

WASTE/BY-PRODUCT HYDROGEN

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Fuel Cell and
Hydrogen
Energy
Association

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The Fuel Cell and Hydrogen Energy Association

FCHEA

- Trade Association for the industry
- Member driven - Market focused
- Developers, suppliers, customers, nonprofits, government
- Advocacy
- Safety and standardization
- Education
- Strategic Alliances



Waste/By-product Hydrogen

Overview

- Growing populations, rising standards of living, and increased urbanization leads to a escalating volume of waste.
- Huge volumes of waste are collected in dumps, creating a major environmental issue.
- Wastewater treatment plants generate noxious gasses that are released in the environment.
- Technological developments, economic conditions, and public policy trends are now aligning to create a significant market opportunity for waste-to-energy (WTE) plants, which utilize municipal solid waste (MSW) and wastewater from treatment plants for the production of electricity and heat.



Waste/By-product Hydrogen

Waste H₂ sources include:

- **Waste bio-mass:** biogas to high temp fuel cells to produce H₂ – there are over two dozen sites where fuel cells have been installed- over 9 MW
- **Chlor-alkali plants:** Hydrogen is created as a by-product manufacturing of chemicals like chlorine. This can be captured and transported for use or used to help power the plants themselves (GM and Dow Chemical had a Demo Program)
- **Reduction furnace operations :** metal powder, heat treatment, -- FCE is pursuing this market—Demo project under DOE-ITP program in NJ
- **Hydrocarbon waste:** can produce hydrogen using high temp fuel cells-such as DFC or SOFC—Paint fume from Ford Motors plant in Canada- FCE's fuel cell
- ***Total market is above 100,000 MW world-wide for all these.***
- NOTE: Each of these opportunities have different clean up requirements.



Waste/By-product Hydrogen

Why Renewable Hydrogen?

- More effective use of waste hydrogen, adds to overall supply, greens the source of energy, and ultimately should help lower the cost of hydrogen.
- Turns a wasted asset into either a marketable product or increased operational efficiency within a plant.
- Using hydrogen helps mitigate the intermittency of renewable energy sources by providing opportunities for storage.
- In the US, there are:
 - 150 manufacturing facilities where hydrogen is currently not recovered
 - 40,000 waste treatment facilities that could be modified to generate hydrogen

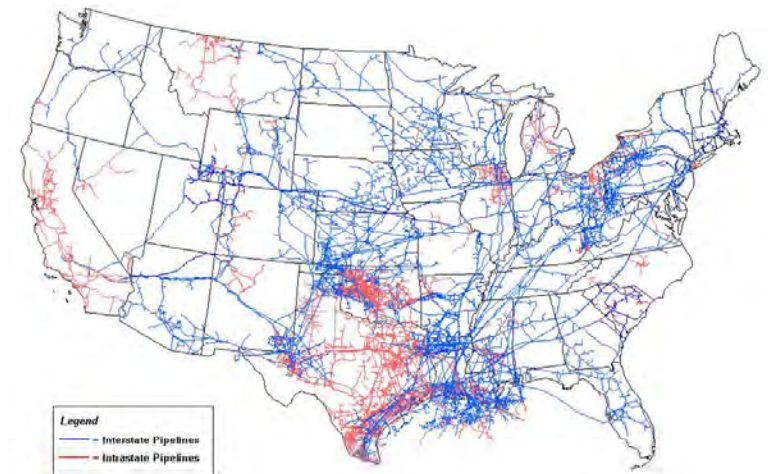


Waste/By-product Hydrogen

Fuel Flexibility

Biogas: generated from organic waste

- Wastewater treatment plants can provide multiple MW of renewable power
- Agricultural and food processing plants can turn waste into power



Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Gas Transportation Information System

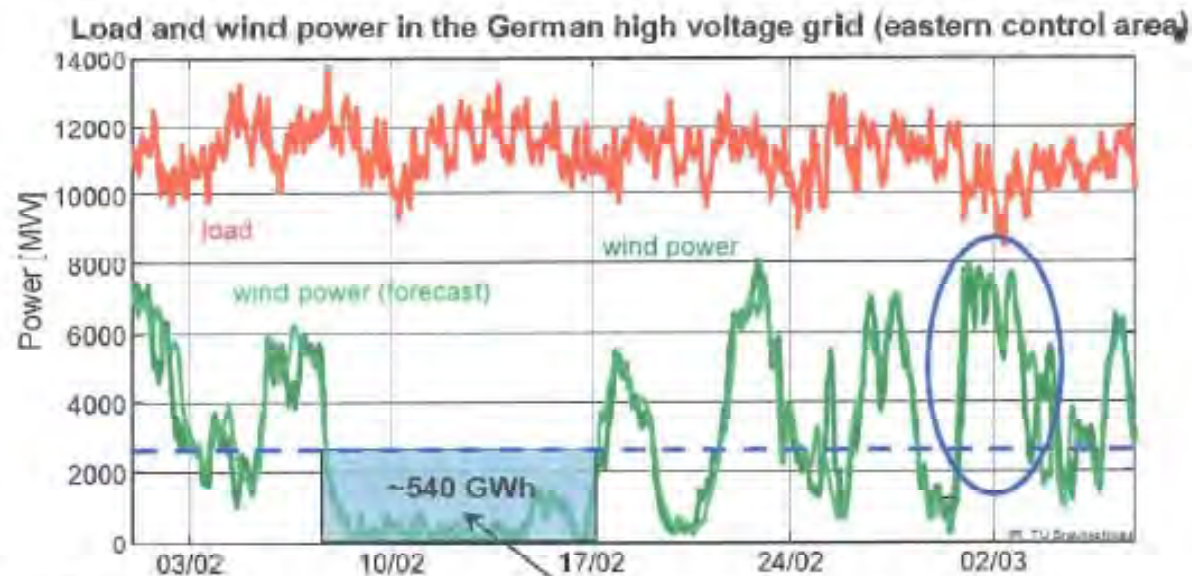


Gills Onions saves \$1.2M/year

Waste/By-product Hydrogen

Integrate Intermittent Energy Sources

Renewable sources are variable. Surplus generation is often wasted and power plants must be fired up to deal with valleys in supply.



Source: IIR / TU Braunschweig

Necessary storage capacity for
continuous supply of average power

Significant power
fluctuations from the
mean and from
forecasts

- Short term (minutes)
- Long term (days)
- Seasonal (months)

Waste/By-product Hydrogen

Advantages of Biomass Hydrogen for Energy Storage

- Maximizes Value of Solar and Wind and other renewables
- Distributed Generation
- No fuel consumption in frequency regulation (standby) state
- Rapid Load following capability (quickly increase power to meet demand)
- High (more than 50-percent) efficiency regardless of output level
 - Superior to micro-turbines or diesel gensets
- Zero emissions
- Super-peaking capability - can exceed 100 Percent of rated capacity



Waste/By-product Hydrogen

Hydrogen can be made renewable in significant quantities and is sustainable

- US: 40,000 anaerobic digester facilities: 10.8 TCF of H₂ (128 Million cars)
- US: Landfill gas facilities: 7 TCF (82 Million cars)
- Biogas fuels approximately 210 Million cars



Waste/By-product Hydrogen

Chlor-alkalai

- Estimated 389 thousand metric tons of hydrogen annually produced from chlor-alkali processes alone are equivalent to the annual fuel consumption of 1.8 million light-duty hydrogen vehicles.
- World production of chlor-alkali hydrogen = 1,438 thousand metric tons/year
- 216 thousand metric tons/year -- 15% of the chlor-alkali hydrogen production -- is vented by chlor-alkali industry
- Potential electricity if vented H₂ were used in fuel cells: 420 MWe (assuming 50 % conversion efficiency)
- Approximately 70 percent of the United States chlor-alkali production capacity is in the Gulf Coast region.
 - Could support the numerous DOD facilities in the region



Waste/By-product Hydrogen

Biogas

- Biogas, including anaerobic digester gas, can be reformed to produce hydrogen and used in a fuel cell to produce significant amounts of electricity and heat.
- When biogas is produced and used on-site in a fuel cell, fuel utilization or overall energy efficiency can reach 90% and can reduce emissions by more than 90% by weight as compared to the emissions associated with grid electricity generation.
- In addition to fuel cells for on-site power generation, the hydrogen produced using biogas can be used to power vehicles.
- Wastewater treatment plants (WWTPs), waste streams from food and beverage processing plants, crop farms and animal feed facilities, and municipal landfills are all biogas sources.



Waste/By-product Hydrogen

California Biogas Potential

Wastewater Treatment

- Wastewater treatment plants release methane, which is normally burned off into CO₂ and released into the air.
- Methane from plants can provide power using fuel cells. Already producing 8+ MW in CA.
- Free, renewable energy: 250 kW – 3 MW per plant.
 - Enough to power up to 3,000 homes.
- Hydrogen from reformed waste methane can also power fuel cell cars. Already happening at Orange County Sanitation in Fountain Valley.



Waste/By-product Hydrogen

California Biogas Potential

Untapped Potential

- CA has capacity to derive 100 MW of power from wastewater treatment plant emissions.
- Other organic waste sources can also be used.
- Biodegradable waste from dairies, food processing plants, livestock and poultry farms, and restaurant oil and grease increase this potential to 450+ MW.
 - That's enough to power 400,000+ homes.
- This power is available 24/7 using fuel cells and could be used to buffer other renewables.



Waste/By-product Hydrogen

Biogas / Waste Project in San Diego (with FCE and UCSD)

- Purification system, developed by Biofuels Energy, to process gas generated by landfills, sewage treatment plants, and large livestock facilities into usable methane.
- Fuel Cell Energy's molten carbonate fuel cells installed at two San Diego treatment plants and on the UC San Diego campus
- 4.5 megawatts generating capacity to generate heat and electricity



Waste/By-product Hydrogen

Fountain Valley, CA Station

- Anaerobic digestion of municipal wastewater
- Converts sludge to electricity, hydrogen and heat
- 100 kg/day capacity (25 cars) and 250Kw of Power
- Host site: Orange County Sanitation District

- Water waste from 100,000 people provide 1MW of power and 500 kg/day of Hydrogen
- ~40,000 waste water digesters in the U.S.



Waste/By-product Hydrogen

South Carolina

- Landfill gas to generate hydrogen for fuel cell powered materials handling equipment
- Involves BMW, DOE, Natural Gas Institute, SC Energy office, and SC Hydrogen and Fuel Cell Alliance
- Landfills generate landfill gas (LFG) from active microorganisms interacting with the waste.
- This gas can be converted into hydrogen and used to provide energy or fuel, effectively turning trash into power.
- DOE Goals: To show that LFG, **cleaned up and reformed**, can be used to power material handling equipment (MHE)



Waste/By-product Hydrogen

What is needed

- Integration of fuel cells and hydrogen with DOE and DOD biomass, biofuels and biogas programs to develop the technologies for this market
- Funding for gas purifiers
- Expand demonstration projects to include Chlor-alkali, bio-refining and hydrogen delivery/distribution infrastructure.



Waste/By-product Hydrogen

Summary

- ✓ Distributed generation: power at the point of use reduces need for congested, faulty, and inefficient transmission and distribution lines
- ✓ Resource maximization: get the most out of fuels and take advantage of existing gas infrastructure and waste gas stream
- ✓ Renewable integration: excess renewable power can be stored as hydrogen and used for power on demand or to fuel vehicles
- ✓ Environment: fuel cells increase efficiency and reduce emissions of all kinds
- ✓ Economy: save money, create jobs and support economic growth here in the USA





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