

**IMPROVED METHOD FOR CONVERTING A FEEDSTOCK CONTAINING A
BIOMASS FRACTION FOR THE PRODUCTION OF HYDROCARBONS BY MEANS
OF FISCHER-TROPSCH SYNTHESIS**

5 **FIELD OF THE INVENTION**

The present invention relates to the value enhancement of biomass, typically for the production of liquid hydrocarbons, biofuels, and optionally the production of petrochemical bases and/or chemical bases and/or hydrogen.

10 More particularly, the present invention relates to an integrated process for converting a feedstock containing at least one biomass fraction, comprising a gasification step, a water electrolysis step and a step of synthesis by Fischer-Tropsch reaction, for the purpose of producing hydrocarbons, notably high-quality LPG (liquefied petroleum gas), naphtha,
15 gasoline, kerosene and gas oil fractions or lubricant bases.

PRIOR ART

20 A large number of patents describe lines for the production of synthetic hydrocarbons via Fischer-Tropsch synthesis in which steps of hydrotreating and isomerization of the hydrocarbon-based cuts obtained from this synthesis are often combined.

Patent application WO 2014/068253 A1 involves a line for the production of biofuels from
25 lignocellulosic biomass. Said patent application describes the possible injection of hydrogen into any point of the process line. The injected hydrogen is produced via any means known to those skilled in the art, without particular distinction or integration between the hydrogen production process and the biofuel production line processes.

30 Patent US 9562196 describes a process for producing synthetic hydrocarbons, in which adjustment of the hydrogen content is made at the inlet of the Fischer-Tropsch unit by

reforming the naphtha produced by the Fischer-Tropsch synthesis. This step has the drawback of reducing the amount of finished products produced by consuming the naphtha produced and thus reduces the productivity of the Fischer-Tropsch synthetic step.

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Patent application WO 2015/101717 describes supplying external hydrogen to adjust the H₂/CO ratio of a synthesis gas produced by gasification of a carbon-based feedstock and more particularly biomass. In particular, said document describes a process comprising a step of converting carbon monoxide with steam to enrich in hydrogen the synthesis gas produced by gasification and a step of adjusting the production of synthesis gas as a function of the amount of hydrogen by means of an external supply of hydrogen so as to maintain a constant production of synthetic fuel. The reaction for conversion of the carbon monoxide with steam is also known as the “water gas shift” reaction.

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One of the problems encountered by a person skilled in the art in the field of the invention relates to improving the production yields and the economic and energy performance of the production line on an industrial scale while at the same time complying with the increasingly strict environmental constraints.

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In the case of the present invention, the Applicant proposes a novel process which presents optimum integration of the gasification, Fischer-Tropsch synthesis and water electrolysis steps, making it possible to achieve improved production yields and better economic and energy performance (energy efficiency, production cost, etc.) while at the same time complying with the environmental constraints such as the emissions of greenhouse gases set at increasingly lower thresholds.

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BRIEF DESCRIPTION OF THE INVENTION

In particular, the invention relates to a process for converting a feedstock comprising at least one biomass fraction into hydrocarbons, said process comprising

- a step a) of pretreating the feedstock,
- a step b) of electrolysis of water into oxygen and hydrogen, for the production of a hydrogen stream and an oxygen stream, in which the water is obtained, at least partly, from a Fischer-Tropsch synthesis step e),
- a step c) of gasification of the feedstock pretreated in step a), in the presence of all or part of the oxygen stream obtained from the water electrolysis step b) so as to obtain a gaseous effluent comprising a synthesis gas,
- an optional step d) of conditioning the gaseous effluent comprising a synthesis gas obtained from step c) so as to obtain a gaseous effluent comprising a purified synthesis gas,
- a step e) of Fischer-Tropsch synthesis of the gaseous effluent obtained from step c) or optionally from step d) in the presence of all or part of the hydrogen obtained from the water electrolysis step b) so as to produce a stream comprising synthetic liquid hydrocarbons and at least one gaseous effluent.

One advantage of the present invention is that of providing a process which presents optimum integration of the gasification, Fischer-Tropsch synthesis and water electrolysis steps, making it possible to achieve improved production yields and better economic and energy performance (energy efficiency, production cost, etc.) while at the same time complying with the environmental constraints such as the emissions of greenhouse gases set at increasingly lower thresholds.

Another advantage of the process according to the invention is that of limiting, and even of dispensing with, the implementation of the steam conversion step for generating hydrogen, which makes it possible to reduce the CO₂ emissions of the biofuel production process and also to maximize the amount of CO obtained from the gasification step and

thus to increase the material yield of the process and/or to reduce the amount of input feedstocks.

5 **DETAILED DESCRIPTION OF THE INVENTION**

The present invention relates to a process for converting a feedstock comprising at least one biomass fraction into renewable hydrocarbons.

Types of feedstocks

10 The biomass fraction may comprise any type of biomass, preferably biomass of solid type, and in particular biomass of lignocellulosic type. Nonlimiting examples of biomass types concern, for example, farming residues (notably straw, corn husks), forestry management residues, forestry management products, wood mill residues and dedicated crops, for example short-rotation coppice.

15 The feedstock converted in the process according to the invention may also comprise at least one fraction of another feedstock, preferably at least one fraction of a gaseous, solid and/or liquid hydrocarbon-based feedstock ("co-processing"). Said hydrocarbon-based feedstock fraction is understood in the context of the present invention as being a

20 feedstock fraction which may advantageously contain at least coal, petcoke, natural gas, petroleum residues, crude oils, topped crude oils, deasphalted oils, deasphalting asphalts, oil conversion process derivatives (for instance: HCO/FCC slurry, coking heavy GO/VGO, visbreaking or similar thermal process residues, etc.), bituminous sands or derivatives thereof, shale gases and bituminous shales or derivatives thereof, liquid

25 biomass (for instance: rapeseed oil, palm oil, pyrolysis oil, etc.), or biomass slurry, corresponding to a mixture of liquid biomass with a solid hydrocarbon-based feedstock. According to the process of the invention, said hydrocarbon-based feedstock fraction may be a gaseous, solid or liquid hydrocarbon-based feedstock fraction or a mixture thereof.

The feedstock of the process according to the invention may thus be a feedstock comprising at least one solid biomass fraction, and optionally at least one fraction of another gaseous, solid or liquid feedstock alone or as a mixture.

- 5 In general, the feedstock used in the process of the invention comprises at least 20%, preferably at least 50%, preferably at least 70% and more preferably at least 90% of biomass fraction.

The various steps of the process according to the invention are described below.

10 **a) Feedstock pretreatment step**

According to the invention, the process comprises a step a) of pretreating the feedstock. Preferably, the pretreatment step comprises at least one from among the operations of drying a1), torrefaction a2) or milling a3) described below. Preferably, the pretreatment step comprises a drying operation a1), a torrefaction operation a2) and a milling operation a3).

15 In an embodiment in which the feedstock used is already dry, the pretreatment step comprises a torrefaction operation a2) and a milling operation a3).

When the hydrocarbon-based feedstock fraction is a gaseous or liquid hydrocarbon-based feedstock fraction, it is advantageously introduced directly into the gasification step c) without being subjected to the pretreatment step a).

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a1) Drying operation

The feedstock pretreatment step a) may advantageously comprise a feedstock drying operation a1) advantageously performed at a temperature of between 20 and 180°C, preferably between 60 and 160°C and preferentially between 100 and 140°C for a time of between 5 and 180 minutes and preferentially between 15 and 60 minutes. At the inlet of the drying operation a1), the feedstock generally comprises a water content of between 15% and 80% by mass. The residual water content in the feedstock on conclusion of the drying operation is advantageously less than 25% by mass, preferably less than 15% by

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mass and more preferably less than 10% by mass. The drying operation may be performed by any means known to a person skilled in the art.

The energy required for the drying is generally provided by placing the feedstock in contact with a hot gas stream.

- 5 The hot gas stream used in the drying step may advantageously originate from the combustion of a process input and preferably from the combustion of natural gas and/or from the combustion of a gas stream obtained from another step of the process. For example, the combustion of the gases obtained from the torrefaction step a2) produces a hot gas stream which can be used for drying the feedstock by any method known to
10 those skilled in the art.

The gaseous effluent obtained from step a1) containing water may be used for preheating the air enabling the combustion of the natural gas and/or of the gas stream produced during the torrefaction.

15 **a2) Torrefaction operation**

The feedstock pretreatment step a) may comprise a torrefaction operation a2), preferably on the dried feedstock obtained from the drying operation a1).

- The torrefaction operation a2) may be performed in a torrefaction furnace which produces a more friable feedstock effluent which consequently requires less energy in order to be
20 finely milled so as to obtain a torrefied effluent. The torrefaction operation is advantageously performed at a temperature of between 220 and 350°C, preferably between 250 and 320°C and more preferentially between 270 and 300°C for a time of between 5 and 180 minutes and preferentially between 15 and 60 minutes, at an absolute operating pressure preferentially between 0.01 and 1.5 MPa, preferably between 0.01
25 and 1.0 MPa and more preferably between 0.05 and 0.15 MPa. The torrefaction operation is performed in an environment in which the oxygen content is advantageously less than

10% by volume, preferably less than 8% by volume and preferentially less than 3% by volume.

The torrefaction operation has the advantage of reducing the energy cost of the milling operation a3) and is accompanied by a loss of solids of between 5% and 40% by mass, preferably between 10% and 35% by mass. However, this loss of solids is accompanied by a much more limited loss of calorific power of the order of 5% to 20%. In this respect, the torrefaction operation makes it possible to increase the energy content per unit volume of the biomass.

a3) Milling operation

The feedstock pretreatment step a) may comprise a milling operation a3), preferably on the torrefied effluent obtained from the operation a2).

The milling operation a3) may be performed under conditions allowing a reduction of the feedstock particles to a size suitable for treatment in a gasification unit as an entrained stream (step c). On conclusion of the milling operation a3), 90% of the feedstock particles preferably have an equivalent diameter of less than 300 microns and 90% of the feedstock particles preferably have an equivalent diameter of greater than 1 micron; preferably, 90% of the feedstock particles have an equivalent diameter of less than 200 microns and 90% of the feedstock particles have an equivalent diameter of greater than 5 microns; and more preferably 90% of the feedstock particles have an equivalent diameter of less than 100 microns and 90% of the feedstock particles have an equivalent diameter of greater than 10 microns. The equivalent diameter, denoted as d_e , is defined, for example, according to the following relationship:

$$d_e = 6 \cdot \frac{V}{S} \quad \text{with } V \text{ being the volume of the particle,}$$

S being the surface area of the sphere having the same volume as the particle.

In a particular embodiment, the milling step a3) may be performed in the presence of a second biomass or fossil feedstock so as to be milled simultaneously in one and the same mill. When said second feedstock is fossil-based, it may be chosen from solid fossil hydrocarbons such as coal and petcoke. When said second feedstock is biomass, then it may be chosen from the biomass feedstocks as defined previously. One advantage of milling in the presence of a second feedstock is that it enables efficient milling and drying of said second feedstock.

Preferably, the milling step a3) may be performed in the presence of an additional compound that is useful for the subsequent gasification step; said compound is chosen from vitrified ash, sand, limestone, lime or other compounds known to those skilled in the art, taken alone or as a mixture.

Preferably, the mill is chosen so as to optimize the pneumatic transport of the powder obtained on conclusion of step a3), by minimizing the minimum fluidization speed (MFS), and also its intrinsic energy consumption.

Preferably, said co-milling step a3) is performed in a mill such as a roller mill, a universal mill, an attrition mill or any other type of mill known to those skilled in the art.

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Electrolysis step b)

The process according to the invention comprises a step of electrolysis of water into oxygen and hydrogen, for the production of a hydrogen stream and an oxygen stream, in which the water is obtained, at least partly, and preferably totally, from the Fischer-Tropsch synthesis step e).

The oxygen obtained on conclusion of step b) is partly or totally sent into the gasification step c). Advantageously, the oxygen produced by the electrolysis has a purity of at least 98.5% by weight (on a dry basis). The impurities that may be present in the oxygen produced are water and/or hydrogen.

According to the invention, all or a portion of the hydrogen obtained on conclusion of the electrolysis step b) is sent into the Fischer-Tropsch synthesis step e).

Advantageously, the hydrogen obtained on conclusion of the electrolysis step b), sent into the Fischer-Tropsch synthesis step e), has a purity of at least 99.8% by weight (on a dry basis). Preferably, the hydrogen sent into step e) contains less than 100 ppm of oxygen and/or of water, preferably less than 60 ppm, preferably less than 40 ppm, preferably less than 30 ppm and preferably less than 15 ppm.

Preferably, all of the hydrogen produced in the electrolysis step b) is introduced into the Fischer-Tropsch synthesis step e).

Advantageously, the mole ratio between the hydrogen and the carbon monoxide, denoted as H_2/CO , of the effluent introduced into the Fischer-Tropsch synthesis step e) is between 0.5 and 4, preferably between 1 and 3, more preferably between 1.5 and 2.5 and very preferably equal to 2, the hydrogen originating from step d) of conditioning the synthesis gas and from the water electrolysis step b).

The electrolysis step b) may be performed by any means known to those skilled in the art, for example by alkaline electrolysis, by proton exchange membrane, by anion exchange membrane or by solid oxide electrolysis.

One advantage of the water electrolysis step b) is that of producing a decarbonated hydrogen making it possible to obtain a fuel for which the reduction of the greenhouse gas emissions is eligible under the European Red II directive.

Another advantage associated with the recycling of the water obtained from the Fischer-Tropsch synthesis step e) into the electrolysis step b) is that of reducing the water consumption of the process and consequently the operating costs.

Another advantage associated with the electrolysis step b) is that the oxygen produced is used in the process in the gasification step c), which makes it possible to limit and even

to dispense with the use of an air separation unit, limiting the investment and the operating costs of the process. Furthermore, the excess oxygen may advantageously be used for SRU/TGTU (sulfur recovery unit/tail gas treating unit) tail gas treatment and/or for the oxycombustion of the combustible gas of the unit and of the residual gas and/or for the combustion of the torrefaction gases.

Gasification step c)

The process according to the invention comprises a step c) of gasification of the feedstock, pretreated in step a), said step c) being performed in the presence of all or a portion of the oxygen obtained from the water electrolysis step b) and preferably of all of the oxygen obtained from the water electrolysis step b). The gasification step c) thus allows the production of a gaseous effluent comprising a synthesis gas.

The gasification step involves a partial oxidation reaction which converts the feedstock into a synthesis gas predominantly comprising carbon monoxide and hydrogen. The gasification step is advantageously performed in the presence of a controlled amount of oxygen obtained from the electrolysis step b) in the form of an oxygen stream having a purity of at least 98.5% by weight (on a dry basis). The use of said oxygen makes it possible to limit the amount of inert compounds, such as nitrogen in the case of using air as the oxygen source, which makes it possible to limit the accumulation of inert matter and thus the problems associated with speed or pressure losses and thus to reduce the size of the equipment used, making it possible to further limit the investment and the operating costs of the process.

Advantageously, the gaseous effluent corresponding to the synthesis gas obtained from the gasification step c) is predominantly composed of water (H_2O), carbon monoxide (CO), hydrogen (H_2) and carbon dioxide (CO_2), and may comprise impurities originating initially from the biomass fraction and/or from the fraction of another feedstock, notably a hydrocarbon feedstock.

According to the invention, the oxygen used in the gasification step is totally or partly obtained from the water electrolysis step b).

Advantageously, an oxygen stream originating from an air separation step may also be used in the gasification step c), in addition to the oxygen stream derived from the water electrolysis step b).

In a particular embodiment, all of the oxygen introduced into the gasification step c) is obtained from the water electrolysis step b).

Step c) of gasification of the feedstock is performed in a gasifier of the fixed-bed or fluidized bed type or, preferably, in a cooled-wall entrained flow gasifier at high temperature, i.e. at a temperature of between 800 and 1800°C, preferably between 1000 and 1600°C and more preferentially between 1200 and 1500°C, and at an absolute pressure advantageously of between 2 and 12 MPa, preferably between 2.5 and 6.0 MPa and more preferentially between 3.0 and 5.0 MPa. The high temperature makes it possible to obtain a high degree of carbon conversion and thus to reduce the amount of unconverted carbon in the ash produced and thus to reduce the amount of ash recycled to the gasifier.

The entrained flow gasifier is preferably a gasifier known to those skilled in the art as a cooled-wall entrained flow gasifier. The cooled wall delimits the gasification chamber which is itself located in the gasifier. The water used for cooling the wall of the gasification chamber circulates in a coil placed outside the gasification chamber wall. The water is partially vaporized, thus generating a stream of medium-pressure steam. This cooling of the walls allows the formation of a protective ash layer on the inner wall of the gasification chamber. Specifically, the feedstocks introduced into the gasifier contain inorganic compounds, which form ash after gasification. At the gasification temperature, this liquid ash, in droplet form, solidifies when it meets the cooled wall and forms a solid layer acting as an insulator. Thus, thermal protection of the gasification chamber wall is provided firstly by a layer of solidified ash and secondly by a layer of molten ash, in contact with the gas

phase, flowing toward the bottom of the gasifier. The combustion chamber wall is thus very resistant to high temperatures and to high temperature variations. Furthermore, as a result of its composition, notably its high content of alkaline compounds, the ash derived from biomass is corrosive to linings of refractory type. Consequently, gasification technologies using internal refractory materials as wall protection are difficult to operate on account of their rapid deterioration, necessitating frequent renewal. Furthermore, refractory materials are highly sensitive to heat shocks, which destroy this protective layer by fracturing.

In the cooled-wall entrained flow gasifier, at least two burners, and preferably four or more burners depending on the gasifier capacity, are placed in the gasification chamber, the walls of which are cooled and which function at a temperature sufficient to allow the fusion of the ash contained in the feedstock. Moreover, the feedstocks introduced into the gasifier may have very different properties. By way of example, the lower calorific power (LCP) of a biomass is lower than that of a petcoke, the ash content of a biomass may be very much lower than that of a coal and the melting point of the ash may vary greatly from one biomass to another. Thus, the melting point of the ash may vary depending on the composition of the feedstock introduced into the gasification chamber. Similarly, the minimum gasification temperature to be above the ash melting point may be adjusted by modifying the nature of the feedstocks, of different properties, and the proportions of the various constituents (other biomass, other hydrocarbon feedstock, etc.) and/or by injecting flux (for example limestone) with the feedstock.

In a preferred version of the invention, the synthesis gas produced in the gasification chamber emerges therefrom co-currentwise with the liquid ash flowing toward the bottom of the gasifier. This co-current configuration has the advantage, with respect to a configuration in which the synthesis gas is evacuated from the gasification chamber toward the top while the liquid ash flows toward the bottom, of avoiding the risks of clogging of the liquid ash evacuation pipe. Specifically, since the liquid ash flows only in the pipe, it can, depending on its viscosity, flow with difficulty and/or become partly

solidified, partially or totally obstructing the evacuation pipe and leading to stoppage of the facility for maintenance. These phenomena may particularly arise during transient phases of rises or drops in temperature or during adjustments associated with a change in the nature of the feedstock. The configuration according to the invention has the advantage in that the gas flowing co-currentwise with the liquid ash in the evacuation pipe of the gasification chamber facilitates the flow of this ash toward the bottom of the gasifier and prevents risks of clogging even in the transient phases.

In a preferred version of the invention, the synthesis gas and the liquid ash pass into an intensive liquid quench zone in contact at least with a film of water as described in patent application DE 102007044726. This quench zone is positioned under the gasification chamber and separates a hot, dry zone at the top and a colder, more humid zone at the bottom. The hot dry zone located under the gasification chamber is characterized by the presence of synthesis gas and of liquid ash flowing toward the bottom of the gasifier. The colder and more humid part is located under the hot dry zone and is characterized by the presence of water-saturated synthesis gas, solidified ash and liquid water. The temperature of the synthesis gas at the outlet of the cold humid zone corresponds to the temperature of the thermodynamic equilibrium between the gas phase and the liquid phase at the operating pressure of the gasifier.

This configuration with quenching allows removal of the fine adhesive ash particles entrained during the scrubbing of the synthesis gas, thus reducing the risks of fouling in the downstream pipework and units. Moreover, the high temperature in the gasification chamber allows the molten ash to flow easily toward the bottom on the wall thereof before falling into the quench zone. After passing into the cold humid unit, the cooled ash ends up at the bottom of the gasifier filled with water. On contact with the water, this molten ash is immediately cooled and vitrified as dense particles. These particles are then extracted from the gasifier in the form of a mixture of water and solid ash (or slurry) by depressurization. The majority of the mineral compounds contained in the feedstock form

the molten ash. This configuration advantageously makes it possible to encapsulate hazardous products such as heavy metals in the vitrified ash. The vitrification process makes this ash very stable, it is not leachable.

5 In an alternative version of the invention, the synthesis gas produced leaves the gasification chamber via the top while the molten ash flows along the wall counter-currentwise relative to the synthesis gas down to the bottom of the gasifier filled with water. On contact with the water, the molten ash solidifies abruptly, forming small-sized particles. These particles are then extracted from the gasifier in the form of a slurry
10 (mixture of water and solid ash) by depressurization. Since the majority of the mineral compounds contained in the feedstock form the molten ash, this configuration advantageously makes it possible to encapsulate hazardous products such as heavy metals in the vitrified ash. The vitrification process makes this ash very stable, it is not leachable. Said synthesis gas leaving the gasification chamber via the top and the finest
15 molten ash particles entrained therewith are cooled by a stream of cooled synthesis gas free of solid particles. This cooling makes it possible to solidify the molten ash as non-adhesive solid particles. After this first step of preliminary cooling, the synthesis gas is sent into a heat exchanger for producing steam. In order to remove the fine solid particles, the synthesis gas then passes through a section for separating the gas phase and the
20 solid phase using any technique known to those skilled in the art, for example cartridge filters. A portion of this cooled, particle-free synthesis gas is recycled to the gasifier outlet to cool the synthesis gas exiting at the top of the gasifier.

Optional step d) of conditioning the synthesis gas

25 The process according to the invention may comprise a step d) of conditioning the synthesis gas obtained from the gasification step c). The synthesis gas obtained from the gasification step c) is predominantly composed of carbon monoxide (CO), hydrogen (H₂), carbon dioxide (CO₂) and water (H₂O), and may comprise impurities originating initially from the biomass fraction and/or from the fraction of another feedstock, notably a

hydrocarbon feedstock. These impurities are essentially metals, in particular alkali metals (Na, K), sulfur compounds and also chlorinated and nitrogenous compounds. In particular, the halogenated compounds initially present in the feedstock according to the invention may reach contents of at least 250 ppm by mass in the crude hydrocarbon feedstock fraction (before drying), and of at least 10 000 ppm by mass in the case of the crude biomass fraction (before drying).

Preferably, step d) comprises, and preferably consists of, steps d1) and/or d2) and/or d3) and/or d4) and/or d5) and/or d6) and/or d7) and/or d8).

10 **Step d1) of scrubbing with water and fractionation of the synthesis gas**

Preferably, step d) comprises a step d1) of scrubbing with water and fractionation of the synthesis gas.

Thus, the synthesis gas obtained from the gasification step c) is advantageously subjected to a step d1) of scrubbing with water to remove the traces of solid in the synthesis gas and also a portion of the water-soluble gaseous compounds. This operation may take place via any type of technique known to those skilled in the art, including a Venturi-effect water scrubber, or Venturi scrubber, a scrubbing column with all types of inserts, etc.

20 Preferably, at the outlet of the water scrubbing step, the synthesis gas is subjected to a step of fractionation into at least two effluents, a first part and an additional part which are subjected to the following steps:

- a step d2) of removal of the halogenated compounds by passing said first part over at least one suitable guard bed;

- optionally a step d3) of steam conversion of the carbon monoxide performed on the effluent obtained from step d2);

- a step d4) of catalytic hydrolysis of the compounds COS and HCN contained in said additional part of the effluent obtained from step d1) into H₂S and NH₃.

In another embodiment, the effluent obtained from step d3) is advantageously recombined with the additional part of the effluent obtained from step d1) before being treated in step d4) of catalytic hydrolysis of the compounds COS and HCN.

- 5 Thus, the “first part” and “additional part” effluents obtained from step d1) of scrubbing with water and of fractionation of the synthesis gas are subjected to separate treatment steps. The first part is subjected to a step d2) of removal of halogenated compounds; while the additional part is subjected to a step d4) of catalytic hydrolysis of the compounds COS and HCN into H₂S and NH₃. The fractionation of the synthesis gas and the separate
10 and distinct treatment of the effluents makes it possible to reduce the size of the units and the amounts of catalysts used in said units.

- Preferably, the respective proportions of said first part of the effluent obtained from step d1) and of said additional part are advantageously determined so as to obtain an effluent
15 at the outlet of step d7) which feeds the Fischer-Tropsch step e) with an H₂/CO mole ratio advantageously between 0.5 and 4, preferably between 1 and 3, more preferably between 1.5 and 2.5 and preferably equal to 2.

Step d2) of removal of the halogenated compounds

- 20 Preferably, step d) comprises a step d2) of removal of the halogenated compounds. Step d2 of removal of the halogenated compounds on at least one suitable guard bed is advantageously performed on the first part of the effluent obtained from step d1). Step d2) allows removal substantially of the halogenated compounds, advantageously chlorine, contained in said first part of the effluent before said part is sent into a carbon
25 monoxide steam conversion unit (step d3). The fixed-bed reactor technology will advantageously be favored to take up the halogenated compounds, notably the chlorine, contained in the synthesis gas of said first part, by means of uptake masses known to those skilled in the art. Advantageously, step d2) is performed on at least one guard bed in the presence of an uptake mass containing an active phase of zeolite type, and/or zinc

oxide, and/or a basic oxide such as an alumina. The active phase may be doped or promoted with one or more compounds of alkali metal and/or alkaline-earth metal and/or rare-earth metal elements. The active phase may be, for example, an alumina promoted with a sodium compound, for example with Na_2O .

- 5 In the context of the invention, the passage of the first part of the effluent obtained from step d1) into at least one guard bed makes it possible to achieve the specifications required for the carbon monoxide steam conversion unit d3). At the outlet of step d2) for removal of the halogenated compounds, the effluent generally contains less than 10 ppm by volume of chlorine, advantageously less than 5 ppm by volume of chlorine, preferably
- 10 between 0.1 ppm and 5 ppm by volume of chlorine, more preferably between 1 ppm and 3 ppm by volume of chlorine and even more preferably between 1 ppm and 2 ppm by volume of chlorine.

Step d3) of steam conversion of the carbon monoxide

- 15 Step d) of conditioning of the synthesis gas optionally comprises a step of steam conversion of the carbon monoxide.

- 20 Step c) of gasification of the feedstock according to the invention such as that performed in the present invention may lead to a production of hydrogen and of carbon monoxide in an H_2/CO mole ratio that is not optimal for the Fischer-Tropsch reaction, particularly when the catalyst used is a cobalt-based catalyst which advantageously requires an optimum H_2/CO mole ratio of about 2 in order to be oriented toward the production of middle distillates.

- 25 In order to achieve the H_2/CO mole ratio required by the Fischer-Tropsch synthesis, the effluent obtained from step d2) for removal of the halogenated compounds is, according to the invention, optionally directed toward a carbon monoxide steam conversion section d3) for producing a gas stream rich in hydrogen and depleted in carbon monoxide.

Step d3) is performed in the case where the hydrogen produced in the water electrolysis step b) does not allow the desired H₂/CO ratio to be obtained at the inlet of the Fischer-Tropsch synthesis step e).

All or some of the hydrogen produced in the carbon monoxide steam conversion step d3) may also advantageously be sent into the Fischer-Tropsch synthesis step e).

The carbon monoxide steam conversion reaction step d3) is advantageously performed at an inlet temperature close to the temperature of the synthesis gas obtained from the water scrubbing and fractionation step d1), making it possible to reduce the energy consumption over the entire line for value enhancement of the biomass. Preferably, step d3) is performed at an inlet temperature of between 150 and 280°C, preferably between 200 and 280°C.

Advantageously, the carbon monoxide steam conversion reaction step d3) is performed at an absolute pressure of between 2.0 and 12 MPa, preferably between 2.5 and 6.0 MPa and more preferentially between 3.0 and 5.0 MPa; at an hourly space velocity HSV (volume of feedstock/volume of catalyst/hour) of between 1000 and 10 000 h⁻¹, preferably between 1000 and 9000 h⁻¹ and more preferably between 1500 and 8500 h⁻¹; at a temperature of between 150 and 550°C, preferably between 200 and 500°C.

The catalyst used in this step d3) is a catalyst comprising at least one element from group VIII and at least one element from group VIB of the Mendeleev Periodic Table (group VIII corresponds to groups 8, 9 and 10, and group VIB to group 6 according to the new notation of the Periodic Table of the Elements: Handbook of Chemistry and Physics, 81st edition, 2000-2001). Preferably, the catalyst is a catalyst comprising sulfurized cobalt and/or sulfurized molybdenum. The support for the catalyst is usually a porous solid chosen from the group consisting of aluminas, silica and silica-aluminas. Preferentially, the support for the catalyst is alumina. The catalyst used may be promoted with an alkali metal or alkaline-earth metal promoter. The carbon monoxide conversion reaction makes

it possible to considerably increase the hydrogen content in the effluent sent into the Fischer-Tropsch synthesis step e).

If need be, a supply of water in liquid form, preferably in steam form and preferentially in superheated steam form, may be provided upstream of the carbon monoxide steam conversion step to adjust the H_2O/CO ratio at the inlet of the unit for step d3). Advantageously, step d3) is performed with an H_2O/CO ratio of between 0.5 and 100, preferably between 0.5 and 25, and more preferably between 1.5 and 10. On account of the exothermic nature of the carbon monoxide steam conversion reaction, the gaseous effluent obtained from this step has a temperature of between 250 and 550°C. This gaseous effluent is advantageously cooled to the operating temperature of the hydrolysis unit of between 100 and 400°C, preferably between 200 and 350°C. This cooling advantageously takes place by generating steam which may be used either in the process line according to the invention or for producing electricity.

In one variant of the process according to the invention, the H_2/CO mole ratio of the gas stream entering the Fischer-Tropsch synthesis step e) may be adjusted to its optimum level of about 2 so as to be oriented toward the production of middle distillates by adding an external gas stream rich in hydrogen produced by any means known to those skilled in the art, including: water electrolysis, steam reforming of natural gas followed by a pressure swing adsorption (PSA) step, or by a temperature swing adsorption (TSA) step or by membrane separation. This hydrogen-rich gas stream may be injected into any point of the line located downstream of the gasification step c) and makes it possible to reduce the size of the carbon monoxide steam conversion step d3).

In one variant of the process according to the invention, a portion of the gas obtained from the carbon monoxide steam conversion step d3) but also optionally upstream or downstream of said step d3) may advantageously be sent into a unit for hydrogen production performed by any means known to those skilled in the art, preferably by

pressure swing adsorption (PSA) or by temperature swing adsorption (TSA) or by membrane separation. The hydrogen produced is advantageously used in the hydrotreating and/or isomerization step f).

5 **Step d4) of catalytic hydrolysis of the compounds COS and HCN**

Preferably, step d) comprises a step d4) of catalytic hydrolysis of the compounds COS and HCN of the additional part obtained from step d1).

The additional part obtained from step d1) is subjected to a step d4) of catalytic hydrolysis of the COS and HCN into H_2S and NH_3 , which makes it possible to obtain a purified effluent. This step allows the removal of the COS and HCN which are poisons for the Fischer-Tropsch synthesis catalyst. According to the invention, step d4) of catalytic hydrolysis of carbon oxysulfide (COS) and hydrogen cyanide (HCN) is advantageously performed in the presence of a catalyst containing a platinum-based compound, or an oxide of an element chosen from the group comprising titanium, zirconium, aluminum, chromium and zinc, or a mixture thereof.

Preferably, the hydrolysis catalyst is a catalyst based on titanium oxide. The catalyst used may also contain at least alkali metals, alkaline-earth metals and/or rare-earth metals, for example obtained from precursors such as potassium hydroxide, zirconium oxide, sodium or barium carbonate, sodium or barium bicarbonate, calcium sulfate, sodium or barium acetate, or sodium or barium oxalate. The hydrolysis step is advantageously performed at a temperature of between 100 and 400°C, preferably between 200 and 350°C.

Advantageously, the effluent at the outlet of the hydrolysis unit of step d4) contains less than 25 ppm by volume of COS and less than 5 ppm by volume of HCN, preferably less than 10 ppm by volume of COS and less than 1 ppm by volume of HCN, and more preferably less than 5 ppm by volume of COS and less than 0.1 ppm by volume of HCN.

In one variant of the process according to the invention, the effluent obtained from the carbon monoxide steam conversion step d3) is at least partly sent as a mixture with said additional part into the step for the catalytic hydrolysis of the COS and HCN into H₂S and NH₃ (step d4). Advantageously, the effluent obtained from the carbon monoxide steam conversion step d3) is sent as a mixture with said additional part into the catalytic hydrolysis step (step d4) after cooling to a temperature preferentially between 100 and 400°C, preferably between 200 and 350°C.

Recombination step d5)

Preferably, at least a fraction and preferably all of the effluent obtained from step d2) of removal of the halogenated compounds and optionally obtained from the carbon monoxide steam conversion step d3) is recombined in step d5) with at least a portion of the effluent obtained from the catalytic hydrolysis step d4) before being sent into the water scrubbing step d6).

Step d6) of scrubbing with water of the recombined effluent

Preferably, step d) comprises a step d6) of scrubbing with water of the mixed effluent obtained on conclusion of steps d2) and d4). Step d6) makes it possible to remove the water-soluble impurities such as NH₃ and HCl, which are particularly harmful to the operation of step d7) for removal of the acidic gases.

In one variant of the process according to the invention, the mixed effluent obtained on conclusion of steps d2) and d4) may be subjected beforehand to a step of removing the heavy metals on at least one suitable guard bed. Said removal step makes it possible substantially to remove the heavy metals, such as lead, arsenic and mercury, before the effluent is treated in step d6) of scrubbing with water and more particularly before step d7) of removal of the acidic gases. The fixed-bed reactor technology will advantageously

be favored for taking up the heavy metals contained in the synthesis gas, by means of uptake masses known to those skilled in the art. Advantageously, the removal step is performed on at least one or more guard beds in the presence of one or more uptake masses containing one or more active phases. Advantageously, said active phases
5 contain at least one sulfur compound, for instance supported elemental sulfur, and/or a metal sulfide such as a copper and/or zinc sulfide, and at least one precious metal such as silver, gold or palladium, and/or a silver-exchanged zeolite, and/or transition metal oxides, for instance copper or nickel oxides. Advantageously, said active phase(s) are supported, for example, on an alumina, a silica, a silica-alumina, or an active charcoal.

10 Advantageously, passage of the effluent through at least one guard bed of the removal step makes it possible to achieve the required specifications at the inlet of step d7) of removal of the acidic gases (step d7), and also the specifications required for the Fischer-Tropsch synthesis unit of step e).

15 In a second variant according to the invention, the step of removing the heavy metals is performed between step d6) of scrubbing with water and step d7) of removing the acidic gases.

20 In a third variant according to the invention, the step of removing the heavy metals is performed after step d7) of removing the acidic gases when the solvent used in step d6) is a chemical solvent derived from an alkanolamine, known to those skilled in the art to be less sensitive than physical solvents to the presence of heavy metals.

25 At the outlet of the step for removing the heavy metals, the effluent has a content generally less than 1 ppb by volume of lead, arsenic and mercury, preferably less than 0.5 ppb by volume, more preferably less than 0.1 ppb by volume and even more preferably less than 0.01 ppb by volume of lead, arsenic and mercury.

Step d7) of removing the acidic gases

Preferably, step d) may advantageously also comprise a step d7) of removing the acidic gases. Step d7) is dedicated to removing the acidic gases such as the sulfur compounds (H_2S) or the CO_2 remaining in the synthesis gas obtained from step d5).

- 5 Said step d7) is advantageously performed in the case where the CO_2 content in the synthesis gas obtained from step d6) is greater than 5% by weight relative to the weight of said effluent, preferably greater than 10% by weight and preferably greater than 20% by weight.

- Step d7) is performed by using chemical or physical solvents or a mixture of chemical
10 and physical solvents or alternatively any other means known to those skilled in the art. The chemical solvent may be, for example, a primary, secondary or tertiary amine derived from an alkanolamine such as monoethanolamine (MEA), diethanolamine (DEA) or methyldiethanolamine (MDEA). The physical solvent may be, for example, based on mixtures of polyethylene glycol (PEG) dialkyl ether such as PEG diethyl ether or dibutyl
15 ether, or methanol.

The step for removing the acidic gases is performed, for example, using a column for absorption of the acidic gases by means of the chemical or physical solvent used followed by a solvent regeneration step in order to reduce the consumption of solvent in the unit.

- 20 This regeneration step may advantageously be performed in two steps so as to remove firstly a gas stream rich in CO_2 and secondly a gas stream rich in H_2S . In one variant of the process according to the invention, said CO_2 -rich gas stream is purified of the H_2S and advantageously recycled into the gasification step c).

Step d8) of final purification

Preferably, step d) comprises a step d8) of final purification. Specifically, the cobalt-based catalyst used in the Fischer-Tropsch synthesis step e) is highly sensitive to the impurities present in the synthesis gas, which are in this respect tolerated only in

amounts of the order of ppb (parts per billion). At the outlet of step d7), the synthesis gas may still contain impurities in contents of about 100 ppb by volume of H_2S and of COS.

Advantageously, the final purification step d8) is performed on at least one guard bed and may be performed so as to totally adsorb the last traces of impurities remaining in the synthesis gas, such as the halogenated compounds, H_2S , COS, HCN and NH_3 . The final purification step d8) is performed by any means known to those skilled in the art, for example on at least one guard bed based on zinc oxide ZnO, Cu/ZnO or active charcoal and makes it possible to achieve the specifications required in terms of impurities in the synthesis gas used in the Fischer-Tropsch synthesis step e).

Advantageously, at the outlet of step d8), the synthesis gas has a sulfur content of less than 100 ppb by volume, preferably less than 50 ppb by volume, more preferably less than 10 ppb by volume; an HCN content of less than 100 ppb by volume, preferably less than 50 ppb by volume, more preferably less than 10 ppb by volume and an NH_3 content of less than 100 ppm by volume, preferably less than 10 ppm by volume and more preferably less than 1 ppm by volume.

Preferably, step d) comprises, and preferably consists of, steps d1) and/or d2) and/or d3) and/or d4) and/or d5) and/or d6) and/or d7) and/or d8).

Step e) of Fischer-Tropsch synthesis catalytic reaction

The process according to the invention comprises a step e) of Fischer-Tropsch synthesis of the effluent obtained from the gasification step c) and optionally from the optional step d) of conditioning of the gaseous effluent comprising a synthesis gas, and preferably from the final purification step d8), said effluent comprising carbon monoxide (CO) and hydrogen is introduced into the Fischer-Tropsch synthesis step e) in the presence of all or some of the hydrogen obtained from the water electrolysis step b) in an optimum H_2/CO mole ratio for the Fischer-Tropsch reaction so as to produce a stream comprising synthetic liquid hydrocarbons and at least one gaseous effluent.

Advantageously, the Fischer-Tropsch synthesis step e) is performed with a mole ratio between carbon monoxide and hydrogen, denoted as H_2/CO , of between 0.5 and 4, preferably between 1 and 3, more preferably between 1.5 and 2.5 and very preferably equal to 2, the hydrogen originating from step d) of conditioning the synthesis gas and from the water electrolysis step b).

Step c) of gasification of the feedstock according to the invention such as that performed in the present invention may lead to a production of hydrogen and of carbon monoxide in an H_2/CO mole ratio that is not optimal for the Fischer-Tropsch reaction, particularly when the catalyst used is a cobalt-based catalyst which advantageously requires an optimum H_2/CO mole ratio of about 2 in order to be oriented toward the production of middle distillates.

Advantageously, all of the hydrogen obtained from the electrolysis step b) is used in the Fischer-Tropsch synthesis step e). Optionally, a supply of hydrogen may be necessary to have an optimum H_2/CO mole ratio for the Fischer-Tropsch reaction. In this case, said supply may be obtained from the optional carbon monoxide steam conversion step d3).

Advantageously, said optional carbon monoxide steam conversion step d3) may be performed at an absolute pressure of between 2 and 12 MPa, preferably between 2.5 and 6.0 MPa and more preferentially between 3.0 and 5.0 MPa; at an hourly space velocity HSV (volume of feedstock/volume of catalyst/hour) of between 1000 and 10 000 h^{-1} , preferably between 1000 and 9000 h^{-1} and more preferably between 1500 and 8500 h^{-1} ; at a temperature of between 150 and 550°C, preferably between 200 and 550°C and more preferably between 250 and 500°C.

The catalyst used in this carbon monoxide steam conversion step is a catalyst comprising at least one element from group VIII and/or at least one element from group VIB of the Mendeleev Periodic Table (group VIII corresponds to groups 8, 9 and 10, and group VIB to group 6 according to the new notation of the Periodic Table of the Elements: Handbook of Chemistry and Physics, 81st edition, 2000-2001). Preferably, the catalyst is a catalyst comprising sulfurized cobalt and/or sulfurized molybdenum. The support for the catalyst

is usually a porous solid chosen from the group consisting of aluminas, silica and silica-aluminas. Preferentially, the support for the catalyst is alumina. The catalyst used may be promoted with an alkali metal or alkaline-earth metal promoter. The carbon monoxide conversion reaction makes it possible to considerably increase the hydrogen content in the effluent sent into the Fischer-Tropsch synthesis step e).

Advantageously, the water formed during the Fischer-Tropsch synthesis step e) is partly or totally sent into the electrolysis step b). Recycling of the water formed in step e) into step b) makes it possible to reduce the operating costs of the process according to the invention.

In one embodiment, the water formed during the Fischer-Tropsch synthesis step e) advantageously undergoes a treatment step before being recycled into the water electrolysis step b) so as to obtain the required specifications of step b). The treatment step may advantageously consist in removing the oxygenated compounds from the water formed during step e).

The Fischer-Tropsch synthesis step e) is performed in a reaction unit comprising one or more suitable reactors, the technology of which is known to those skilled in the art. They may be, for example, multitubular fixed-bed reactors, or bubble-column reactors, also known as slurry bubble columns, or microchannel reactors.

According to a preferred embodiment of the invention, step e) involves one or more bubble-column reactors. As the synthesis is highly exothermic, this embodiment makes it possible, inter alia, to improve the heat control of the reactor and to create only small pressure losses.

The catalyst used in this Fischer-Tropsch synthesis step e) is generally any catalytic solid known to those skilled in the art for performing the Fischer-Tropsch synthesis. Preferably, the catalyst used in said step includes cobalt or iron, more preferably cobalt. The catalyst

used in step e) is generally a supported catalyst. The support may be, for example, based on alumina, silica or titanium.

The temperature and pressure conditions are variable and are adapted to the catalyst used in this step e). The absolute pressure is generally between 1.0 and 6.0 MPa, preferably between 1.5 and 3.5 MPa and preferentially between 2.0 and 3.0 MPa. The temperature may generally be between 170 and 280°C, preferably between 190 and 260°C and preferentially between 210 and 240°C.

10 According to one variant of the process of the invention, at least one gaseous fraction obtained from the Fischer-Tropsch synthesis (step e) is advantageously recycled into the gasification step c) so as to be converted into synthesis gas and thus to improve the mass yield of the process line.

15 In another configuration of the process according to the invention, the gaseous fraction obtained from the Fischer-Tropsch synthesis e) is advantageously at least partly sent into an independent synthesis gas production unit (for example POx: Partial oxidation, SMR: Steam Methane Reforming, ATR: Autothermal Reforming, EHTR: Enhanced Heat Transfer Reformer, etc.); this synthesis gas may be recycled into any point of the line
20 upstream of the gasification step c) and the hydrotreating and/or isomerization step f).

In another configuration of the process according to the invention, at least a portion of the gaseous fraction obtained from the Fischer-Tropsch synthesis step e) can at least partly feed with energy the drying operations a1) and/or the torrefaction operations a2) to
25 maximize the energy efficiency of the process line.

In another configuration of the process according to the invention, the gaseous fraction obtained from the Fischer-Tropsch synthesis step e) makes it possible to produce

electricity in a combined cycle which may be partially fed with the steam produced in steps c), d3) and e) to increase the energy efficiency of the process line.

These various configurations may be advantageously combined so as to optimize the economy of the integrated process line according to the invention.

Hydrotreating and/or isomerization step f)

The process of the invention advantageously comprises a step f) of hydrotreating and/or isomerization of at least a portion and preferably all of the stream comprising liquid hydrocarbons obtained from the Fischer-Tropsch synthesis step e).

Step f) is performed under common operating conditions known to those skilled in the art in the presence of hydrogen and is directed toward value-enhancing the hydrocarbon cuts obtained from step e) by the production of liquid hydrocarbons, in particular very high quality liquid biofuels, namely bio-naphtha, bio-gasoline, bio-kerosene, bio-gas oil and bio-lubricant bases.

The hydrogen required for performing step f) may advantageously be totally or partly obtained from the water electrolysis step b).

One possible option is the production of paraffinic cuts, base products for petrochemical processes, for example production of a C10-C13 cut intended for the production of (bio-)LAB (Linear Alkyl Benzene), or alternatively (bio-)waxes for various industrial applications.

BRIEF DESCRIPTION OF THE FIGURES

Description of the figures

Figure 1 illustrates the process of the invention according to claim 1 and including the step of isomerizing the effluent obtained from the process according to the invention.

The biomass is introduced into the pretreatment unit (A) via pipe 1 in which it undergoes a drying step a1), a torrefaction step a2) and/or a milling step a3).

- 5 The pretreated biomass is then sent via pipe 2 into a gasification step in a unit (C) as a mixture with the oxygen 11 produced during the water 10 electrolysis step which takes place in the water electrolysis unit (B).

The water used in the electrolysis unit (B) comes at least partly from the Fischer-Tropsch synthesis step performed in the unit (E).

- 10 During the water electrolysis step, a hydrogen stream is produced and sent via pipe 8 into the Fischer-Tropsch synthesis step upstream of the unit (E).

The step of gasification of the pretreated biomass which takes place in the unit (C) in the presence of the oxygen 11 obtained from the water electrolysis step makes it possible to produce a gaseous effluent comprising a synthesis gas which leaves the gasification unit

- 15 (C) via pipe 3 and is sent into an optional step d) for conditioning of the effluent comprising the synthesis gas which may comprise a step d1) of scrubbing with water and of fractionation of the synthesis gas and/or a step d2) of removing the halogenated compounds and/or a step d3) of steam conversion of the carbon monoxide and/or a step d4) of catalytic hydrolysis of the compounds COS and HCN and/or a step d5) of recombination of the effluents and/or a step d6) of scrubbing with water of the recombined effluent and/or a step d7) of removing the acidic gases and/or a step d8) of final purification of the effluent comprising the synthesis gas.

- 20 The effluent comprising the optionally purified synthesis gas is then sent via pipe 5 into a Fischer-Tropsch synthesis step which takes place in the unit (E) in the presence of at least a portion of the hydrogen stream 8 produced during the water electrolysis step. A stream 6 comprising synthetic liquid hydrocarbons is produced during the Fischer-Tropsch synthesis step and may be sent into a hydrotreating and/or isomerization step f) not shown in the figure.

Figure 2 illustrates the process according to comparative example 1. The description of the process is given in example 1.

5 **EXAMPLES**

Example 1 (comparative)

Example 1 reproduces the process described in patent application WO 2014/058253, comprising the following steps:

- a step of pretreatment by torrefaction;
- 10 a step of air separation to produce an oxygen stream;
- a step of entrained flow gasification;
- a step of steam conversion of the carbon monoxide;
- a step of removal of the acidic gases and of final purification;
- a step of Fischer-Tropsch synthesis.
- 15 The process according to example 1 is comparative in that it does not involve a water electrolysis step. The process performed in comparative example 1 is represented in figure 2.

Example 1 processes 100 t/h of dry biomass introduced into the pretreatment step via
20 pipe 1. The torrefied lignocellulosic biomass at the outlet of the pretreatment unit A via pipe 2 contains 50% by weight of carbon and 40% of oxygen.

The torrefied biomass 2 is then introduced into a gasification unit C in the presence of an oxygen stream 7 produced in an air separation unit (B).

The gasification unit produces, on a molar basis, three times as much CO as CO₂, i.e.
25 an amount of 67.4 t/h. The H₂/CO ratio at the outlet of the gasification unit is 0.5.

At the outlet of the gasification unit C, an effluent comprising synthesis gas 3 is produced and sent into a carbon monoxide steam conversion unit D. The carbon monoxide steam conversion unit makes it possible to increase the ratio from 0.5 to 2.

The effluent 4 leaving the carbon monoxide steam conversion unit is then sent into a unit (D') comprising a step of removing the acidic gases from the effluent comprising the synthesis gas and a step of final purification of said effluent.

5 The effluent comprising the purified synthesis gas 5 is then sent into a Fischer-Tropsch synthesis unit E to produce a stream comprising liquid hydrocarbons 6.

The various steps of the process below resulting in the reduction of the carbon yield are:
the torrefaction step with a 23% loss of carbon;

the gasification step with a further 19% loss of carbon;

10 the carbon monoxide steam conversion step with a further 29% loss of carbon.

The carbon loss is calculated according to the following formula: $(C_{inlet} - C_{outlet}) / C_{inlet} * 100$

The overall carbon yield of the line is thus 29% by weight, i.e. a total material yield of 17% by weight.

15 The overall carbon yield is calculated according to the following formula: $(C_{biomass} - C_{effluentFT}) / C_{biomass} * 100$.

The material yield is calculated according to the following formula: $(Q_{biomass} - Q_{effluentFT}) / Q_{biomass} * 100$, Q being the flow rate.

20 The CO₂ is mainly produced in the following two steps:

the gasification step representing 35.3 t/h,

the carbon monoxide steam conversion step for a flow rate of 88.2 t/h.

These emissions do not take into account the CO₂ emitted for the production of the utilities.

25

The amount of oxygen required to provide the energy to the gasification step is 46 t/h.

The Fischer-Tropsch synthesis step makes it possible to produce a synthetic liquid hydrocarbon effluent representing 17 t/h.

30 **Example 2 (according to the invention)**

Example 2 reproduces a process according to the invention represented in figure 1 and comprising the following steps:

a step a) of pretreatment by torrefaction;

a step b) of alkaline water electrolysis;

5 a c) step of entrained flow gasification;

a step d) of conditioning the synthesis gas;

a step e) of Fischer-Tropsch synthesis.

The process of example 2 according to the invention differs from that of example 1 in that it involves a step of water electrolysis rather than of carbon monoxide steam conversion.

10 Example 2 processes 100 t/h of dry biomass via pipe 1 in a torrefaction unit (A). The torrefied lignocellulosic biomass 2 contains 50% by weight of carbon and 40% of oxygen. The torrefied biomass is then sent into a gasification unit C in the presence of an oxygen stream 11 produced in the water 10 electrolysis unit (B).

15 As in example 1, the gasification unit produces, on a molar basis, three times as much CO as CO₂, i.e. an amount of CO of 67.4 t/h. The H₂/CO ratio at the outlet of the unit is 0.5. In this example, the H₂/CO ratio is increased from 0.5 to 2 by a supply of external hydrogen produced by alkaline electrolysis.

20 The amount of hydrogen required is 7.2 t/h. To produce such an amount of hydrogen, oxygen, the electrolysis co-product, is produced in an amount of 58 t/h. This flow rate is higher than the flow rate required for the gasification step (46 t/h, see the preceding example).

25 An effluent comprising synthesis gas 3 is produced at the outlet of the gasification unit C and sent into a synthesis gas conditioning unit D to produce a purified effluent 5 which is then sent into a Fischer-Tropsch synthesis unit E in the presence of a stream 6 of hydrogen produced in the water electrolysis unit B.

The various steps of the process resulting in the reduction of the carbon yield are:

the torrefaction step with a 23% loss of carbon;

the gasification step with a further 19% loss of carbon.

The overall carbon yield of the line is thus 58% by weight, i.e. a total material yield of 34%
5 by weight.

The Fischer-Tropsch synthesis step produces about 43 t/h of water, i.e. 66% of the water
need of the electrolysis step and a synthetic liquid hydrocarbon effluent representing
34 t/h.

10 The amount of CO₂ emitted into the atmosphere is mainly derived from the gasification
step, i.e. 35.3 t/h. The CO₂ emissions emitted by the process are reduced by 70% relative
to the reference scheme and the water consumption is reduced by 2/3 relative to the
consumption required for the electrolyzer, markedly improving the environmental balance
15 of the channel.

Relative to example 1, the process according to the invention makes it possible:

to increase by 100% the amount of synthetic hydrocarbons obtained on conclusion of the
Fischer-Tropsch synthesis step,

20 to reduce the CO₂ emissions of the process by 85%,

to reduce the water consumption by 2/3 relative to the consumption required for the
electrolyzer.

Thus, the process according to the invention makes it possible to markedly improve the
25 environmental balance of the channel and to limit the operating cost of the process.

CLAIMS

1. A process for converting a feedstock comprising at least one biomass fraction into hydrocarbons, said process comprising
 - 5 - a step a) of pretreating the feedstock,
 - a step b) of electrolysis of water into oxygen and hydrogen, for the production of a hydrogen stream and an oxygen stream, in which the water is obtained, at least partly, from a Fischer-Tropsch synthesis step e),
 - a step c) of gasification of the feedstock pretreated in step a), in the presence of
 - 10 all or part of the oxygen stream obtained from the water electrolysis step b) so as to obtain a gaseous effluent comprising a synthesis gas,
 - an optional step d) of conditioning the gaseous effluent comprising a synthesis gas obtained from step c) so as to obtain a gaseous effluent comprising a purified synthesis gas,
 - 15 - a step e) of Fischer-Tropsch synthesis of the gaseous effluent obtained from step c) or optionally from step d) in the presence of all or part of the hydrogen obtained from the water electrolysis step b) so as to produce a stream comprising synthetic liquid hydrocarbons and at least one gaseous effluent.
- 20 2. The process as claimed in claim 1, in which the pretreatment step a) comprises at least one from among the operations of drying a1), torrefaction a2) or milling a3).
3. The process as claimed in claim 1, in which the mole ratio between the hydrogen and the carbon monoxide, denoted as H_2/CO , of the effluent introduced into the Fischer-Tropsch synthesis step e) is between 0.5 and 4, preferably between 1 and 3, more
 - 25 preferably between 1.5 and 2.5 and very preferably equal to 2, the hydrogen originating from step d) of conditioning the synthesis gas and from the water electrolysis step b).
4. The process as claimed in any one of the preceding claims, in which the electrolysis step b) is performed by alkaline electrolysis, by proton exchange membrane, by anion exchange membrane or by solid oxide electrolysis.

5. The process as claimed in any one of the preceding claims, in which an oxygen stream originating from an air separation step may also be used in the gasification step c), in addition to the oxygen stream derived from the water electrolysis step b).
6. The process as claimed in any one of claims 1 to 5, in which the all of the oxygen
5 introduced into the gasification step c) is obtained from the water electrolysis step b).
7. The process as claimed in any one of the preceding claims, in which step d) comprises, and preferably consists of, the steps d1) of scrubbing with water and fractionation of the synthesis gas and/or d2) of removing the halogenated compounds and/or d3) of carbon monoxide steam conversion and/or d4) of catalytic hydrolysis of the compounds COS and
10 HCN and/or d5) of recombination and/or d6) of scrubbing with water of the recombined effluent and/or d7) of removing the acidic gases and/or d8) of final purification.
8. The process as claimed in any one of the preceding claims, in which the water formed during the Fischer-Tropsch synthesis step e) is partly or totally sent into the electrolysis step b).
- 15 9. The process as claimed in any one of the preceding claims, in which at least a portion of the gaseous fraction obtained from the Fischer-Tropsch synthesis step e) is recycled into the gasification step c) so as to be converted into synthesis gas.
10. The process as claimed in any one of claims 1 to 8, in which at least a portion of the gaseous fraction obtained from the Fischer-Tropsch synthesis step e) can at least partly
20 feed with energy the drying operations a1) and/or the torrefaction operations a2).
11. The process as claimed in any one of the preceding claims, in which the Fischer-Tropsch synthesis step e) is followed by a step f) of hydrotreating and/or isomerization of the hydrocarbon cuts obtained from step e).