



Innovation for Our Energy Future

Waste-to-Energy and Fuel Cell Technologies Overview

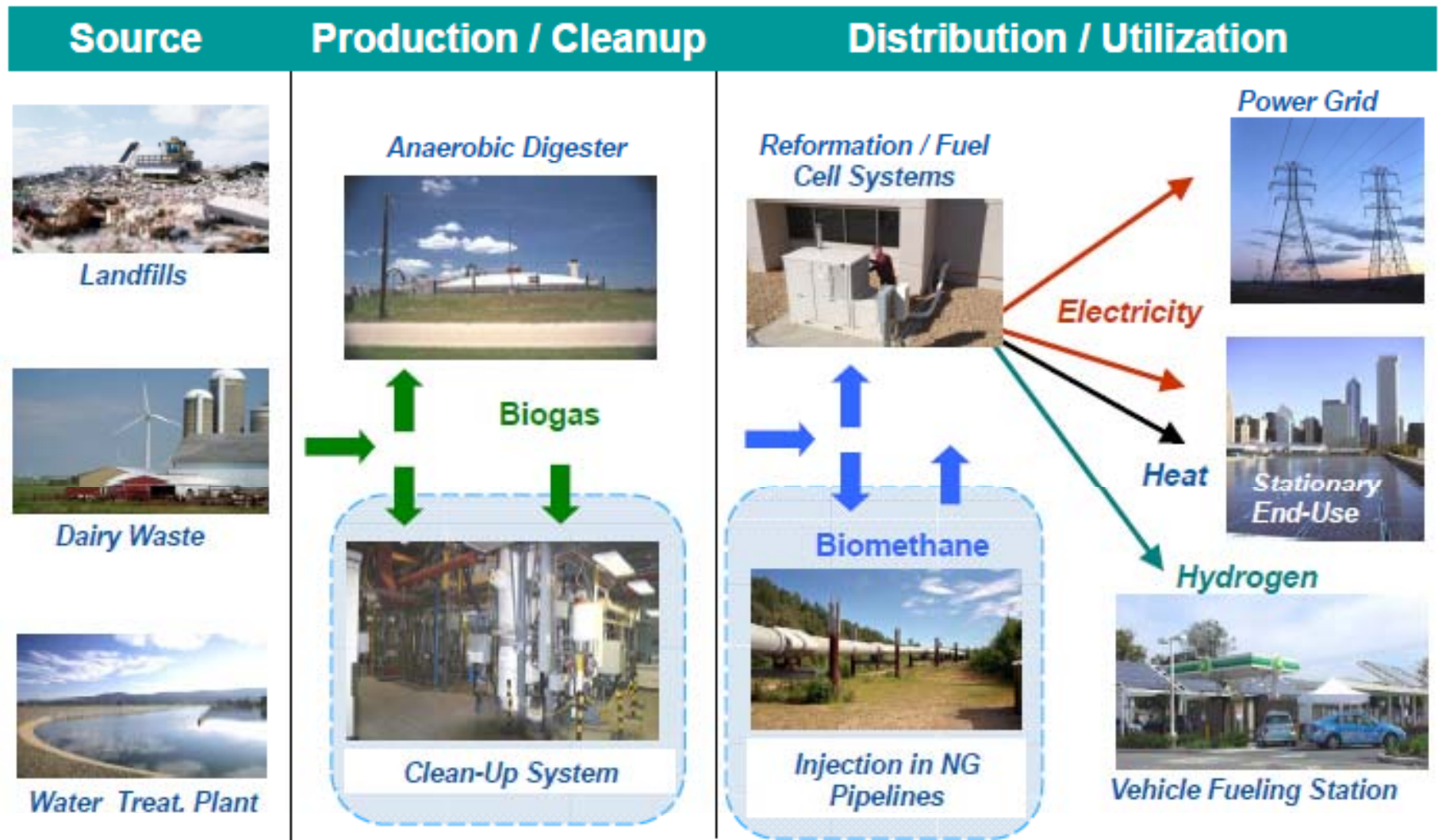


**Presented to:
DOD-DOE Waste-to-
Energy Workshop**

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Capital Hilton Hotel
Washington, DC**

Global Approach for Using Biogas



Anaerobic Digestion of Organic Wastes is a Good Source of Methane.

Organic waste + methanogenic bacteria → methane (CH₄)

Issues:

High levels of contamination

Time varying output of gas quantity and quality

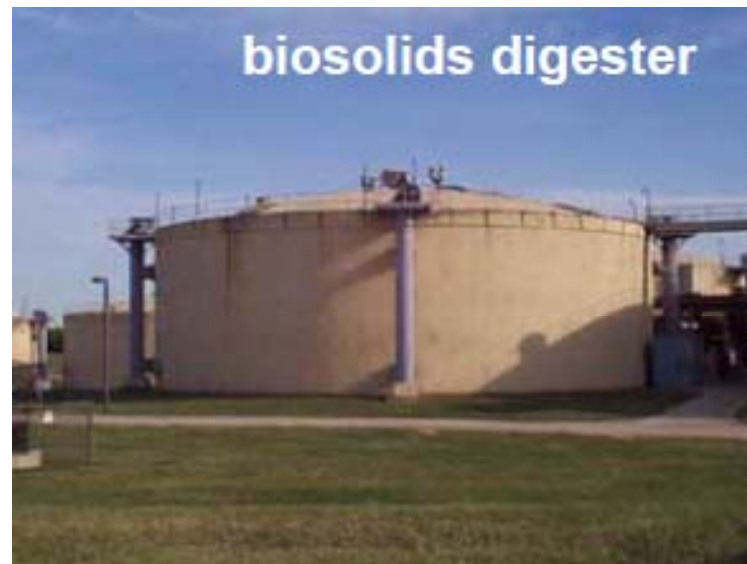
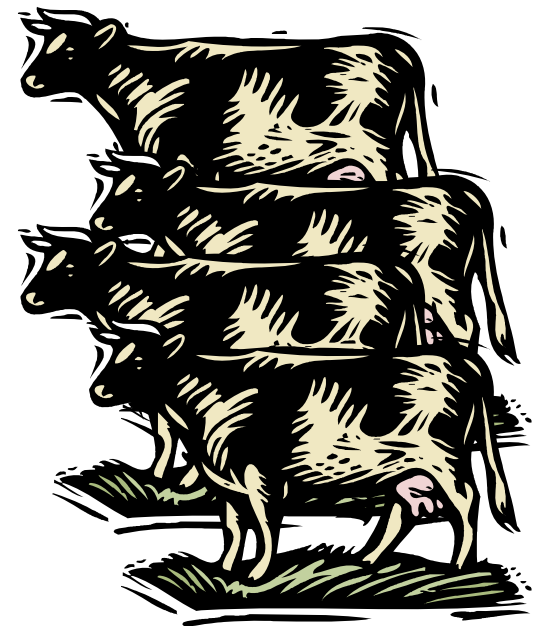


Photo courtesy of Dos Rios Water Recycling Center, San Antonio, TX

Opportunities for Methane Production via Anaerobic Digestion

- Breweries (~73 Watts per barrel of beer)
- Municipal Waste Water Treatment Plants (~4 W/person)
- Industrial-scale Food Processing
- Landfills
- Dairy and Pig Farms (~200 W/Cow)
- Pulp and Paper Mills



Stationary Fuel Cell Products Currently on the Market are Configured to Operate on Natural Gas

UTC Power, Inc.

FuelCell Energy Inc.

Bloom Energy, Inc.

PureCell 400

DFC 300, 1500, and 3000

ES-5000 Energy Server

Waste processes that produce methane, like anaerobic digestion of organic matter, are most easily mated to these fuel cell systems.



Comparison by Generator Type

(based on 40-million SCF* of biogas per year**)

Generator Type	Megawatt-hours/year
PAFC	2,900
MCFC	3,300
Micro-turbine	1,800
Reciprocating Engine	1,500

* ~830 Btu/SCF (HHV)

** WWTP serving a community of about 110,000 people

This comparison ignores the fact that generators do not come in an infinite range of sizes.

Contaminants in Biogas are a problem.

Commercial stationary power plants of all types are configured to operate on pipeline quality natural gas. Additional cleanup is necessary to use biogas from anaerobic digesters or landfills with these generators.



Compressor Station



PSA Cleanup System

Photos courtesy of Guild Associates, Inc.

Landfill Gas Contaminants vs Fuel Cell Specs.

Contaminant	Landfill Gas	Fuel Cell Spec*
Carbon Dioxide	~30%	3%
Nitrogen	~10%	4%
Oxygen	~1%	0.2%
C ₄ ⁺ hydrocarbons	0.2%	0.5%
Sulfides (mainly H ₂ S)	300 ppm	6 ppm
Organic Chlorine	<50 ppm	0.05 ppm
Organic Silicon	<30 ppm	Trace to 0

* Based on fuel specifications for the PureCell®400

Gasification of wood wastes is another potential source of useful fuel gas.

Wood waste → Gasification → Cleanup → Fuel Cell

Gasification uses high temperature to convert cellulosic materials to fuel gas

- Hydrogen (H_2)
- Carbon monoxide (CO)
- Methane (CH_4)
- Carbon Dioxide (CO_2)



One technology we have been following is inductive gasification developed by a German company Pyromex.

In 2009 NREL Performed a Study for the Los Alamos Joint Forces Training Base

Project Goal

- Increase base sustainability by producing on-site power
- Provide base energy needs through renewable pathways
- Provide backup power functionality to mission critical loads
- Provide hydrogen for on-site and public fuel cell vehicle refueling

Resource Availability

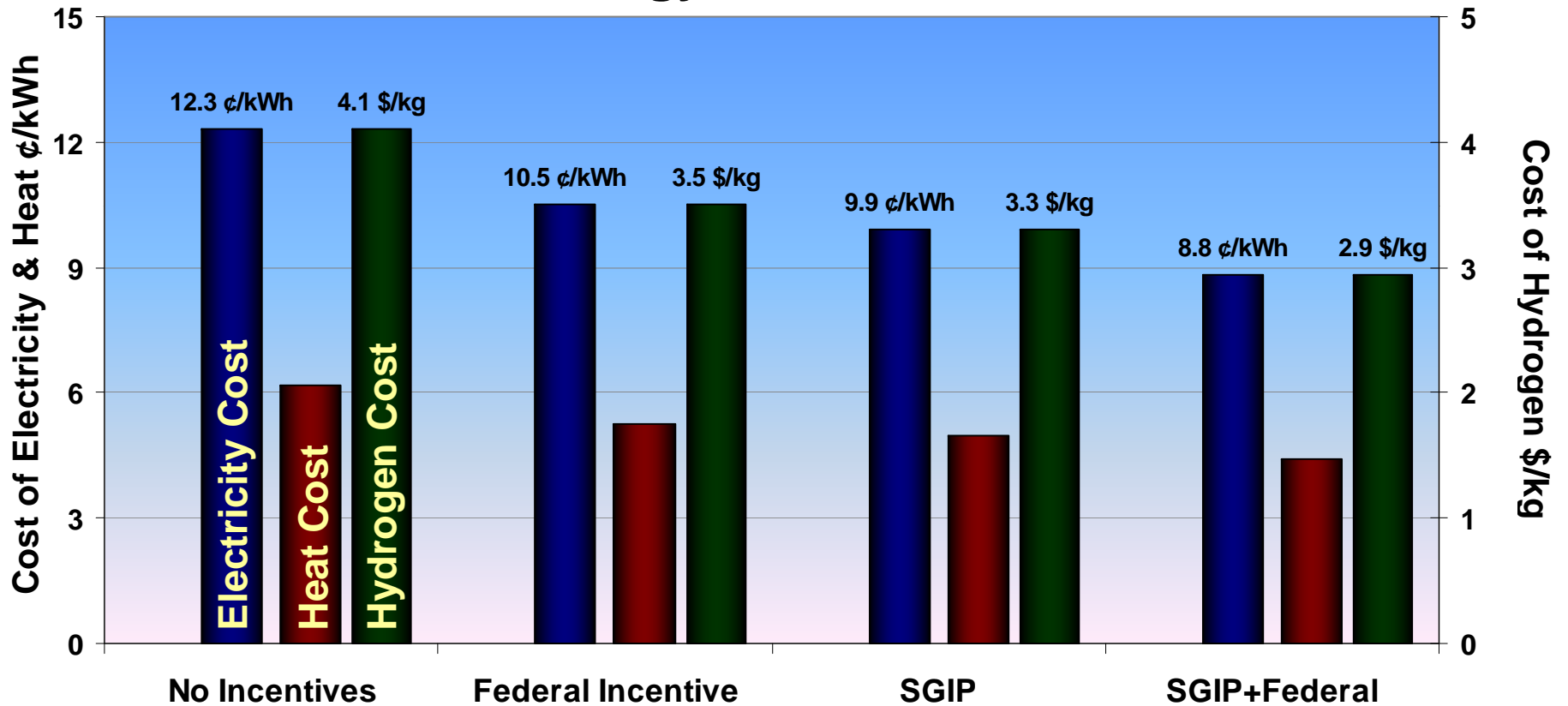
- Biomass up to 300 tons/day
- Land available for energy conversion hardware

Technology Evaluated

- Inductive gasification (Pyromex, German technology, mfg in Carson City, NV)
- Molten carbonate fuel cell (Fuel Cell Energy, US Technology, mfg in Connecticut)

Study evaluated the cost of electricity, heat, and hydrogen produced by the system.

Cost of Energy vs. Incentive Levels



25 tons/day biomass consumption, 350 kg/day H₂ and 31.2 MWh/day electrical output and 200 MMBtu/day heat

Technology Overview Summary

- Stationary fuel cells operating on natural gas are commercial technology.
- Integration of stationary fuel cells with anaerobic digesters is a demonstrated technology.
- A reasonable business case can be made for both at current costs when federal and state incentives are available.
- Integration of stationary fuel cells with biomass gasification is a developing technology that is in need of demonstration.

For Information Resources on Fuel Cells & H₂ the Place to Start is www.hydrogen.energy.gov



U.S. Department of Energy
Energy Efficiency and Renewable Energy *Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable*

Hydrogen, Fuel Cells & Infrastructure Technologies Program

Hydrogen and fuel cells have the potential to solve several major challenges facing America today: dependence on petroleum imports, poor air quality, and greenhouse gas emissions. The Hydrogen, Fuel Cells & Infrastructure Technologies Program is working with partners to accelerate the development and successful market introduction of these technologies.

- Hydrogen Production >
- Hydrogen Delivery >
- Hydrogen Storage >
- Fuel Cells >
- Technology Validation >
- Safety, Codes & Standards >
- Education >
- Systems Analysis >

INCREASE YOUR H₂IQ
Looking for easy-to-understand information about hydrogen and fuel cell technologies? **INCREASE YOUR H₂IQ** by checking out our educational fact sheets, fuel cell animation, and other introductory resources.

Quick Links

- DOE Announces Hydrogen Funding Opportunity for Small Businesses > September 27, 2006
- DOE Loan Guarantee Program Promotes Innovative Technologies > August 23, 2006
- 2006 Fuel Cell Seminar > November 13-17, 2006
- DOE Hydrogen Program Web Site

U.S. DEPARTMENT OF ENERGY
Hydrogen Program

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- > Education
- > Basic Research
- > Systems Analysis
- > Systems Integration

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Announcement Public Welcome Technical Advisory Meeting

News
New DOE Employment Opportunity Hydrogen Production
DOE seeks a chemical engineer to serve as production team leader in the HFCIT Program. August 28, 2006 [More >](#)

Carbon Nanotubes for On-Board H₂ Go/No-Go Decision
A recent Federal Register Notice solicited in upcoming go/no-go decision on pure carbon. August 28, 2006 [More >](#)

DOE Loan Guarantee Program Promotes Innovative Technologies
The DOE Loan Guarantee Program is available to promote the commercial use of innovative technologies. August 23, 2006 [More >](#)

NREL National Renewable Energy Laboratory
Hydrogen & Fuel Cells Research

Capabilities
Projects
Research Staff
Working with Us
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Awards

Hydrogen is the simplest and most abundant element in the universe. Hydrogen can be produced from a wide variety of domestic resources using a number of different technologies. Fuel cells harness the chemical energy of hydrogen to generate electricity without combustion or pollution. NREL is working to develop and demonstrate advanced hydrogen and fuel cell technologies to reduce our nation's dependence on foreign oil, improve our air quality, and maintain our economic competitiveness. [Learn more](#) about hydrogen and fuel cells.

Hydrogen and fuel cell R&D efforts at NREL are focused on hydrogen production and delivery, hydrogen storage, fuel cells, technology validation, safety, codes and standards, and analysis. These research areas directly support the [NREL Hydrogen, Fuel Cells & Infrastructure Technologies Program](#). The goal of this program is to help industry develop technologies to produce, store, transport and use hydrogen made from renewable resources in quantities large enough, and at costs low enough, to compete with traditional energy sources such as coal, oil and natural gas.

NREL's hydrogen and fuel cell research activities crosscut and contribute to advances across the laboratory in photovoltaics (PV), bioenergy, transportation, wind, buildings, and basic sciences. The Hydrogen Technologies & Systems Group of the [Center for Electric & Hydrogen Technologies & Systems](#) coordinates and integrates

RESOURCES
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Hydrogen Photos

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Information on
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