NREL
NATIONAL RENEWABLE ENERGY LABORATORY

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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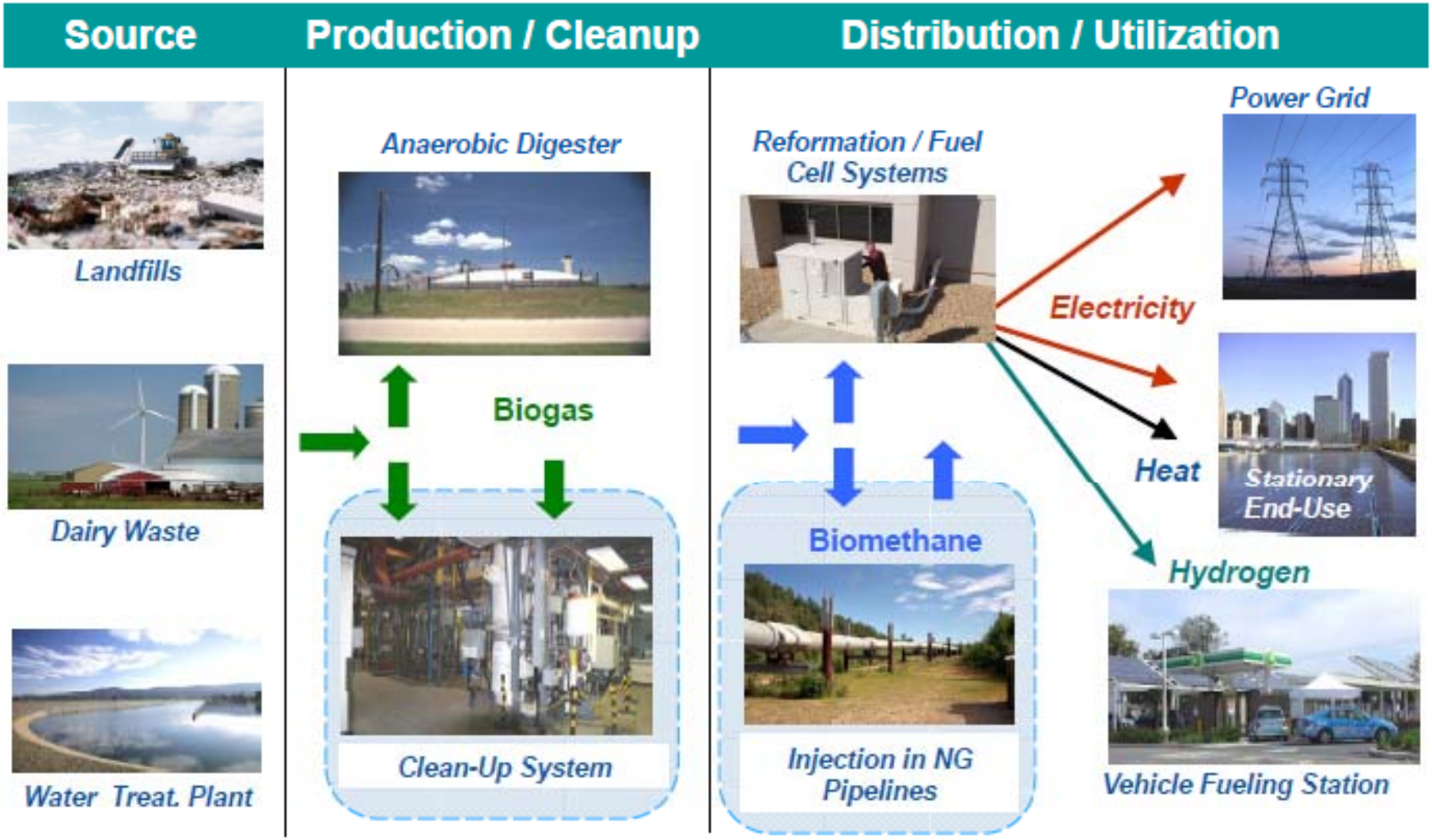
Global Approach for Using Biogas



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

Organic waste + methanogenic bacteria → methane (CH_4)

Issues:

- High levels of contamination
- Time varying output of gas quantity and quality

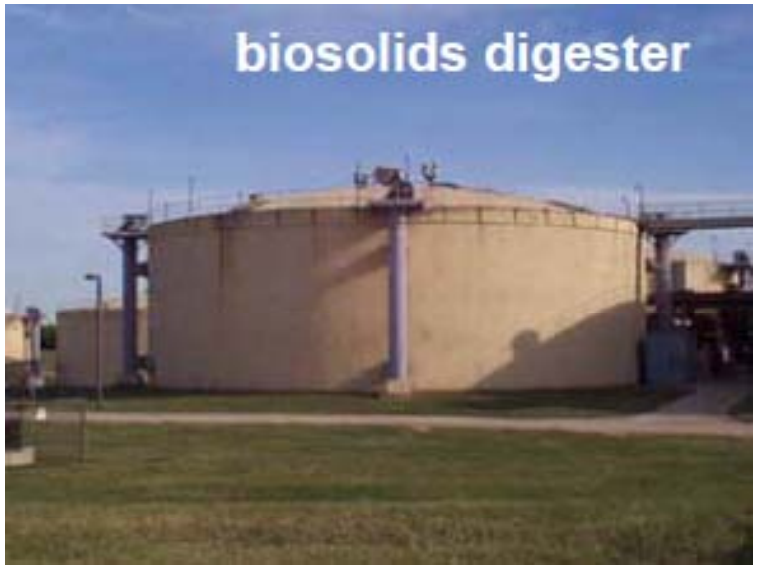
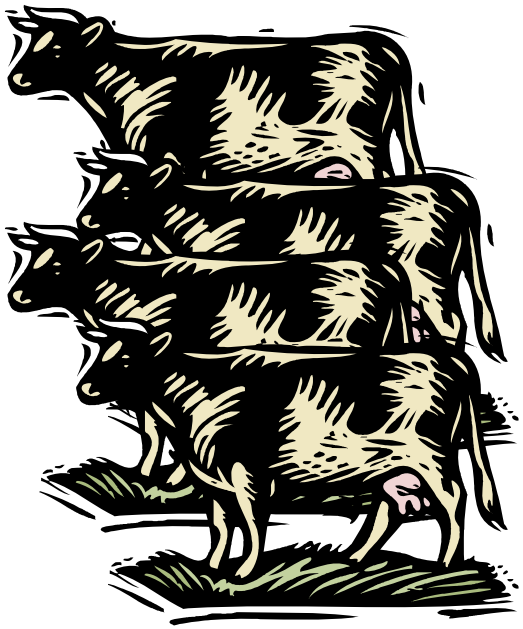


Photo courtesy of Dos Rios Water Recycling Center, San Antonio, TX

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.	PureCell 400
FuelCell Energy Inc.	DFC 300, 1500, and 3000
Bloom Energy, Inc.	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_2S)	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 Alamitos 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

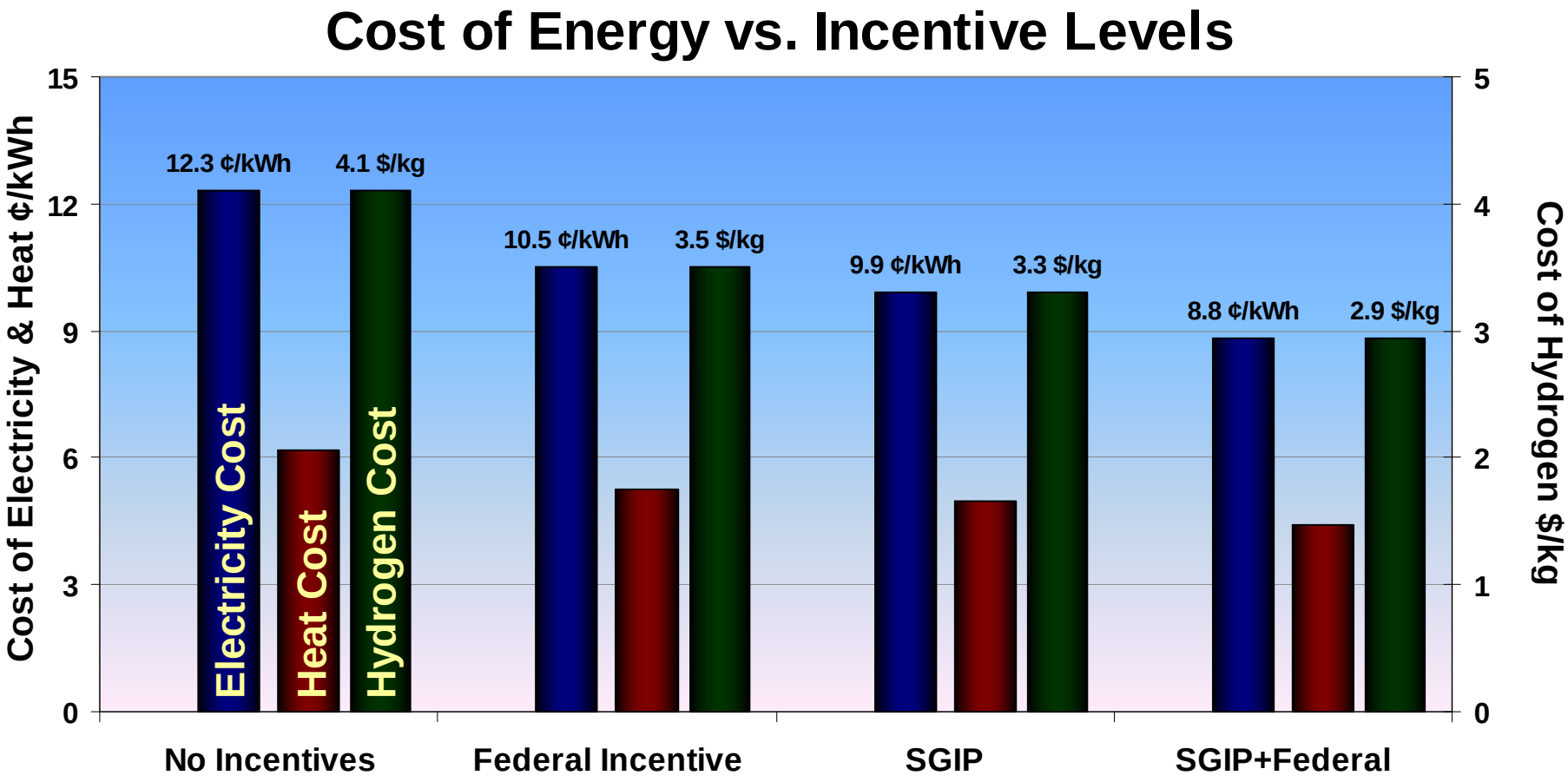
Resource Availability

- 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.



25 tons/day biomass consumption, 350 kg/day H_2 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 & H_2 the Place to Start is www.hydrogen.energy.gov