

SYSTEM AND PROCESS FOR PRODUCING SYNGAS FROM ORGANIC SUBSTANCES SUSPENDED OR DISSOLVED IN AQUEOUS SOLUTION

Abstract

A multi-stage system and process for producing syngas from organic substances suspended or dissolved in aqueous solution, in which organic substances are pre-treated in at least one chemical bond breaking stage and then gasified in supercritical water.

Drawings

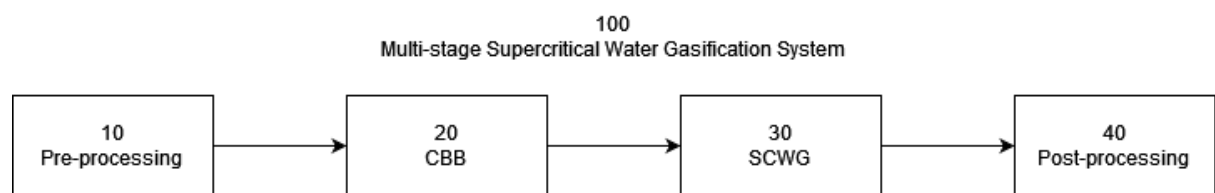


FIG. 1

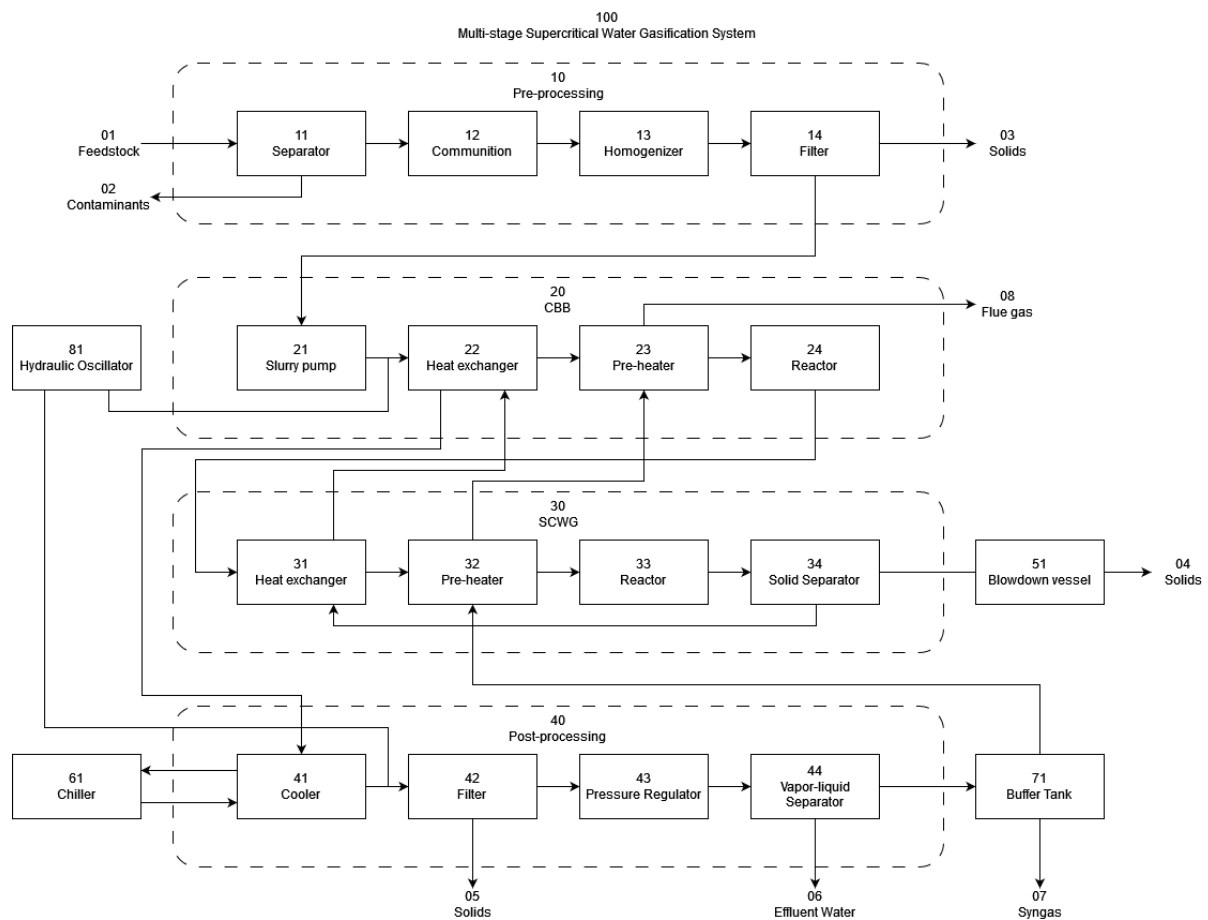


FIG. 2

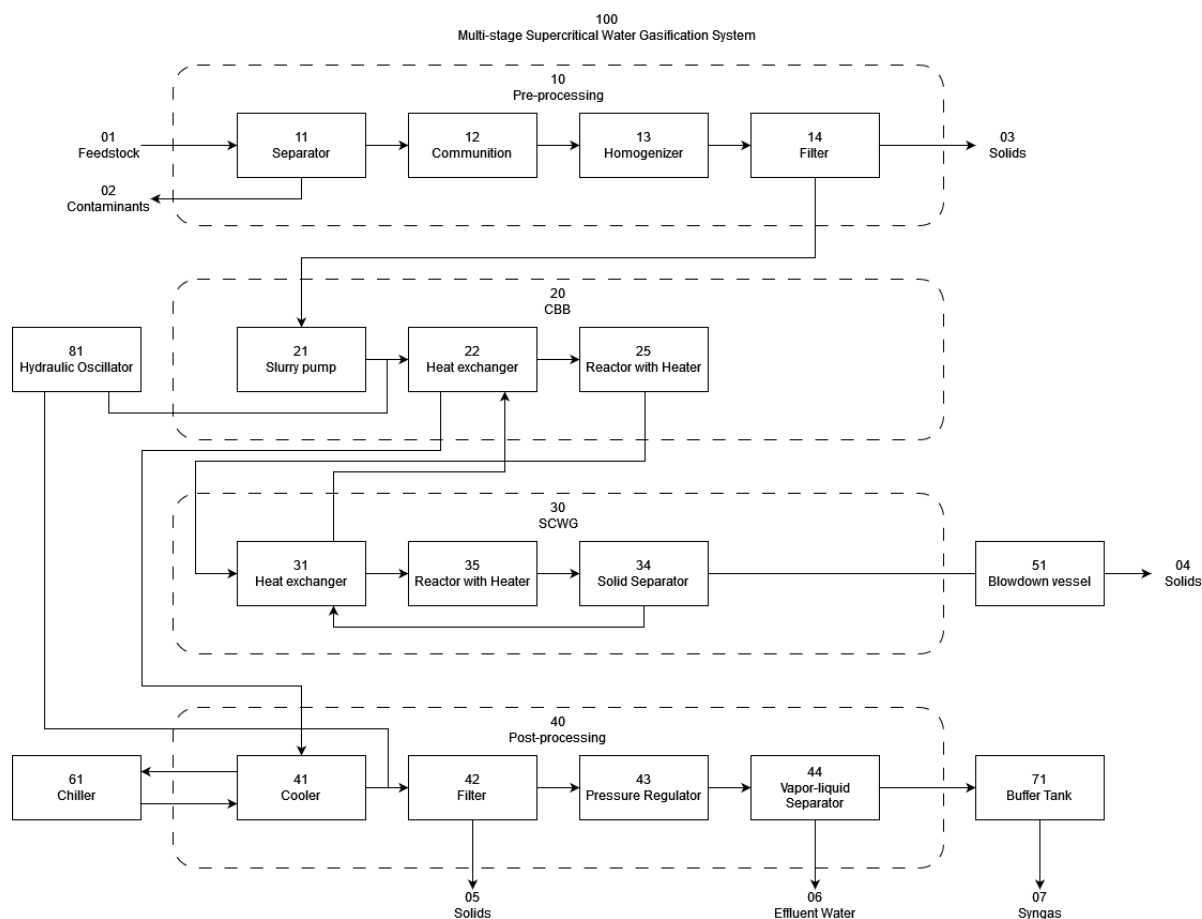


FIG. 3

FIELD OF THE INVENTION

The invention relates generally to syngas production and organic substance conversion systems and processes. More particularly, the invention relates to a multi-stage supercritical water gasification system and process for the production of syngas from organic substances suspended or dissolved in aqueous solution.

BACKGROUND OF THE INVENTION

Organic substances with high water content pose a significant challenge to energy recovery systems and are typically treated via open dumping, composting, landfilling, or incineration, resulting in a significant loss of raw material for energy production as well as environmental pollution. Utilization of these substances for fuel production is a viable method to produce renewable energy while also eliminate waste from these substances.

The process of supercritical water gasification is a well-studied approach with the potential to utilize organic waste streams with high water content such as food waste, bio-sludge, oil sludge, digestate sludge, algal biomass, and livestock manure. This process makes direct use of the high water content in the waste, under high temperature and high pressure, to break down the organic components into syngas, eliminating the need for energy-intensive drying, and thus achieving high efficiency.

A disadvantage of traditional supercritical water gasification is that there is little control over the reaction pathways that can result in the formation of unwanted products that are chemically stable. These products do not break down easily even in supercritical water conditions and appear in the solid and liquid outputs. They not only reduce gasification efficiency but also add to by-product treatment requirements.

The present invention is a multi-stage system and process for supercritical water gasification that allows high gasification efficiencies, by controlling the reaction pathway to enhance desired reactions and inhibiting the formation of unwanted products.

SUMMARY OF THE INVENTION

The invention is a multi-stage system and process for supercritical water gasification of organic substances suspended or dissolved in aqueous solution for the production of syngas involving at least one chemical bond breaking stage, followed by supercritical water gasification for near-complete gasification. The system may include a pre-processing stage to improve flowability and pumpability of the feedstock, by particle size reduction, homogenization, and separation of undesired solid particles. The system may include a chemical bond breaking (CBB) stage to convert the pre-processed feedstock into intermediate products. The intermediate products may be fed into the supercritical water gasification (SCWG) stage to produce syngas, solids, and effluent water in a combined flow. The solids may be separated from the combined flow in supercritical water. The separated solids may be treated and used for applications including agricultural use and production of alternative sand, depending on the mineral composition. The combined flow with solids removed may be cooled in a post-processing stage and depressurized to allow vapor-liquid separation to separate syngas and condensed effluent water. The separated syngas may be treated or used directly for heat and power production, or as feedstock for chemical production. A portion of separated syngas may be reused within the system in gas-fired pre-heaters to make the system self-sustaining. The effluent water may be treated before discharge or reused for dilution in the pre-processing stage.

Separators may be implemented in the pre-processing stage to remove contaminants from the feedstock to improve flowability and pumpability of the feedstock and system efficiency. Contaminants that may be removed are metal and ceramic objects, as well as stones and gravel. Separators suitable for use include, but are not limited to paddle separators, hammer mill separators, magnetic separators, eddy current separators, and combinations of separators.

Comminution devices may be implemented in the pre-processing stage after separators to reduce particle size of the feedstock to improve flowability, pumpability and heat exchange efficiency of the feedstock. Comminution devices suitable for use include, but are not limited to shredders, macerators, colloidal mills, hammer mills, and combinations of comminution devices.

Stirred feed tanks may be implemented in the pre-processing stage after comminution devices to maintain the homogeneity of the feedstock slurry. Stirred feed tanks may include inlets for additives such as water, catalysts, oxidants, and emulsifiers to allow the additives to be added and mixed into the feedstock. Stirred feed tanks may include heaters to provide heat to reduce viscosity of some types of feedstocks.

Filters may be implemented in the pre-processing stage after stirred feed tanks to remove contaminants or particles that are above the particle size limit of the system. Filters suitable for use include, but are not limited to cylinder filters, mesh filters, and combinations of filters.

Slurry pumps may be implemented in the CBB and SCWG stages to pump the pre-processed feedstock to high pressure required in the CBB and SCWG stages. Slurry pumps suitable for use include, but are not limited to plunger pumps, positive displacement pumps, piston pumps, lobe pumps, diaphragm pumps, progressive cavity pumps, metering pumps, variable displacement pumps, fixed displacement pumps, and combinations of pumps.

Hydraulic oscillators may be implemented within the high pressure region of the system to increase turbulence and mixing efficiency in the system.

Heat exchangers may be implemented in the CBB and SCWG stages to recover heat from the SCWG stage reactor output to pre-heat feedstock and intermediate products to raise the temperatures close to the required temperatures for the CBB and SCWG stage processes. Heat exchangers suitable for use include, but are not limited to double-pipe heat exchangers, shell and tube heat exchangers, and combinations of heat exchangers.

Reactors may be implemented to process feedstock into intermediate products in the CBB stage and to process intermediate products into output products in the SCWG stage. Reactors suitable for use include, but are not limited to continuous stirred tank reactors, fluidized bed reactors, packed-bed reactors, tubular reactors, and combinations of reactors.

Additional heaters may be implemented before or together with the CBB and SCWG reactors for precise control of process temperatures. Heaters suitable for use include, but are not limited to gas-fired heaters, electric heaters, heaters using heat carriers, and combinations of heaters.

Solid separators may be implemented in the SCWG stage after the SCWG reactor to remove solid by-products and precipitated mineral salts. Solid separators suitable for use include, but are not limited to cyclone separators, cylinder filters, and combinations of solid separators.

Blowdown vessels may be implemented to discharge solids separated in solid separators from the high pressure system to ambient conditions safely.

Coolers may be implemented in the post-processing stage to cool the SCWG stage outputs after heat recovery to ambient temperatures using cooling water. Coolers suitable for use include, but are not limited to double pipe heat exchangers, shell and tube heat exchangers, shell and helical tube heat exchangers, and combinations of heat exchangers.

Chillers may be implemented to supply cooling water to coolers. Chillers suitable for use include, but are not limited to air-cooled chillers, water-cooled chillers, vapor absorption chillers, vapor compression chillers, and combinations of chillers.

Filters may be implemented in the post-processing stage after coolers to remove solid by-products that may be damaging to downstream components. Filters suitable for use include, but are not limited to cylinder filters, mesh filters, and combinations of filters.

Pressure regulators may be implemented in the post-processing stage after coolers and filters to reduce the pressure of the SCWG products to ambient pressure. Pressure regulators suitable for use include, but are not limited to back pressure regulators, pressure reducers, and combinations of pressure regulators.

Vapor-liquid separators may be implemented in the post-processing stage to separate the condensed effluent water from the syngas.

Buffer tanks may be implemented for syngas storage for utilization or transfer.

Feedstocks may be derived from biomass-based or fossil-based waste sources or feedstocks for energy production. The biomass-based feedstock sources include, but are not limited to food waste, sewage waste, digestate sludge, algal biomass, livestock manure, agricultural residues, food and beverage production wastes, horticultural waste, bio-crude, energy crops, and combinations of biomass-based feedstocks. The fossil-based feedstock sources include, but are not limited to oil sludge, tank bottom sludge, oil field sludge, refinery wastewater treatment sludge, and combinations of fossil-based feedstocks.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments of the present disclosure are described in detail below with reference to the attached drawing figures, wherein:

FIG. 1 is an overall schematic flow diagram of a syngas production system and process according to various embodiments of the present disclosure;

FIG. 2 is a schematic flow diagram of an example syngas production system and process in accordance with **FIG. 1**;

FIG. 3 is a schematic flow diagram of another example syngas production system and process in accordance with **FIG. 1**;

A more detailed description of various embodiments of the present invention will now be discussed herein with reference to the foregoing drawings. The following description is to be taken by way of illustration and not undue limitation.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

A multi-stage supercritical water gasification system and process are described for the production of syngas from organic substances suspended or dissolved in aqueous solution, by controlling the reaction pathway to enhance desired reactions and inhibiting the formation of unwanted products, that maximizes gasification efficiency and energy efficiency while mitigating operational issues from by-product formation. The following description includes a best mode of the present invention. The invention is intended to cover all modifications, alternative constructions, and equivalents falling within the scope of the present invention as defined in the claims listed hereafter. Accordingly, the description of exemplary embodiments should be seen as illustrative only and not limiting.

FIG. 1 shows a multi-stage supercritical water gasification system **100** of the present invention. System **100** may include a pre-processing stage **10** and process that improves the flowability and pumpability of feedstock, a chemical bond breaking (CBB) stage **20** and process that breaks apart large polymers and high molecular weight compounds into intermediate products, a supercritical water gasification (SCWG) stage **30** and process that converts the intermediate products into syngas, and a post-processing stage **40** and process that cools, depressurizes, and separates the output products and by-products.

FIG. 2 shows an example of system **100** with stages **10**, **20**, **30**, and **40** and additional blowdown vessel component **51**, chiller component **61**, buffer tank component **71**, and hydraulic oscillator component **81**. Stage **10** may include a separator stage **11**, a comminution stage **12**, a homogenizer stage **13**, and a filter stage **14**. Stage **20** may include a slurry pump stage **21**, a heat exchanger stage **22**, a pre-heater

stage **23**, and a reactor stage **24**. Stage **30** may include a heat exchanger stage **31**, a pre-heater stage **32**, a reactor stage **33**, and a solid separator stage **34**. Stage **40** may include a cooler stage **41**, a filter stage **42**, a pressure regulator stage **43**, and a vapor-liquid separator stage **44**.

Raw feedstock **01** may enter stage **10** starting from stage **11**, which removes coarse contaminants **02** that are large objects that cannot be treated by the system such as metal and ceramic objects, stones and gravel. The output of stage **11** may be fed into stage **12**, which reduces the particle size of the feedstock to improve the flowability and pumpability of the feedstock, and increase the heat transfer efficiency in subsequent stages **20** and **30**. The output from stage **12** may be fed into stage **13**, which may include a mixer or stirrer, inlets for the addition of water, catalysts, oxidants, and emulsifiers, and a heater, to further improve the flowability and pumpability of the feedstock, while also preparing the feedstock for chemical processes in stages **20** and **30**. The output of stage **13** may be fed into stage **14** which removes solid particles **03** that do not meet the size requirement of stage **21**.

The output of stage **14** is a feedstock slurry that may enter stage **20** starting from stage **21**, which pumps the feedstock slurry to process pressure. The output of stage **21** may be fed into stage **22** and thereafter stage **23**, which heat the feedstock slurry to the reaction temperature of stage **20**. The output of stage **23** may be fed into stage **24** to be held at the reaction conditions for the required residence time of stage **20**, where the chemical bonds in the feedstock are broken to reduce the molecular size of large polymers and high molecular weight compounds, while inhibiting the formation of chemically stable molecular structures.

The output of stage **24** contains intermediate products that may enter stage **30** starting from stage **31** and thereafter stage **32**, which heat the intermediate products to the reaction temperature of stage **30**. The output of stage **32** may be fed into stage **33** to be held at the reaction conditions for the required residence time of stage **30**, where the intermediate products are gasified in supercritical water to produce syngas and by-products in a combined flow. The output of stage **33** may be fed into stage **34** to separate solids from the fluid in the combined flow. The solids may be fed into component **51** to be discharged from the high pressure system **100** as solids **04** that contain mineral salts, solid by-products, and solid contaminants. The fluid may be fed into stage **31** and thereafter stage **22** as a heat source for the heat exchangers in stages **31** and **22**.

The fluid may leave stage **22** to enter stage **40** starting from stage **41**, where it is cooled to ambient temperature. The output of stage **41** may be fed into stage **42** where additional solid by-products that are formed from cooling are filtered to prevent damage to downstream components. The filtered solids may subsequently be removed as solids **05**. The fluid output of stage **42** may be fed into stage **43** where the pressure is reduced to ambient pressure. The output of stage **43** may be fed into stage **44** to separate the syngas from the condensed effluent water **06**. The syngas output from stage **44** may be fed into component **71** to be stored for usage. A portion of the syngas from component **71** may be fed into stage **32** and thereafter stage **23** as a fuel source to generate heat for the heaters in stages **23** and **32**. Syngas **07** from component **71** may be utilized for heat and power production, or as feedstock for chemical production.

System **100** may include component **61** to provide cooling water for stage **41**.

System **100** may include component **81** between stages **21** and **42** to increase turbulent flow in stages **20** and **30** for enhanced mixing and heat transfer efficiency, and reduced risk of particle sticking with inner surfaces of system components.

FIG. 3 shows another example of system **100** which is similar to the example in **FIG. 2**, except stages **23** and **24** are replaced by reactor with heater stage **25**, and stages **32** and **33** are replaced by reactor

with heater stage **35**. Stages **25** and **35** combine the functions of a pre-heater and a reactor, use electricity instead of syngas to provide heat, and hold the reactants for the required residence time for stages **20** and **30** respectively. This example of system **100** allows for a more compact design without the emission of flue gas, which may allow the system **100** to be deployed in locations with more stringent regulatory requirements with regards to air emissions.

Feedstocks

Feedstocks may be derived from biomass-based or fossil-based waste sources or feedstocks for energy production. The biomass-based feedstock sources include, but are not limited to food waste, sewage waste, digestate sludge, algal biomass, livestock manure, agricultural residues, food and beverage production wastes, horticultural waste, bio-crude, energy crops and combinations of biomass-based feedstocks. The fossil-based feedstock sources include, but are not limited to oil sludge, tank bottom sludge, oil field sludge, refinery wastewater treatment sludge, and combinations of fossil-based feedstocks.

Feedstocks with high inorganic ash content exceeding 40% may be treated to reduce the inorganic ash content such as by washing or mineral precipitation.

Feedstocks may be dewatered or diluted in stage **10** to adjust feed concentration to desired level. Feed concentrations are typically below 30% of the total weight fed into system **100**.

Additives

Additives may be added in stage **10** including oxidants, emulsifiers and catalysts. The concentrations of each additive are typically below 1% of the total weight. Catalysts used for stage **20** may be acid or base salts. Catalysts used for stage **30** may be base salts.

Temperatures, Pressures, and Residence Times

Stage **20** may operate at a temperature between 250°C to 350°C, pressure between 100 bar to 300 bar, and a residence time of 30 seconds to 10 minutes, depending on the feedstock composition, catalysts used, and desired reaction pathway.

Stage **30** may operate at a temperature between 500°C to 700°C, pressure between 225 bar to 300 bar, and a residence time of 5 seconds to 3 minutes, depending on the catalysts used, desired syngas composition, and desired gasification and energy efficiencies.

Syngas

The syngas output may contain hydrogen, methane, carbon dioxide, carbon monoxide, and other hydrocarbon gases. Depending on the feedstock and process conditions used, the hydrogen content ranges between 10% to 50%, methane content ranges between 5% to 30%, carbon dioxide content ranges between 30% to 60%, carbon monoxide content ranges between 2% to 20%, and other hydrocarbon gases content ranges between 0% to 10%.

Claims

- 1) A system of producing syngas from organic substances suspended or dissolved in aqueous solution, the system comprising:
 - a pre-processing stage that separates contaminants, reduces particle size, maintains feedstock homogeneity, adds required additives, and filters large particles;

a chemical bond breaking stage that pumps pre-processed feedstock from the pre-processing stage to process pressure, utilizes recovered heat to pre-heat pressurized feedstock, heats pre-heated feedstock to chemical bond breaking process temperature, and holds feedstock at chemical bond breaking process conditions for required residence time to break down feedstock into intermediate products;

a supercritical water gasification stage that utilizes recovered heat to pre-heat intermediate products from the chemical bond breaking stage, heats pre-heated intermediate products to supercritical water gasification process temperature, and holds intermediate products at supercritical water gasification process conditions for required residence time to break down intermediate products into syngas; and

a post-processing stage that cools, depressurizes, and separates the syngas and effluent water.

- 2) The system in accordance with Claim 1 further comprising a hydraulic oscillator that increases turbulence and improves mixing in the high pressure region of the system.
- 3) The system in accordance with Claim 1 further comprising a blowdown vessel that safely discharges solid particles from the supercritical water gasification stage from high temperature high pressure conditions to ambient conditions.
- 4) The system in accordance with Claim 1 further comprising a chiller that supplies cooling water for cooling requirements in the post-processing stage.
- 5) The system in accordance with Claim 4, wherein the chiller is one of an air-cooled chiller, water-cooled chiller, vapor absorption chiller, vapor compression chiller, or a combination of chillers.
- 6) The system in accordance with Claim 1 further comprising a buffer tank that safely stores syngas produced by the system for further usage.
- 7) The system in accordance with Claim 1, wherein the pre-processing stage further comprises:
 - a separator stage that removes coarse contaminants that are inorganic in nature, such as metal and ceramic objects, stones, and gravel;
 - a comminution stage that breaks down feedstock particles mechanically into fine particles that are pumpable and have high surface area to volume ratio for high heating efficiency;
 - a homogenizer stage that ensures the homogeneity of the feedstock by stirring, adds required additives, and heats to reduce viscosity; and
 - a filter stage that filters out particles that are above the size limit of the slurry pump in the chemical bond breaking stage.
- 8) The system in accordance with Claim 7, wherein the separator stage is one of a paddle separator, hammer mill separator, magnetic separator, eddy current separator, or a combination of separators.
- 9) The system in accordance with Claim 7, wherein the comminution stage is one of a shredder, macerator, colloidal mill, hammer mill, or a combination of comminution devices.
- 10) The system in accordance with Claim 7, wherein the homogenizer stage is a stirred feed tank with a heater and inlets for water, oxidants, emulsifiers, and catalysts.
- 11) The system in accordance with Claim 7, wherein the filter stage is one of a cylinder filter, mesh filter, or a combination of filters.
- 12) The system in accordance with Claim 1, wherein the chemical bond breaking stage further comprises:
 - a slurry pump stage that pumps pre-processed feedstock to chemical bond breaking process pressure of 100 to 300 bar;
 - a heat exchanger stage to heat feedstock by utilizing recovered heat from the system;
 - a pre-heater stage to further heat the feedstock to chemical bond breaking process temperature of 250°C to 350°C; and

a reactor stage to hold feedstock for the chemical bond breaking process required residence time of 30 seconds to 10 minutes.

- 13) The system in accordance with Claim 12, wherein the slurry pump stage is one of a plunger pump, positive displacement pump, piston pump, lobe pump, diaphragm pump, progressive cavity pump, metering pump, variable displacement pump, fixed displacement pump, or a combination of pumps.
- 14) The system in accordance with Claim 12, wherein the heat exchanger stage is one of a double-pipe heat exchanger, shell and tube heat exchanger, or a combination of heat exchangers.
- 15) The system in accordance with Claim 12, wherein the pre-heater stage is one of a gas-fired heater, electric heater, heater using heat carriers, or a combination of heaters.
- 16) The system in accordance with Claim 12, wherein the reactor stage is one of a continuous stirred tank reactor, fluidized bed reactor, packed-bed reactor, tubular reactor, or a combination of reactors.
- 17) The system in accordance with Claim 12, wherein the pre-heater stage and reactor stage may be combined in a reactor with heater stage.
- 18) The system in accordance with Claim 1, wherein the supercritical water gasification stage further comprises:
 - an optional slurry pump stage to pump intermediate products from the chemical bond breaking stage to the supercritical water gasification process pressure of 225 to 300 bar, if the process pressure used in the chemical bond breaking stage is lower than the process pressure used in the supercritical water gasification stage;
 - a heat exchanger stage to heat feedstock by utilizing recovered heat from the system;
 - a pre-heater stage to further heat the feedstock to supercritical water gasification process temperature of 500°C to 700°C;
 - a reactor stage to hold feedstock for the supercritical water gasification process required residence time of 5 seconds to 3 minutes; and
 - a solid separator stage to remove solid by-products from the reactor product stream.
- 19) The system in accordance with Claim 18, wherein the optional slurry pump stage is one of a plunger pump, positive displacement pump, piston pump, lobe pump, diaphragm pump, progressive cavity pump, metering pump, variable displacement pump, fixed displacement pump, or a combination of pumps.
- 20) The system in accordance with Claim 18, wherein the heat exchanger stage is one of a double-pipe heat exchanger, shell and tube heat exchanger, or a combination of heat exchangers.
- 21) The system in accordance with Claim 18, wherein the pre-heater stage is one of a gas-fired heater, electric heater, heater using heat carriers, or a combination of heaters.
- 22) The system in accordance with Claim 18, wherein the reactor stage is one of a continuous stirred tank reactor, fluidized bed reactor, packed-bed reactor, tubular reactor, or a combination of reactors.
- 23) The system in accordance with Claim 18, wherein the pre-heater stage and reactor stage may be combined in a reactor with heater stage.
- 24) The system in accordance with Claim 18, wherein the solid separator stage is one of a cyclone separator, cylinder filter, or a combination of solid separators
- 25) The system in accordance with Claim 1, wherein the post-processing stage further comprises:
 - a cooler stage to cool the supercritical water gasification stage outputs after heat recovery to ambient temperatures using cooling water;
 - a filter stage to remove solid by-products that may be damaging to downstream components;

- a pressure regulator stage to reduce pressure of the supercritical water gasification products to ambient pressure; and
 - a vapor-liquid separator stage to separate the condensed effluent water from the syngas.
- 26) The system in accordance with Claim 25, wherein the cooler stage is one of a double pipe heat exchanger, shell and tube heat exchanger, shell and helical tube heat exchanger, or a combination of heat exchangers.
 - 27) The system in accordance with Claim 25, wherein the filter stage is one of a is one of a cylinder filter, mesh filter, or a combination of filters.
 - 28) The system in accordance with Claim 25, wherein the pressure regulator stage is one of a back pressure regulator, pressure reducer, or a combination of pressure regulators.
 - 29) The system in accordance with Claim 1, wherein the syngas product when combusted generates sufficient energy such that the sum of the energy demands for conversion of the feedstock to the syngas is a net positive.
 - 30) The system in accordance with Claim 1, wherein the effluent water by-product is used to dilute the feedstock in the pre-processing stage to adjust feed concentration if dilution is necessary.
 - 31) A process of producing syngas from organic substances suspended or dissolved in aqueous solution, the process comprising:
 - a pre-processing process that improves the flowability and pumpability of the feedstock and system efficiency;
 - a chemical bond breaking (CBB) process that breaks down large polymers and high molecular weight compounds in the pre-processed feedstock into intermediate products;
 - a supercritical water gasification (SCWG) process that converts the intermediate products into syngas and by-products; and
 - a post-processing process that processes the products and by-products for usage and discharge.
 - 32) The process in accordance with Claim 31, wherein the pre-processing process further comprises:
 - a separation process to separate contaminants from the feedstock;
 - a comminution process to reduce particle size of the feedstock;
 - a homogenization process to maintain homogeneity of the feedstock and add require additives; and
 - a filtration process to remove particles in the feedstock above the desired size limit;
 - 33) The process in accordance with Claim 32, wherein the separation process separates contaminants that are inorganic in nature including metal and ceramic objects, stones, and gravel.
 - 34) The process in accordance with Claim 32, wherein the comminution process reduces particle size to a desired particle size not exceeding 50 microns.
 - 35) The process in accordance with Claim 32, wherein the homogenization process dilutes the feedstock to a desired feed concentration not exceeding 30% of the total weight, if necessary.
 - 36) The process in accordance with Claim 32, wherein the homogenization process adds oxidants, emulsifiers, and catalysts to a desired concentration each not exceeding 1% of the total weight.
 - 37) The process in accordance with Claim 36, wherein the catalysts added comprises an acid or base salt.
 - 38) The process in accordance with Claim 32, wherein the filtration process filters particles exceeding the desired particle size.
 - 39) The process in accordance with Claim 31, wherein the chemical bond breaking process further comprises:
 - a slurry pumping process to increase the pressure of the pre-processed feedstock to the chemical bond breaking process pressure;

- a heat exchange process to utilize heat from downstream product flows to heat feedstock;
 - a pre-heating process to heat feedstock to chemical bond breaking process temperature; and
 - a reaction process to hold the feedstock for the required chemical bond breaking process residence time, to break down feedstock into intermediate products.
- 40) The process in accordance with Claim 39, wherein the chemical bond breaking process pressure is between 100 to 300 bar.
- 41) The process in accordance with Claim 39, wherein the heat exchange process heats the feedstock to a temperature not exceeding the chemical bond breaking process temperature.
- 42) The process in accordance with Claim 39, wherein the chemical bond breaking process temperature is between 250°C to 350°C.
- 43) The process in accordance with Claim 39, wherein the chemical bond breaking process residence time is between 30 seconds to 10 minutes.
- 44) The process in accordance with Claim 31, wherein the supercritical water gasification process further comprises:
- an optional slurry pumping process to increase the pressure of the intermediate products to the supercritical water gasification process pressure;
 - a heat exchange process to utilize heat from downstream product flows to heat intermediate products;
 - a pre-heating process to heat intermediate products to supercritical water gasification process temperature;
 - a reaction process to hold the intermediate products for the required supercritical water gasification process residence time, to break down the intermediate products into syngas and by-products in a combined flow; and
 - a separation process to separate solid by-products from the combined flow.
- 45) The process in accordance with Claim 44, wherein supercritical water gasification process pressure is between 225 to 300 bar.
- 46) The process in accordance with Claim 44, wherein the heat exchange process heats the intermediate products to a temperature not exceeding the desired supercritical water gasification process temperature.
- 47) The process in accordance with Claim 44, wherein the supercritical water gasification process temperature is between 500°C to 700°C.
- 48) The process in accordance with Claim 44, wherein the supercritical water gasification process residence time is between 30 seconds to 10 minutes.
- 49) The process in accordance with Claim 31, wherein the post-processing process further comprises:
- a cooling process to cool the supercritical water gasification stage outputs after heat recovery to ambient temperatures;
 - a filtration process to remove solid by-products from the combined flow to prevent damage to downstream components;
 - a pressure regulation process to reduce the pressure of the combined flow to ambient pressure; and
 - a vapor-liquid separation process to separate the syngas product from the effluent water by-product.
- 50) The process in accordance with Claim 31, wherein the feedstock comprises biomass-based or fossil-based waste sources or feedstocks for energy production.