: 55-70% methane by volume
- LFG: 40-60% methane by volume
- Manure: Not yet identified

FCEV Supported

- 57 miles/gge *10,000 miles driven/yr [10]
- 230 million vehicles in US fleet 2011 [11]

Accomplishments – WWTP Top Sites

WWTP geographically correlate to population centers very well!

Top 10 U.S. Counties for WWTP

County	State	Population 2007 (millions)	H2 (thousand tonne)	FCEV Supported
Cook	IL	5.4	27	155,000
Los Angeles	CA	10.1	18	101,000
Wayne	MI	2	15	85,000
Harris	TX	3.9	12	65,000
Clark	NV	1.9	10	57,000
Essex	NJ	0.8	10	54,000
Kings	NY	2.5	9	52,000
Maricopa	AZ	3.9	9	51,000
King	WA	1.9	9	49,000
Suffolk	MA	0.7	8	44,000

Top 10 U.S. Point Sources for WWTP

State	Authority	H2 (thousand tonne)	FCEV Supported
IL	Chicago MWRDGC	16	91,000
MI	Detroit Board of Water CO	13	71,000
NJ	Passaic Valley SC	9	53,000
MA	Mass. Water Resources Authority	8	44,000
CA	City of Los Angeles, Bureau of Sanitation	7	39,000
WA	Municipal of Metro Seattle	6	34,000
NV	Clark County Ward	5	30,000
CA	LACSD	5	30,000
DC	District of Columbia Water and Sewer Authority	5	28,000
IL	Chicago MWRDGC	5	27,000

Accomplishments – Animal Manure Top Counties

Animal manure can bridge population centers and provide economic opportunities for export to other counties.

Top 10 U.S. Counties for Animal Manure

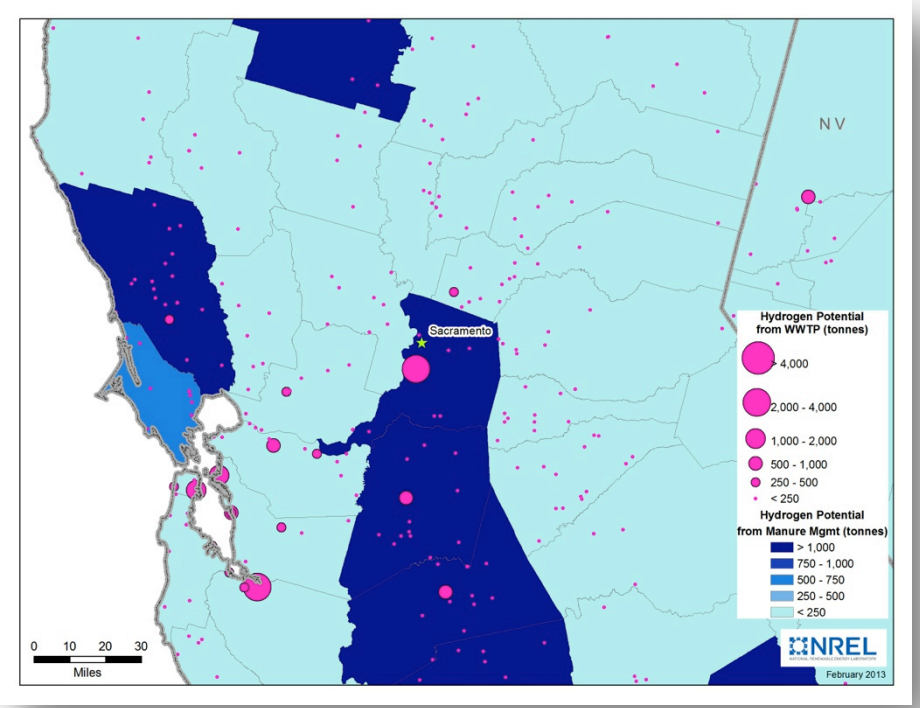
County	State	H2 (thousand tonne)	FCEV Supported
Tulare	CA	25	141,000
Duplin	NC	21	117,000
Sampson	NC	20	110,000
Merced	CA	14	81,000
Stanislaus	CA	11	60,000
Texas	OK	9	52,000
Kings	CA	9	49,000
Chaves	NM	7	42,000
Bladen	NC	7	42,000
Kern	CA	7	37,000

Collaborations

Aggregating data sources make regional source maps possible

- **Methodology Validation**
  - EPA
- **Data Sources**
  - EPA
  - USDA
  - U.S. Census Bureau
- **Conversions**
  - DOE
  - IPCC

Sacramento area showing hydrogen potential from animal manure and WWTP



Future Work – FY 13

Estimating net availability is a high priority for FY13

Sources	Data Authentication	Data Conversion	Net Availability	Final Products	Documentation
WWTP	✔	✔	O	~	~
LFG	~	~	~	~	~
Animal Manure	✔	✔	O	~	~
Industrial Processes	O	O	O	O	~

✔ Completed
~ In Progress
O Not Started

Biogas:

- **Will have competing markets for renewable fuels**
- **Collaborative markets provides early hydrogen market flexibility**
- **Has geographic proximity to urban demand**

Final Report 4th Quarter FY 13

Proposed Future Work – Beyond FY 13

- Resource assessment of lipids (fats, oils, grease)
- Inclusion into OpenEI
- Techno-economic analysis of biogas production and purification
- Cost and biogas quality implications
- Regional differences in cost & incentives
- Pathways assessment of spatial distribution for combining multiple sources

Summary

- **Biogas has a diversity of geographic availability and can help support early market FCEV rollout.**
  - Includes rural connectors stations
- **WWTP and LFG are highly correlated to population centers where demand is highest.**
- **Animal manure helps bring diversity of locations and economic opportunity for rural areas.**
- **Initial estimates suggest WWTP, LFG, and animal manure could support upwards of 10 million FCEV**
- **Cost and contaminant cleanup need further study.**
- **LFG estimates are net availability; WWTP and animal manure are gross estimates**

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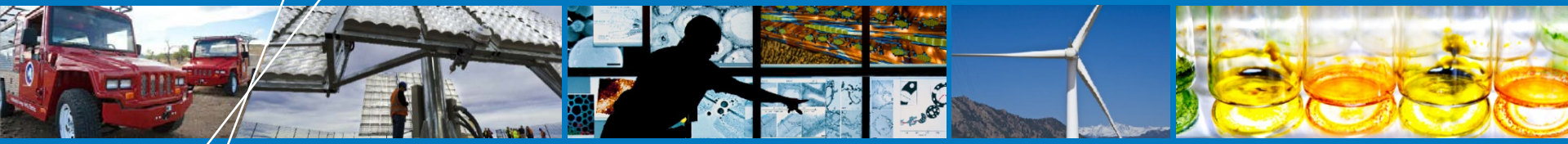

Technical Back-up

References

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