XI.8 Hydrogen from Biogas: Resource Assessment

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Project Start Date: October 2012
Project End Date: September 2013

Overall 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.

Fiscal Year (FY) 2013 Objectives

- Update prior study on methane from wastewater treatment, landfills, and manure management.
- Expand analysis to include methane from industrial processes and organic food waste.

Technical Barriers

This project addresses the following technical barriers from the Systems Analysis section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

(A) Future Market Behavior - Expand analysis to include current net availability by assessing sources currently in use.

(C) 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.

Contribution to Achievement of DOE Systems Analysis Milestones

This project will contribute to achievement of the following DOE milestones from the Systems Analysis section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

- Milestone 1.6: Complete analysis of biogas availability for stationary power generation and hydrogen production. (4Q, 2013)

FY 2013 Accomplishments[1]

- Collected data from several sources: Environmental Protection Agency Clean Watersheds Needs Survey, 2007; Environmental Protection Agency Landfill Methane Outreach Program; Department of Agriculture Census, 2007; U.S. Census Bureau County Business Patterns 2011; and the Homeland Security Infrastructure Program Gold Dataset 2012 to estimate biogas from wastewater treatment plants, landfills, animal manure, and industrial, institutional, and commercial (IIC) sites [1-5]. Preliminary estimates of net methane availability are 1.9, 2.5, 1.8, and 1.2 (total) million tonnes annually for wastewater treatment plants, landfills, animal manure, and IIC, respectively.
- Developed hydrogen estimates for the four biogas sources using biogas purification efficiency of 87% and methane-to-hydrogen conversion of 3.3 kg CH_4/kg H_2 from DOE's H2A Production Hydrogen from Steam Methane Reforming Central case study [6]. Preliminary estimates of hydrogen for biogas from wastewater treatment plants, landfills, animal manure, and IIC are 508, 648, 486, and 305 thousand tonnes of hydrogen, respectively.
- Produced estimates for fuel cell electric vehicles (FCEVs) supported using efficiency of 57 miles/gasoline gallon equivalent and annual usage of 10,000 miles driven/yr [5]. Preliminary estimates of FCEVs supported by wastewater treatment plants, landfills, animal manure, and IIC are 2.9, 3.7, 2.7, and 1.7 million vehicles annually.
- Developed U.S. national maps and two regional maps (Sacramento, CA, and Boston, MA) for understanding the geographic distribution of the resources.

INTRODUCTION

This analysis includes a resource assessment of four sources of biogas in the U.S. that updates and expands a previous study on the subject; wastewater treatment plants (WWTPs), landfills, animal manure, and industrial, institutional and commercial source of organic waste (IIC) [1-5]. Biogas is produced by anaerobic digestion of organic matter in an oxygen-free environment. This addresses both the total resource as well as a net availability against some

[1] Results are updated from the AMR 2013 presentation.

of the competing demands for the biogas. From this resource assessment the potential for renewable hydrogen from biogas is calculated as well as the FCEVs that it might support. The geographic distribution is also provided to help consider regional policies that might support increased utilization of the resource.

APPROACH

The analysis uses databases of biogas resources from the Environmental Protection Agency, Department of Agriculture, and U.S. Census Bureau to calculate the methane potential of each resource in a consistent manner. The total potential of each source is calculated on either a point source or county basis dependent on the data; WWTP and landfills by point source, animal manure and IIC by county. A net availability is also estimated by either cross-referencing existing applications or by candidate sites recommended for development. WWTP and animal manure net availability is estimated using a database of combined heat and power plants and the animal manure by existing anaerobic digestion plants. Candidate landfills assessed by the Environmental Protection Agency are used to calculate the net availability of the resource. National and regional maps are used to show the geographic distribution of resources.

From the methane availability the amount of hydrogen and FCEVs supported can be estimated. The hydrogen potential is calculated from the methane potentials in the resource assessment by assuming an 87% methane purification efficiency in the process to make biomethane and a usage of 3.3 kg CH_4/kg H_2 in steam methane reforming of the biomethane to produce hydrogen. Annual FCEVs supported were calculated using an estimate of 56.5 miles/kg H_2 and 10,000 miles driven annually [7].

RESULTS[2]

The U.S. potential for methane and hydrogen is shown in Table 1. The total annual potential from all sources was about 16 million tonnes of methane or 4.2 million tonnes of hydrogen if purified and converted. However, the net availability was estimated at only about 6.2 million tonnes of methane or 1.6 million tonnes of hydrogen annually. Landfills had the highest potential, but when estimating net availability all resources showed between 300-650 thousand tonnes of hydrogen potential annually. The methane and hydrogen potentials could enhance the renewable portfolio of either stationary power expansion or vehicle infrastructure.

From the methane and hydrogen estimate, maps were developed by point sources for WWTP and landfills (Figure 1) or at the county level for animal manure and IIC (Figure 2). The geographic distribution of resources is important for considering policies, incentives, and techno-economic system design of diverse biogas sources. To understand some of the local geographic elements of biogas sources maps regional maps were also made of the Sacramento, CA, and Boston, MA, (Figure 3) areas. These maps help highlight the distribution of resources and how targeted policy might foster development as well as the system design intricacies for making economically feasible projects.

TABLE 1. U.S. Methane and Hydrogen Potentials by Source

Source	Methane Potential (thousand tonnes/yr)		Hydrogen Potential (thousand tonnes/yr)	
	Total	Available	Total	Available
WWTP*	2,339	1,927	618	509
Landfills**	10,586	2,455	2,795	648
Animal Manure***	1,905	1,842	503	486
IIC Organic Waste	1,158	Not Available	306	N/A
Total	15,989	6,224	4,222	1,643

* Total potential for WWTP is higher, given that the analysis was done for only half of the WWTPs in the country (water flow data for the rest is missing).
** Total potential for landfills could be higher given that the estimate accounts for only the waste in place recorded for a given year and doesn't take into account additional waste that may have come in since the record was taken (as it was done for available potential estimate). It is an approximate value. Available potential for landfills is estimated using candidate landfills only. Available potential could be higher if we include "other" and "potential" landfills.
*** Existing digesters (dairy, poultry, and swine) capture about 62,942 tonnes/yr [2,3].

In order to facilitate future studies some distribution plots of plant sizes were created for WWTP and landfills (Figure 4). These help to understand the size considerations for developing economically feasible projects. They can help target certain size plants or analyze the impact of co-digestion and economies of scale for biogas purification. Knowledge of both the spatial and size elements of biogas sources can help inform strategies for their development.

The impact on early market FCEV rollout was also considered in relation to how many vehicles the renewable hydrogen from biogas might support. Table 2 shows the estimated FCEV supported by hydrogen from the biogas sources. This is also taken in comparison to the U.S. fleet estimates for 2010 for cars and light-duty trucks of about 230 million vehicles [8]. Overall, the net availability of biogas could support about 11 million FCEVs which would be about 5% of the U.S. fleet in 2010 if that portion were replaced by FCEVs.

CONCLUSIONS AND FUTURE DIRECTIONS

The updated resource assessment for methane and hydrogen production from biogas was completed, which included three sources previously studied and one new source of organic matter. The conclusions of the analysis are that biogas can be a significant source of renewable fuel, but it

[2] Results are updated from the AMR 2013 presentation.

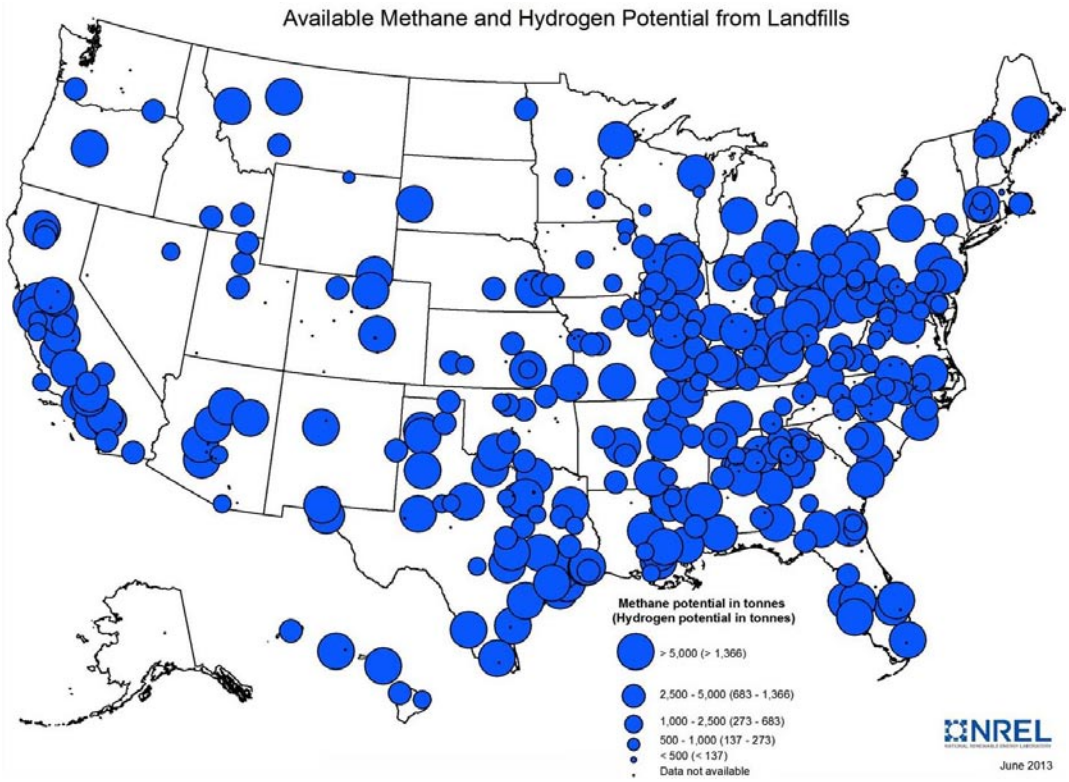

FIGURE 1. Net Availability of Methane and Hydrogen Potential from Landfills

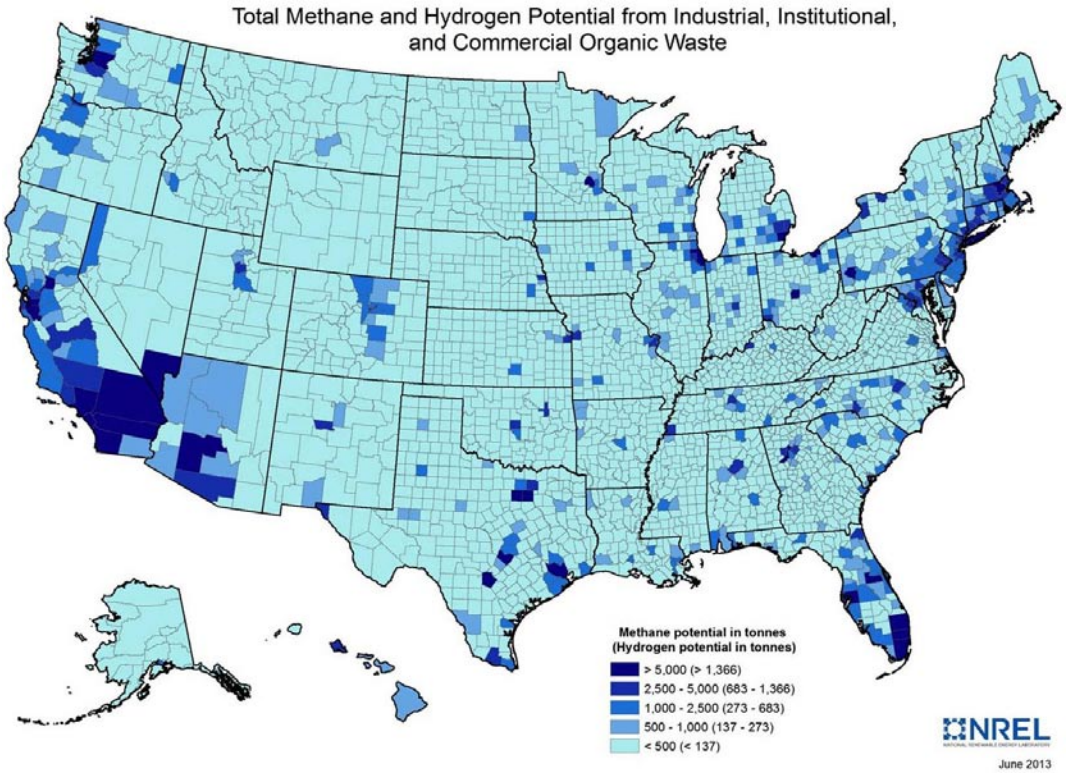

FIGURE 2. Total Methane and Hydrogen Potential from Industrial, Institutional, and Commercial sources of Organic Waste

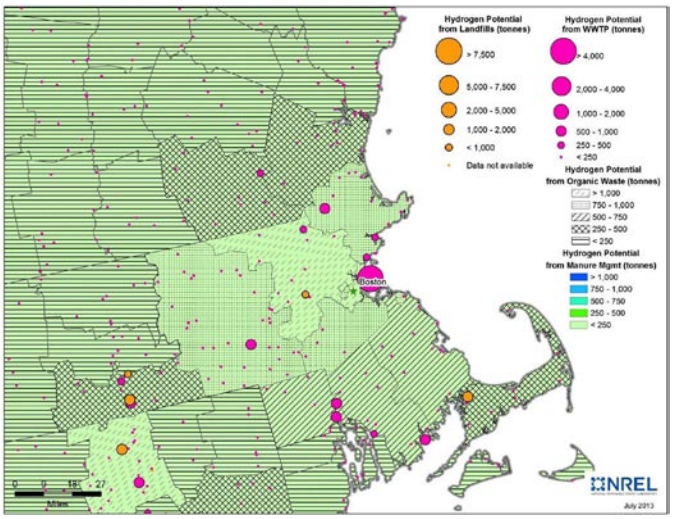

FIGURE 3. Hydrogen Potential from Biogas in Boston, MA

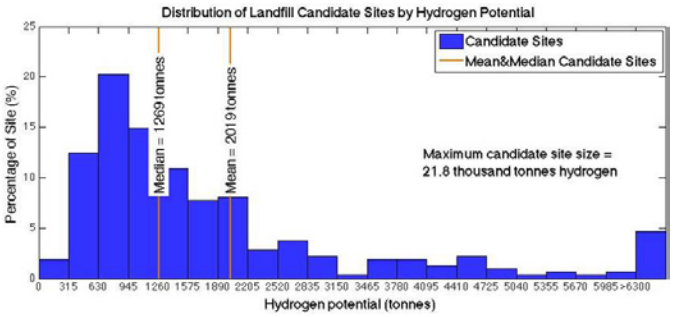

FIGURE 4. Size Distribution of Landfill Candidate Sites by Hydrogen Potential

TABLE 2. FCEVs Supported by Biogas Source Net Availability

Biogas Source	FCEVs Supported (millions annually)	Percentage of 2010 U.S. Light-Duty Fleet (%)
WWTP	2.9	1%
Landfills	3.7	2%
Animal Manure	2.7	1%
IIC*	1.7	1%
Total	11.0	5%

* IIC is total potential.

is not going to meet all of our energy needs. As a fuel it has challenges both in the techno-economic system feasibility as well as for policy and incentives. The diverse nature of the resources may make designing systems that span sources more viable. For that purpose, information about the spatial and size distribution of sources is an important step.

Future work could include:

- Resource assessment of lipids (fats, oils, grease)
- Inclusion into (http://en.openei.org/wiki/Main_Page), an energy data repository, for better collaboration
- Techno-economic analysis of biogas production and purification
- Cost and quality implications in biogas and biomethane
- Regional differences in cost, policy & incentives
- Pathways assessment of spatial distribution for combining multiple sources

FUTURE DIRECTIONS

The following will be completed in FY 2013:

- Finalize methodology and estimates for methane and hydrogen potential from wastewater treatment plants, landfills, and animal manure.
- Estimate net potential of the different biogas sources.
- Estimate methane and hydrogen potential from industrial and commercial processes and facilities that have organic waste using U.S. Census Bureau data on business patterns.
- Generate U.S. maps using the geographic data to show distribution and intensity of the different biogas sources.
- Estimate the FCEVs supported in the U.S. by biogas.
- Complete final report on the biogas assessment from wastewater treatment plants, landfills, animal manure, and industrial/commercial processes.

FY 2013 PUBLICATIONS/PRESENTATIONS

1. Hydrogen from Biogas: Resource Assessment, presented at DOE Annual Merit Review, May 13–17, 2013, Washington, D.C.

REFERENCES

1. U.S. EPA's Clean Watersheds Needs Survey (CWNS) 2008.

2. U.S. EPA's Landfill Methane Outreach Program (LMOP) (2012).

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4. U.S. Census Bureau County Business Patterns 2011.

5. Homeland Security Infrastructure Program (HSIP) Gold Dataset 2012.

6. U.S. DOE (2012) H2A: Current Central Hydrogen Production from Natural Gas without CO2 Sequestration v. 3.0. U.S. Department of Energy. http://www.hydrogen.energy.gov/h2a_prod_studies.html

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8. Davis, S.C., S.W. Diegel, and R.G. Boundy, *Transportation Energy Data Book: Edition 31*, 2012, Oak Ridge National Laboratory: Oak Ridge, TN.