Waste-to-Energy and Fuel Cell Technologies Overview

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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.
Global Approach for Using Biogas
Anaerobic Digestion of Organic Wastes is a Good Source of Methane.

Organic waste + methanogenic bacteria $\rightarrow$ 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.  
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**)

<table>
<thead>
<tr>
<th>Generator Type</th>
<th>Megawatt-hours/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAFC</td>
<td>2,900</td>
</tr>
<tr>
<td>MCFC</td>
<td>3,300</td>
</tr>
<tr>
<td>Micro-turbine</td>
<td>1,800</td>
</tr>
<tr>
<td>Reciprocating Engine</td>
<td>1,500</td>
</tr>
</tbody>
</table>

* ~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.

Photos courtesy of Guild Associates, Inc.
# Landfill Gas Contaminants vs Fuel Cell Specs.

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Landfill Gas</th>
<th>Fuel Cell Spec*</th>
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</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>~30%</td>
<td>3%</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>~10%</td>
<td>4%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>~1%</td>
<td>0.2%</td>
</tr>
<tr>
<td>C₄⁺ hydrocarbons</td>
<td>0.2%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Sulfides (mainly H₂S)</td>
<td>300 ppm</td>
<td>6 ppm</td>
</tr>
<tr>
<td>Organic Chlorine</td>
<td>&lt;50 ppm</td>
<td>0.05 ppm</td>
</tr>
<tr>
<td>Organic Silicon</td>
<td>&lt;30 ppm</td>
<td>Trace to 0</td>
</tr>
</tbody>
</table>

* 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 (H₂)
- Carbon monoxide (CO)
- Methane (CH₄)
- Carbon Dioxide (CO₂)

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

Cost of Energy vs. Incentive Levels

- No Incentives: 12.3 ¢/kWh, 4.1 $/kg
- Federal Incentive: 10.5 ¢/kWh, 3.5 $/kg
- SGIP: 9.9 ¢/kWh, 3.3 $/kg
- SGIP+Federal: 8.8 ¢/kWh, 2.9 $/kg

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