BIOENERGY INTO BIOINDUSTRY

PRODUCING RENEWABLE HYDROGEN FROM BIOMASS

Technologies that use low value waste biomass have great potential to help create a national hydrogen economy.

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BIOMASS has the potential to become a significant source of renewable hydrogen. Technologies that convert fiber, starches and sugars from trees, woody plants and crops, and food processing residues into useful products and hydrogen are seeing important advances in R&D. Communities and facilities that are rich in these renewable biomass resources have the potential to become energy independent and economically robust. In addition, many of the processes which produce hydrogen from biomass are complementary to those that produce biomaterials. States and communities with large agricultural economies have potential for significant economic development through incorporation of bioenergy into bioindustry.

While renewable hydrogen technologies that use low value waste biomass as feedstock have great potential to become cost competitive, it is currently more expensive to produce hydrogen from biomass than it is to derive it from natural gas. Independent of the source of hydrogen, there are many logistical and market challenges that must also be overcome before a national hydrogen economy can become a reality.

The biological and thermochemical conversion technologies currently used to produce hydrogen from biomass are summarized here.

BIOLOGICAL CONVERSION TECHNOLOGIES

Fermentation and Anaerobic Digestion: Fermentation uses yeast to convert the sugars extracted from biomass, often derived from starch in corn, to ethanol. Microscopic yeast cells break down the starch and water, creating ethanol and carbon dioxide gas. Anaerobic digestion uses bacteria to decompose wastes, such as manure or sewage sludge, to methane gas. When either ethanol or methane is fed into high temperature steam and run through a catalytic converter, hydrogen is produced. Hydrogen can also be produced by the anaerobic fermentation of sugar-rich wastewater from food processing plants through use of a hydrogen-producing bacteria, common in soil.

Photobiological Processes: The green algae, *Chlamydomonas reinhardtii*, like all green plants, use photosynthesis to convert carbon dioxide and water into sugar, oxygen and water. But these algae contain "hydrogenase," an enzyme that also produces hydrogen. When the algae are put into an environment absent of sulfur, they stop emitting oxygen and producing sugar, and instead use stored sugar and the hydrogenase enzyme to emit hydrogen. The cycle can be repeated as long as the algae are returned to normal photosynthetic conditions frequently enough to maintain their health.

THERMOCHEMICAL CONVERSION PROCESSES

Pyrolysis: Pyrolysis uses heat to convert biomass to a mixture of gases, char, and an oxygen-rich liquid called "bio-oil." Pyrolysis takes place at moderately high temperatures (1000°-1300°F), in the absence of oxygen. Bio-oil can be used to make products, such as adhesives, or be used to make hydrogen. If the bio-oil is subjected to 1600°F oxygen-rich steam and a nickel-based catalyst, it is converted into hydrogen, carbon monoxide, and water. An additional process converts the carbon monoxide and steam into more hydrogen.

Gasification: Gasification uses heat to convert biomass to a mixture of gases and residual solids. Gasification takes place at high temperature (1500°F), in an atmosphere of steam or air (or both), with approximately 30 percent the amount of oxygen needed for ideal combustion. The mixture of gases produced is about one-third hydrogen. Removing the hydrogen and subjecting the other gases and material to high temperature steam produces a synthesis gas, or "syngas" (composed of carbon monoxide and hydrogen). An additional process converts this carbon monoxide and steam into more hydrogen.

High Pressure Aqueous: When pulverized biomass is mixed with water to make a slurry and then put under high pressure, either a high or low temperature process can be used to produce oils and fuels, including hydrogen. After being subjected to high temperature, a pressurized slurry can be suddenly depressurized, or "flashed," to produce high quality oils and gases. The low temperature, high pressure technology forces the slurry through a catalyst to produce fuels, including hydrogen.

Direct Catalyst: Glucose, a sugar derived from waste biomass — such as sugar beet or cheese plants, corn stover or wood waste — is being used to produce hydrogen. When sugar-rich wastewater is run through a pressurized vessel and a nickel-tin catalyst at 440   F, hydrogen is generated. Although the wastewater must still be discharged, because it is not vaporized in the process, less energy is needed compared to other processes.

POTENTIAL FOR GREAT SIGNIFICANCE

All of these biomass-to-hydrogen technologies have potential to play a significant role in the hydrogen economy and thereby strengthen agricultural communities. Early commercial versions of pyrolysis, gasification and high pressure aqueous facilities are currently being built and tested in real-world conditions. When waste biomass is used, these technologies show promising economic viability, particularly if the hydrogen is used locally. However, if a technological breakthrough occurs with any of the other biomass-to-hydrogen technologies, they could become economically viable sooner than currently anticipated.

Producing hydrogen from biomass holds promise that the Midwest, which has functioned as the nation's bread basket, can also serve as its renewable energy backbone.

The National Renewable Energy Laboratory >www.nrel.gov< is a leading research center on renewable energy and has a wide range of information available renewable hydrogen technologies.

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