Thermal Conversion of Biomass to Valuable Fuels, Chemical Feedstocks and Chemicals
Technology #8126

Applications

- Conversion of diverse forms of biomass (a non-fossil source of carbon, e.g. wood, municipal solid wastes, energy crops, agricultural and forest product residues) to valuable, storable products, e.g. calcium carbide CaC$_2$ a solid, and CO + H$_2$ gas (also called synthesis gas). These can in turn be converted to a wide selection of valuable products, i.e., fuels, chemical feedstocks, chemicals, pharmaceuticals, fertilizer, and industrial gases.
- Conversion of mixtures of biomass with fossil materials, e.g. heavy oil, natural gas, coal, shale oil, oil from tar sands, etc. to valuable fuels, chemical feedstocks, and chemicals while reducing the fossil-carbon footprint of converting fossil raw materials to these products.
- Storage of electricity, including from solar and wind sources, as solid and gaseous products.
- Reducing the fossil-carbon footprint of steel making.
- Conversion of lignin and other organic residues of pulping to valuable fuels, chemical feedstocks and chemicals, rather than burning these residues.
- Recycling of pulping chemicals, e.g. Na$_2$CO$_3$ and NaOH from pulping wastes.
- Potential elimination (or significant down-sizing) of high capital cost conventional waste liquor recovery furnaces used in pulp and paper manufacture.

Technology

This is a high temperature technology to convert many forms of biomass, e.g., wood, straw, grass, energy crops, municipal solid wastes, agricultural residues, forest products residues, and concentrated waste pulping liquors to two major high value products: (a) solid calcium carbide which can be converted to acetylene as well as to cyanamide, which is used to produce pharmaceuticals and other organic chemicals including fertilizer; and (b) CO + H$_2$ mixtures. Acetylene and CO + H$_2$ mixtures are each useful as fuels in their own right, and as feedstocks for producing a wide range of high value fuels and chemicals. Acetylene and H$_2$ are also industrial gases. For pulp and paper manufacture, this technology offers potential for significant environmental and economic benefits, i.e.: recycling pulping chemicals (e.g. Na$_2$CO$_3$, NaOH) from waste pulping liquors; converting organic residues in the pulping wastes to useful products rather than burning them; and eliminating (or greatly downsizing) high capital cost recovery furnaces that can pose safety hazards. The technology is also of interest for converting mixtures of biomass with fossil feedstocks, e.g. petroleum, heavy oil, natural gas, coal, shale oil, etc., to premium fuels and chemicals. This can offset the lower energy content of biomass and the fossil-carbon footprint of the fossil raw materials. Use of electricity generated only from renewable or nuclear sources further reduces the fossil-carbon footprint of processing such mixtures while if the only feedstock is biomass the invention is an essentially zero fossil-carbon footprint process for manufacture of premium fuels and chemicals. Moreover, when a thermal plasma or other electrical heating source supplies the process heat, this invention provides means to store electricity in the form of a useful solid material (calcium carbide) plus CO and H$_2$. These products can be converted back to electricity or to valuable fuels, chemical feedstocks, and chemicals.
**Simplified Process Description**

Biomass and a metal oxide, e.g., calcium oxide (CaO), are heated at ≥ 1400°C for short times using a thermal plasma or other suitable means. The reaction products are then rapidly quenched to ≤ 800°C. Reactions of the calcium oxide redirect the process chemistry to: (a) provide products valuable in their own right and as precursors to fuels, chemicals, chemical feedstocks, industrial gases, fertilizer, and pharmaceuticals; and (b) significantly reduce yields of unwanted substances such as tars and solid carbon. For example, using CaO, significant amounts of biomass carbon are converted to calcium carbide (CaC$_2$). By reaction with water, calcium carbide can in turn be converted to acetylene (C$_2$H$_2$) by a well-established chemical process. Acetylene is a high heating value fuel, a feedstock to a wide range of chemicals, and an industrial gas. Reaction of CaC$_2$ with nitrogen gas (N$_2$) produces calcium cyanamide (CaCN$_2$) which can in turn be converted to cyanamide (H$_2$NCN) which is used in the production of pharmaceuticals and other organic compounds. Moreover, reaction of cyanamide with water or steam produces urea (CO(NH$_2$)$_2$) a fertilizer. This biomass conversion process also produces mixtures of CO and H$_2$ (synthesis gas; syn gas) useful as a fuel and further convertible to chemicals and to various other fuels as well as industrial gases, including hydrogen (H$_2$). Synthesis gas is now of interest as a substitute for coal-derived coke in blast furnaces to reduce the fossil-carbon footprint of the steel industry. When the biomass feedstock consists of concentrated waste pulping liquors, the process also recycles pulping chemicals such as Na$_2$CO$_3$ and NaOH. Heat recovered from the high temperature (biomass-treatment) reactor can be used to pre-heat and remove moisture from the biomass feedstock, e.g. to concentrate waste pulping liquors.

**Advantages**

- Conversion of diverse forms of biomass as well as mixtures of biomass with other raw materials e.g. petroleum, heavy oil, natural gas, coal, shale oil, etc. to premium fuels and chemical feedstocks, fertilizer, industrial gases, and pharmaceuticals. For example, calcium carbide from this process can be converted to valuable fuels and chemical feedstocks and to calcium cyanamide for further conversion to cyanamide for use in pharmaceuticals or conversion to urea, a valuable fertilizer. CO + H$_2$ mixtures from our process can be directly used to substitute for coke in blast furnaces to reduce the fossil-carbon footprint of the steel industry and can also be converted to premium fuels and chemicals by established catalytic processes.
- Major products are gases and solids enabling easier products separation and recovery
- Chemical solidification of the fuel value of biomass or biomass mixtures in the form of solid calcium carbide for economical storage and transport and then up-conversion to acetylene, a valuable gaseous fuel, chemical feedstock, and industrial gas, by a well-known reaction with water
- High single-pass conversions of feed at large throughputs with good selectivity to two major high value products using compact reactor vessels
- Modular reactors to reduce initial capital costs and allow process capacity to be expanded in increments matched to growth in product demand
- Increased electrification of the chemical process industries, e.g. manufacture of fuels, chemicals, pulp and paper, and fertilizer opening the door for: (a) diversification of process energy sourcing; and (b) reduced dependence on fossil-carbon sources of process energy. To elaborate, in one embodiment of the present invention, an electrical discharge (a thermal
plasma) operating at approximately 1 atm (absolute) pressure provides the process endothermicity (heat input for chemical process reactions). There are various means to generate the electricity to operate the plasma. Moreover, when that electricity is generated from non-fossil sources, e.g. solar, hydro, geothermal, wind, nuclear, the process operates with an essentially zero fossil-carbon footprint

- Electricity storage and load leveling. This technology uses electricity to supply the heat input (endothermicity) that converts a significant fraction of the biomass carbon to a solid, e.g. CaC$_2$ and a valuable gaseous product, i.e. CO + H$_2$ (syn gas). These products can be converted back to electricity, e.g. syn gas combustion; syn gas conversion to H$_2$ for fuel cell power generation; CaC$_2$ to acetylene for combustion or further conversion to another fuel for combustion. Thus, this invention provides means to store electricity, e.g., from intermittent generation sources such as solar and wind power and from surplus generation during periods of off peak power demand.

**Categories For This Invention:**

Energy
Biofuels (Energy)

**Intellectual Property:**

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