Creating a Global Hydrogen Infrastructure from Waste

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ABSTRACT

The lack of a hydrogen infrastructure has impeded the implementation of fuel cell technology in many areas worldwide. At the same time, the world is awash with waste materials.

Eco Energy International (EEI) has developed a new technology that economically converts over 80% of the municipal and agricultural solid waste going to landfills into clean, renewable and profitable energy, significantly reducing the need for landfills. Since all of the organic or biogenic materials are converted, we eliminate the production of carbon dioxide and methane gases typically associated with landfills.

This is a new modular, scalable technology that can produce hydrogen, syngas and renewable diesel anywhere from multiple locally available feedstocks.

This technology does not require large scale, stationary facilities to be economical. The process equipment can be containerized to be readily deployable to the field, scaled to meet the onsite demand. With 1700 existing landfills and 2.1 million farms scattered across the US alone, these hydrogen production facilities can be spotted strategically to form a hydrogen infrastructure with minimal transportation costs.

Keywords: hydrogen, fuel-cells, renewable-energy, carbon-sequestration, waste-management

1 CHALLENGES

1.1 Global Waste

Municipal and agricultural waste management are two of the world's biggest challenges. In most of the world, we recycle what we can but the bulk is either incinerated or buried in landfills, neither of which is good for the environment.

• Worldwide, the total municipal solid waste produced in 2012 was estimated at 1.3 billion tons per year and projected to double by 2025. [1]
• The US currently produces over 258 million tons of municipal solid waste per year. [2]

- 13% is converted to energy through old incinerators
- 34% recycled (mostly paper, glass, and metals and some plastic)
- 53% is still landfilled. Over 136 million tons per year are deposited into 1,700 existing operating landfills

• The USDA estimates that the US produces 335 million tons of agricultural solid waste. [3]
• Both municipal and agricultural waste emit millions of tons of methane and carbon dioxide into the atmosphere (greenhouse gases).

1.2 Increasing Hydrogen Demand

Historically, the hydrogen market has been largely positioned on the petroleum and chemical industry sectors. However, there has been a rise in usage of hydrogen in the fuel cell sector (i.e. most automobile manufacturers are introducing fuel cell electric vehicles and many major distribution centers are converting to fuel cell fork lifts). Add to this a growing interest in hydrogen as an energy storage medium. These and other factors are accelerating the growth in the hydrogen merchant market, with a twenty fold increase in demand forecasted by 2030. [4]

It should also be noted that there is an increasing demand for "renewable hydrogen". For example, California has ruled that at least 33% of all hydrogen produced for the new hydrogen filling stations must come from renewable sources. [5] For example, municipal and agricultural waste materials are considered as renewables, thus any hydrogen produced from these feedstock is considered renewable hydrogen.

1.3 Lack of a Hydrogen Intrastructure

Further exasberating the issue is the lack of a hydrogen infrastructure. Today most hydrogen is produced by large scale steam methane reformers principally dedicated to a nearby industrial facility such as refinery or chemical processing plant. There are very few hydrogen pipelines so any merchant market hydrogen from these facilities generally has to be highly compressed or liquified for transport in specialized tanker trucks. When the hydrogen is delivered to the end user, it must be regasified and/or reduced in pressure. All of these steps greatly increases the cost of the delivered hydrogen.

1.4 Steam Methane Reformer Issues

There are some negative issues associated with steam methane reformation (SMR):

- SMRs use non-renewable natural gas as a feedstock, tus is does not qualify as renewable hydrogen.
- SMRs have to be large scale to be economical which prohibits their use for smaller distributed applications.
- The SMR process releases 11 tons of carbon dioxide into the atmosphere for every ton of hydrogen produced. This amounts to over 700 million tons per year of carbon dioxide added to the atmosphere from SMRs.

2 SOLUTION TO THESE CHALLENGES

2.1 Breakthrough Technologies

Eco Energy International (EEI) has been working on fuel cells for defense applications for a number of years. However like others in the industry, the lack of readily available hydrogen became a major roadblock to implementing fuel cells in many applications. As a consequence, EEI developed technologies to produce hydrogen from locally available organic or biogenic materials.

2.2 Base Facilitated Reformation

The technologies developed are covered in 20 US and International Patents and is referred to as Base Facilitated Reformation or BFR. In simplistic terms, the process involves an aqueous caustic solution containing any of a variety of organic or biogenic feedstocks. A specialized catalyst is added and hydrogen is produced in the reactor. The following formula represents the reaction for the cellulose component of the feedstock:

$$(C_6H_{10}O_5)_n + 12nNaOH + nH_2O \leftrightarrow 6nNa_2CO_3 + 12nH_2 \quad (1)$$

It should be noted that in this reaction and that of all the other feedstocks, all of the carbon is sequestered in a carbonate, thus no carbon released to the atmosphere, unlike the SMR process.

Figure 1: Small scale BFR

2.3 Wide Range of Feedstocks

EEI's BFR technology can use many different renewable feedstocks such as:

- Municipal Solid Waste (MSW): paper products, wood, food waste and yard waste and other organic materials
- Agricultural Solid Waste (ASW): animal waste, crop waste and other agricultural organic wastes
- Food Industry Waste (FIW): food processing, meat processing and food service wastes; i.e. fryer oils, potato peels
- Lumber Industry Waste (LIW): forest slash piles, woodchips, sawdust, etc
- Biomass: grass, grain, crops, algae, sawdust, cellulose, hemicelluloses, lignin, etc
- Alcohols: methanol, ethanol, crude ethanol, E95, ethylene glycol, glycerol (byproduct of bio-diesel production)
- Sugars and Starches: glucose, fructose, corn starch, potato starch, etc

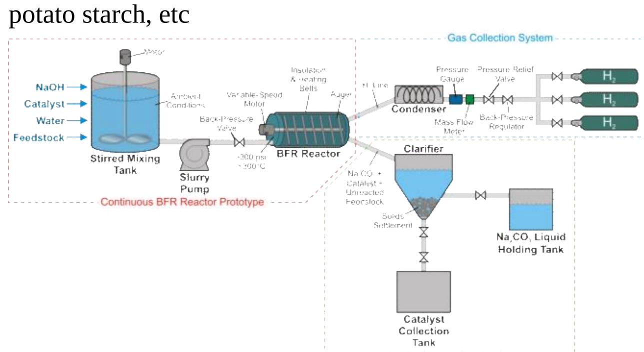

Figure 2: Process flow diagram of a BFR

2.4 Recausticizing

In each of the reactions above, the byproduct is sodium carbonate, Na_2CO_3, commonly known as washing soda or soda ash. This material has numerous applications such as in the production of glass, paper, rayon, soaps and detergents. However, if we add calcium hydroxide ($Ca(OH)_2$ or slaked lime) to the solution, the sodium and calcium trade places resulting in the production of calcium carbonate ($CaCO_3$ or lime) and sodium hydroxide.

$$Na_2CO_3 + Ca(OH)_2 \rightarrow CaCO_3 + 2NaOH \qquad (2)$$

In this case, the sodium hydroxide is recycled back to the front of the process greating reducing its need as a feedstock (reference equations 1 and 5). The calcium carbonate has many agricultural and industrial uses. However we can make this a totally closed cycle system if we recaustisize the calcium carbonate to get back the calcium hydroxide, minimizing its need as a feedstock (reference equation 3).

$$CaCO_3 + heat \rightarrow CaO + CO_2 \qquad (3)$$

$$CaO + H_2O \rightarrow Ca(OH)_2 \qquad (4)$$

The carbon dioxide produced in equation (4) is pure and can be used in a variety of applications including the food industry.

3 PRACTICAL APPLICATIONS

3.1 Eliminating Landfills and Greenhouse Gases while Producing Energy

EEI's technologies can economically convert over 80% of the municipal and agricultural solid waste going to landfills into clean, renewable and profitable energy, significantly reducing the need for landfills. Since all of the organic or biogenic materials are converted, this eliminates the production of carbon dioxide and methane gases typically associated with landfills.

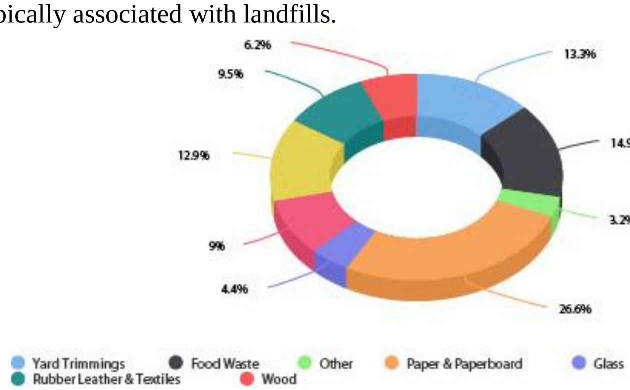

Figure 3: Average mix of materials in MSW [2]

Material Recovery Facilities (MRF) are found in every municipality around the country. This is where your trash initial goes for sorting out recyclables before sending the rest to the landfill. If the BFR technology is inserted into the MRF process, very little of the waste material ends up going to the landfill.

The MRF can be further enhanced with the additional of a second line to convert the plastics and other undissolved feedstocks into re-engineered fuel. This fuel can then be converted into syngas and renewable diesel.

The following diagram illustrates how this combined technology upgrades a traditional MRF to a Total Recovery Facility® (TRF®).

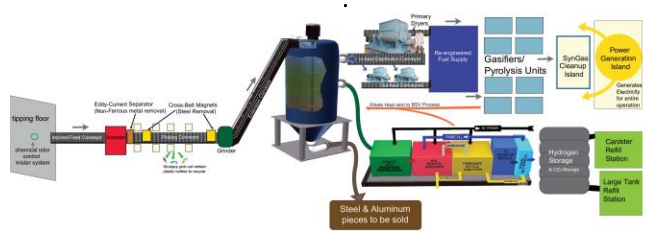

Figure 4: Total Recovery Facility.

Depending on the demand for renewable diesel and hydrogen in a given area, the two lines can be adjusted to produce more diesel and less hydrogen or visa versa. For exaample, the facility below is designed to initial take in 250 tons per day of MSW and produce 6 million gallons of renewable diesel per year. Then as the hydrogen demand in that area grow, the facility will begin producing 1.5 million kg per year of hydrogen as well. If only hydrogen were produced, the facility could produce 7 million kg per year of hydrogen.

Figure 5: TRF producing renewable diesel and hydrogen.

3.2 Utilizing Biodiesel Waste Products

It is not a well known fact that biodiesel production produces a large amount of glycerol as a byproduct. Depending on market conditions, gylcerol has a positive or negative market value. In addition, large amounts of lignins are waste materials from the process. Both the glycerol and the lignin are excellents feedstocks for the BFR process which can result in an overall economic improvement of a biodiesel plant while eliminating waste products.

The BFR formula for converting glycerol to hydrogen:

$$C_3H_5(OH)_3 + 6NaOH \leftrightarrow 3Na_2CO_3 + 7H_2 \quad (5)$$

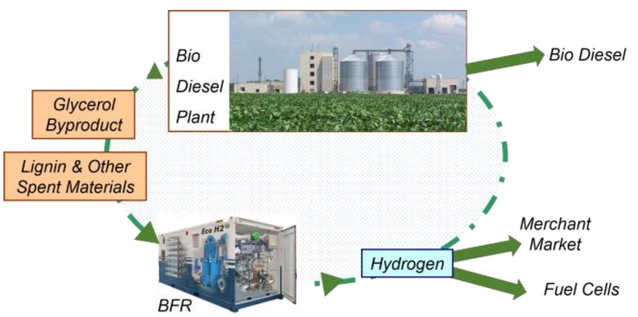

Figure 6: Producing renewable hydrogen from glycerol and lignin.

3.3 Cardboard Operating Fork Lifts

Another practical applications is the utilization of cardboard waste at major distribution centers. There is a current trend at major distribution centers to change over to fuel cell operated fork lifts for a number of reasons. In doing so, they are creating a demand for hydrogen. These distribution centers also have an abundance of wasate cardboard that they usually have to pay for disposal. By placing a BFR nearby, they can utilize their cardboard to produce hydrogen onsite to power their fork lifts.

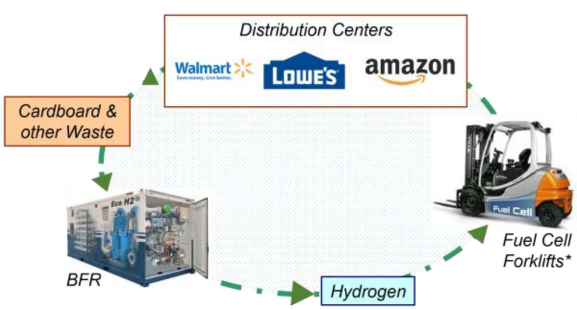

Figure 7: Producing renewable hydrogen cardboard for onsite use.

4 CREATING THE HYDROGEN INFRASTRUCTURE

In solving our hydrogen infrastructure challenge, consider if BFRs are placed near or at some of the following feedstock sources:

- 1700 landfills,
- 2.1 million farms,
- 1000's of distribution centers.

The result is renewable hydrogen being available nationwide without the issues of SMRs and without the added costs of transporting long distances.

5 SUMMARY

- Reformation of municipal wastes, agricultural waste, biomass and other organic materials produces clean energy, helps solve environmental and social issues; all while making a profit.
- Using the TRF can convert nearly all organic waste to useful energy, thus reducing landfill space requirements along with the resultant long term methane and carbon dioxide emissions from the landfills proportionately
- If the BFR process is applied to just a third of MSW waste management facilities in the US alone, the potential is equivalent to 8.4 Gigawatts continuously.
- Eco Energy International reformation process is a bridge to the hydrogen economy, providing immediate cost and distribution advantages to present and future hydrogen users by enabling a low cost hydrogen distribution infrastructure.

REFERENCES

[1] The Worldwatch Institute
[2] US Environmental Protection Agency (EPA)
[3] US Department of Agriculture (USDA)
[4] Navigant Research Report
[5] California Renwable Hydrogen Rule