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Biomass to Hydrogen

Additional submitted attachment is included below.



Regarding Green Hydrogen Production in California:
Why Consider Biomass-to-Hydrogen Conversion Methods

Comments Provided by:
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What is Biomass?

Biomass is the universal solar-energy storage system, built from atmospheric carbon by harvesting sunlight combined with nutrients from the earth. Biomass materials are time-sensitive, perishable, and presently we dispose of these solar building blocks that would otherwise form an elegant natural solar energy storage system (**Figure-1**).

Figure 1. Separated Biomass, A Renewable Energy Feedstock

Biomass is an abundant domestic resource. "In the United States, there is more biomass available than is required for food and animal feed needs. A recent report projects that with anticipated improvements in agricultural practices and plant breeding, up to 1 billion dry tons of biomass could be available for energy use annually. For more information, see **U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry**.

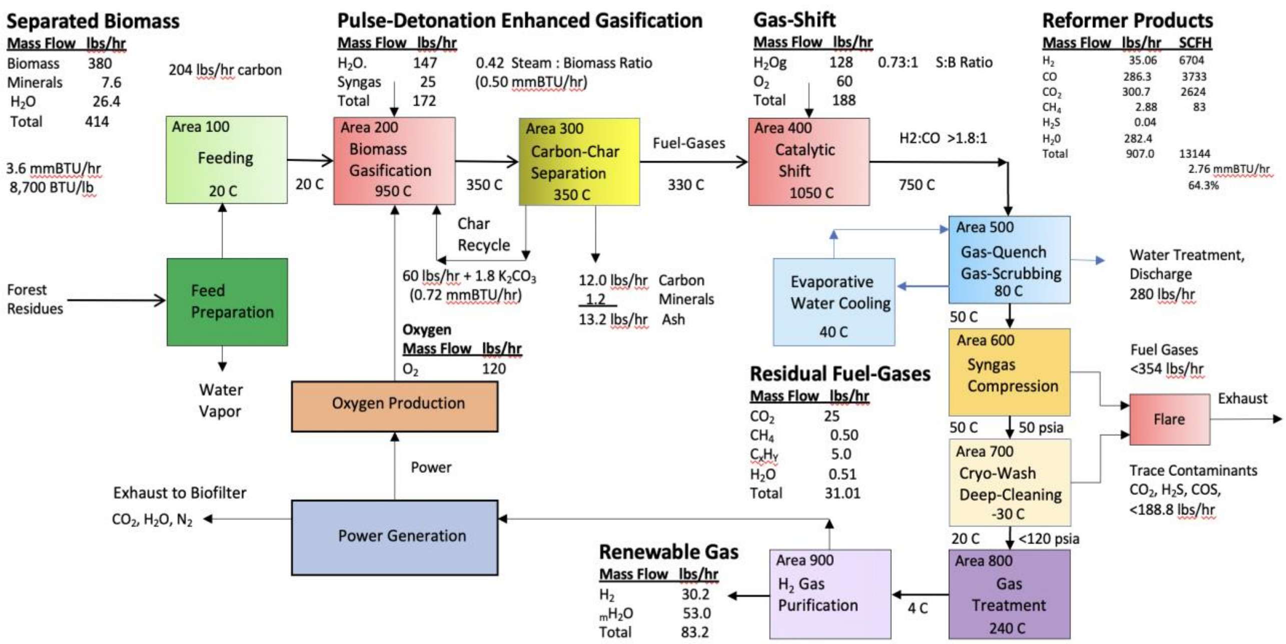
Biomass "recycles" carbon dioxide. Plants consume carbon dioxide from the atmosphere as part of their natural growth process as they make biomass, offsetting the carbon dioxide released from producing hydrogen through biomass gasification and resulting in low or negative net greenhouse gas emissions."

How Does Biomass Gasification Work?

Biomass gasification is a mature technology pathway that uses controlled processes involving heat, steam, and oxygen to convert biomass to hydrogen and other products, without combustion. (https://www.energy.gov/eere/fuelcells/hydrogen-production-biomass-gasification)

Thermo-catalytic gasification methods can convert 15-tons of biomass into 1-ton of hydrogen. We probably dispose of 30-million tons per year of waste biomass in California, enough biomass residues to make about 2-million tons per year of green hydrogen, based on average energy content of 7,000 Btu/pound biomass with 60% conversion to hydrogen; both are conservative assumptions obtained from project results (**Figure-2**).

Figure 2. Projected Mass & Energy Balance for Thermo-catalytic Conversion of Biomass to H_2



"Mostly Dry" feedstocks are efficiently processed using thermo-catalytic gasification methods to produce H_2. Whereas the "mostly wet" energy feeds should be directed to aqueous biological or supercritical methods. The divisions between "wet" and "dry" energy feeds are usually obvious, although grass clippings and some leafy urban biomass residues have moisture content above 50%; food wastes look fairly dry, but typically belong with wet streams for biological processing. For example, it is logical that wastewater treatment plants process more organic wet wastes, increasing green energy production.

However, we decry the use of dry energy feeds input for wet processing methods; for example, adding "separated dry-biomass" to existing wastewater treatment plants would be inefficient compared to thermo-catalytic methods that recovery >60% of the net energy content of "separated-biomass" as hydrogen and co-products; wet-processing pathways using dry-biomass are less than half as efficient.

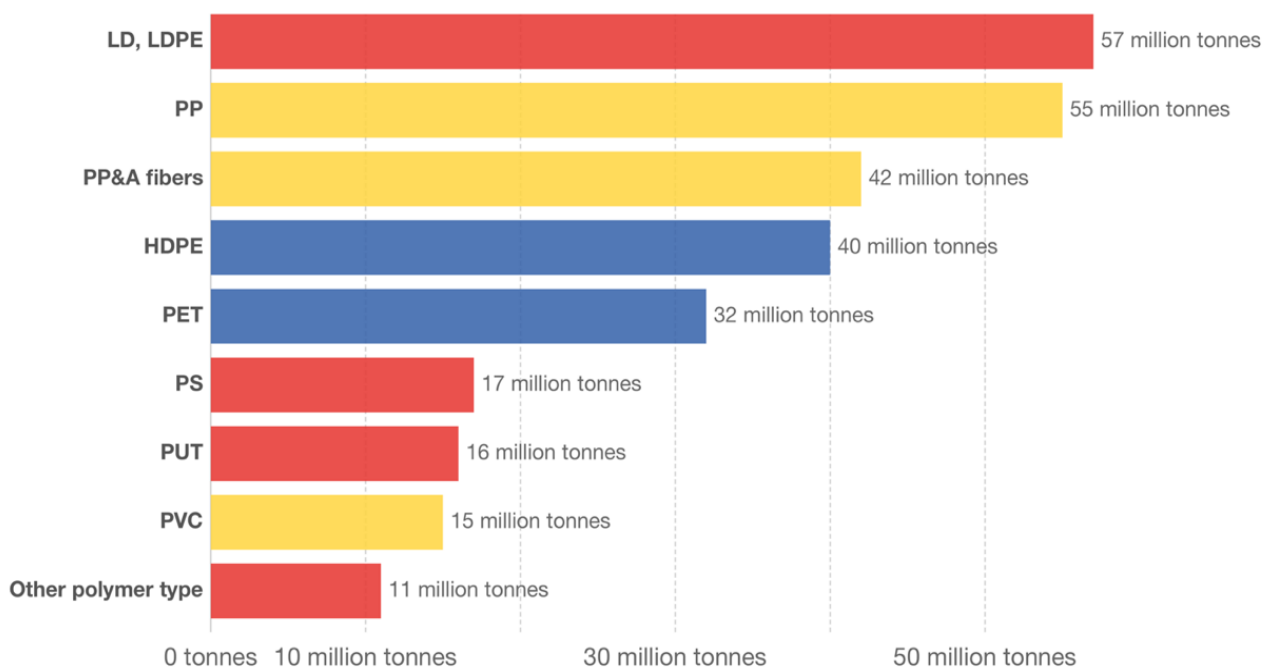
Economic production of hydrogen with co-products

Because biomass-to-hydrogen methods start with long-chain biocarbon; therefore, co-products easily made in the same batch with hydrogen should be considered. Whereas cracking H_2O with electricity only makes $H_2 + O_2$. Thermo-catalytic biomass conversion methods have the added benefit of making high-value co-products.

For example, we would particularly favor a topping cycle that would produce 20% of the stored energy in biomass as renewable ethylene, the monomer used to make both low-density and high-density polyethylene plastics. The high-purity hydrogen product would constitute more than half the energy output, while power for H_2-compression and H_2-liquefaction for transport would consume the balance, along with other on-site parasitic power needs.

Presently produced at refinery scale from petroleum products, ethylene is the largest volume plastic material consumed throughout the worldwide. Low-density & high-density polyethylene contribute 97-million tonnes per year, by far the largest volume plastic material (**Figure-3**).

Figure-3. The Combined Ethylene (PE) and Propylene (PP) Market Consumes 152-million tonnes per year



The world market for chemical grade ethylene monomer has grown steadily for 25-years and is expected to continue growing at a significant and predictable rate, 5% per year. Purified ethylene monomer sells for \$0.50 to \$1.50/pound, thus qualifying as high-value chemicals, whereas the cost to produce syngas (H_2 + CO) is probably about \$0.06/pound using separated biomass residues. Generally, ethylene value is an order of magnitude greater than H_2.

Who Needs Biomass-to-Hydrogen Technology?

The City and Port of Los Angeles can use biomass gasification technology. A 10 tonne/day H_2 demonstration project is contemplated to support the Port's customers who will need fuel cell transportation systems (**Figure-4**). Biomass would be sourced from 160,000 tons/year of green waste used as Alternate Daily Cover at LA Department of sanitation landfills. Cities are working towards developing alternatives for green waste management. Challenges include inadequate green waste management capacity due to permitting new composting facilities, limited markets for compost made from green waste, and the high costs for long-distance transportation to out-of-county facilities.

Figure 4. Biomass-to-Hydrogen Technology Planned for Los Angeles County

The City of Los Angeles adopted a 20-year (2005-2025) solid resources management plan called RENEW LA to achieve zero waste within the city by 2025. RENEW LA relies on the establishment of seven "conversion technology facilities," with one facility located in each of the city's six waste-sheds, and a seventh facility located in the southern California region, to process post-source separated municipal organic wastes still being landfilled. The layout for a 500 ton/day biomass gasification plant making 30 tonne/day high-purity hydrogen can be architecturally appealing (**Figure-5**).

Figure 5. Design for Separated Biomass-to-Hydrogen Facility: 500-TPD feed, 30 TPD H_2 output

Labor Relations

Biomass-to-hydrogen plants require people. Approximately 30-full time and another 30-part time people are the minimum needed for commercial systems. It may be surprising to some, but there are people who like to manage and operate thermo-catalytic conversion facilities. It's typically happy work; the level of difficulty is about like sailing a ship, and the skills and the challenges enable a workplace that builds people's talents and meaningful relationships. An apt analogy might be the crew of a Yankee schooner; keeping the ship sailing briskly under all conditions takes skilled hands, and people like to rise to that challenge. When projects are executed properly, using highly advanced technology, biomass-to-hydrogen can provide good wages that are commensurate with all skill levels.

In recognition of Maslow's hierarchy of needs, some modest contribution to a higher sense of purpose is also provided by contributing to the hydrogen challenge; in our case, helping bring about the biomass-to-hydrogen revolution. One may say, "a democratization of the hydrogen supply," because thermo-catalytic gasification is the most economic and diverse conversion method: any space or place in the universe, on land or at sea, where the sun shines, some type of biomass can be produced in great abundance, and that place can potentially produce low-cost hydrogen for high purity uses now and in the future. Ultimately, green plants will produce food, diverse pharmacological products, and hydrogen plus co-products from the plant residues.

Near-Term Low-Cost Source of High-Purity Hydrogen

Advanced biomass-to-hydrogen methods offer a near term source half a million tonne per year of low-cost hydrogen (as high-purity gas and cryogenic liquid), while providing a solution for diverse biomass residues, materials which elegantly store solar energy, biocarbon that is both renewable and perishable, since the energy and carbon soon return to the biosphere. Before returning to the biosphere, biomass can give us her stored light as ultra-pure H_2 molecules.

These organic waste residues must either be used as a resource material or disposed. Composting is to give away the energy content, sending volatile fractions into the biosphere. Using landfill burial methods exhibit very low energy recovery, well below the 70% biogas recovery purported in some technical literature (CO_2 & CH_4).

Separated biomass residues used as energy feed for advanced gasification methods can become a near-term source of 500,000 tonne/year of low-cost hydrogen (H_2). Separated biomass residues are generated every day and are an unfailing source of stored low-cost solar energy.

These activities would fit with CE-CERT's R&D objectives at the University of California Riverside, working in collaboration with Taylor Energy, a California Corporation based in Riverside, presently developing thermo-catalytic gasification methods used to convert biomass residues into pipeline-quality renewable-gases.