

PROCESSES AND SYSTEMS FOR SEPARATING LIQUIFIED NATURAL GAS**CROSS-REFERENCE TO RELATED APPLICATION**

[0001] This application claims priority to and the benefit of U.S. Provisional Application No. 63/145,645 having a filing date of February 04, 2021, the disclosure of which is incorporated herein by reference in its entirety.

FIELD

[0002] This disclosure relates to processes and systems for separating a liquefied natural gas (“LNG”) composition. Particularly, this disclosure relates to processes and systems for separating an LNG stream comprising, in addition to methane, ethane and optionally heavier hydrocarbons, using distillation.

BACKGROUND

[0003] Natural gas (“NG”) as produced from a production field can comprise various quantities (e.g., over 20 mol%, based on the total moles of the hydrocarbons in the NG) of C₂+ hydrocarbons (also known as natural gas liquids (“NGLs”) such as ethane, propane, and the like, in addition to the predominant hydrocarbon - methane. The global, long-distance transportation of natural gas from its production site to its use market can include: pipeline transportation from the production site to an exporting port; refrigeration and liquefaction at the exporting port to form LNG; loading the LNG into an LNG transportation vessel; moving the vessel to the destination importing port; and unloading the LNG from the vessel to local storage at the port. The unloaded LNG can be vaporized and used directly as a fuel. However, due to presence of NGLs, especially if at a high concentration, the heating value of the LNG may be too high for the LNG to be acceptable as certain specific fuel, e.g., fuel supplied in certain NG delivery network for residential use. One solution to this problem is to blend in an amount of inert gas such as N₂ into the LNG to form a mixture with lower heat value, which is then fed into the NG delivery network. Combustion of an N₂-containing NG stream can result in the undesirable NO_x. Thus, it has been proposed to separate the LNG, by distillation, to form an NG stream comprising less NGLs and one or more NGL streams at the receiving port. The hitherto proposed separation processes utilizes sea water at least partly as a heat source, and the chilled sea water is typically disposed of into the sea, resulting in significant waste of energy spent at the exporting port and on the vessel to refrigerate and liquefy the NG, which translates to large quantity of carbon emissions for the overall LNG transportation process. Moreover, the known separation processes tend to be very complex, costly to construct and costly to operate.

[0004] There is clearly a need for more energy efficient processes and systems for separating an LNG. This disclosure satisfies this and other needs.

SUMMARY

[0005] This disclosure proposes simplified and energy efficient processes and systems for separating an LNG stream comprising methane and C2+ hydrocarbons. The processes and systems, if integrated with a petroleum refinery, a petrochemical production plant, a chemical plant, and the like, can achieve tremendous energy and material synergies.

[0006] A first aspect of this disclosure provides a process for separating an LNG stream, the process comprising one or more of: (I) providing an LNG stream comprising methane, ethane, and optionally C3+ hydrocarbons having a temperature ≤ -80 °C, and an absolute pressure of ≥ 500 kPa-a; (II) feeding the LNG stream into a distillation column at the top-most ideal stage of the distillation column; (III) supplying heat to the distillation column; (IV) obtaining an overhead stream from the distillation column comprising methane at a concentration ≥ 70 wt%, based on the total weight of the hydrocarbons in the overhead stream, without using an overhead compressor, an overhead condenser, and an overhead reflux stream; and (V) obtaining a bottoms stream from the distillation column comprising C2+ hydrocarbons and from 0.01 to 10 wt% methane, based on the total weight of the bottoms stream.

[0007] A second aspect of this disclosure provides a process for separating an LNG stream, the process comprising one or more of: (i) providing an LNG stream comprising methane, ethane, and optionally C3+ hydrocarbons having a temperature ≤ -80 °C and an absolute pressure of ≥ 500 kPa-a; (ii) heating the LNG stream to obtain a vapor-liquid mixture feed stream; (iii) feeding the vapor-liquid mixture feed stream into a distillation column comprising 2 to 20 ideal stages; (iv) obtaining a first overhead vapor stream from the distillation column comprising methane at a concentration ≥ 70 wt%, based on the total weight of the hydrocarbons in the overhead stream; (v) condensing at least a portion of the first overhead vapor stream, without compressing the first overhead vapor stream, to obtain a vapor-liquid mixture overhead stream; (vi) separating the vapor-liquid mixture overhead stream to obtain a liquid reflux stream and a second vapor overhead stream; (vii) feeding at least a portion of the liquid reflux stream into the distillation column as a reflux stream; (viii) providing heat to the distillation column; and (ix) obtaining a bottoms stream from the distillation column comprising C2+ hydrocarbons and from 0.1 wt% to 10 wt% methane.

[0008] A third aspect of this disclosure provides a process for separating an LNG stream, the process comprising one or more of: (1) providing an vapor-liquid mixture LNG stream comprising methane, ethane, and optionally C3+ hydrocarbons having a temperature ≤ -80 °C

and an absolute pressure of ≥ 500 kPa-a; (2) feeding the vapor-liquid mixture LNG stream into a flashing drum; (3) obtaining an flashing drum overhead vapor effluent rich in methane and a flashing drum bottoms liquid effluent rich in ethane, wherein the flashing drum bottoms liquid effluent constitutes ≤ 50 wt% of the vapor-liquid mixture LNG stream; and (4) separating the flashing drum bottoms liquid effluent in a distillation column.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a schematic illustration of a process in the prior art for separating an LNG stream to produce an NG stream and a C2+ hydrocarbon-rich stream.

[0010] FIGs. 2, 3, and 4 are schematic illustrations of exemplary processes according to various aspects and embodiments of this disclosure.

DETAILED DESCRIPTION

[0011] Various specific embodiments, versions and examples of the invention will now be described, including preferred embodiments and definitions that are adopted herein for purposes of understanding the claimed invention. While the following detailed description gives specific preferred embodiments, those skilled in the art will appreciate that these embodiments are exemplary only, and that the invention may be practiced in other ways. For purposes of determining infringement, the scope of the invention will refer to any one or more of the appended claims, including their equivalents, and elements or limitations that are equivalent to those that are recited. Any reference to the “invention” may refer to one or more, but not necessarily all, of the inventions defined by the claims.

[0012] In this disclosure, a process is described as comprising at least one “step.” It should be understood that each step is an action or operation that may be carried out once or multiple times in the process, in a continuous or discontinuous fashion. Unless specified to the contrary or the context clearly indicates otherwise, multiple steps in a process may be conducted sequentially in the order as they are listed, with or without overlapping with one or more other steps, or in any other order, as the case may be. In addition, one or more or even all steps may be conducted simultaneously with regard to the same as or different batch of material. For example, in a continuous process, while a first step in a process is being conducted with respect to a raw material just fed into the beginning of the process, a second step may be carried out simultaneously with respect to an intermediate material resulting from treating the raw materials fed into the process at an earlier time in the first step. Preferably, the steps are conducted in the order described.

[0013] Unless otherwise indicated, all numbers indicating quantities in this disclosure are to be understood as being modified by the term “about” in all instances. It should also be

understood that the precise numerical values used in the specification and claims constitute specific embodiments. Efforts have been made to ensure the accuracy of the data in the examples. However, it should be understood that any measured data inherently contains a certain level of error due to the limitation of the technique and/or equipment used for making the measurement.

[0014] Certain embodiments and features are described herein using a set of numerical upper limits and a set of numerical lower limits. It should be appreciated that ranges including the combination of any two values, *e.g.*, the combination of any lower value with any upper value, the combination of any two lower values, and/or the combination of any two upper values are contemplated unless otherwise indicated.

[0015] As used herein, the indefinite article “a” or “an” shall mean “at least one” unless specified to the contrary or the context clearly indicates otherwise. Thus, embodiments using “an alkyne converter” include embodiments where one, two or more alkyne converters are used, unless specified to the contrary or the context clearly indicates that only one alkyne converter is used.

[0016] The term “hydrocarbon” as used herein means (i) any compound consisting of hydrogen and carbon atoms or (ii) any mixture of two or more such compounds in (i). The term “C_n hydrocarbon,” where n is a positive integer, means (i) any hydrocarbon compound comprising carbon atom(s) in its molecule at the total number of n, or (ii) any mixture of two or more such hydrocarbon compounds in (i). Thus, a C₂ hydrocarbon can be ethane, ethylene, acetylene, or mixtures of at least two of these compounds at any proportion. A “C_m to C_n hydrocarbon” or “C_m-C_n hydrocarbon,” where m and n are positive integers and m < n, means any of C_m, C_{m+1}, C_{m+2}, ..., C_{n-1}, C_n hydrocarbons, or any mixtures of two or more thereof. Thus, a “C₁ to C₃ hydrocarbon” or “C₁-C₃ hydrocarbon” can be any of methane, ethane, ethylene, acetylene, propane, propylene, methylacetylene, propadiene, cyclopropane, and any mixtures of two or more thereof at any proportion between and among the components. A “saturated C₂-C₃ hydrocarbon” can be ethane, propane, cyclopropane, or any mixture of two or more thereof at any proportion. A “C_n+ hydrocarbon” means (i) any hydrocarbon compound comprising carbon atom(s) in its molecule at the total number of at least n, or (ii) any mixture of two or more such hydrocarbon compounds in (i). A “C_n- hydrocarbon” means (i) any hydrocarbon compound comprising carbon atoms in its molecule at the total number of at most n, or (ii) any mixture of two or more such hydrocarbon compounds in (i). A “C_m hydrocarbon stream” means a hydrocarbon stream consisting essentially of C_m hydrocarbon(s). A “C_m-C_n

hydrocarbon stream” or “C_m to C_n hydrocarbon stream” means a hydrocarbon stream consisting essentially of C_m-C_n hydrocarbon(s).

[0017] The term “crude” as used herein means whole crude oil as it flows from a wellhead, a production field facility, a transportation facility, or other initial field processing facility, optionally including crude that has been processed by a step of desalting, treating, and/or other steps as may be necessary to render it acceptable for conventional distillation in a refinery. Crude, as used herein, is presumed to contain resid. The term “crude fraction”, as used herein, means a hydrocarbon fraction obtained via the fractionation of crude.

[0018] The term “olefin product” as used herein means a product that includes an alkene, preferably a product consisting essentially of one or more alkenes. An olefin product in the meaning of this disclosure can be, for example, an ethylene stream, a propylene stream, a butylene stream, an ethylene/propylene mixture stream, and the like.

[0019] The term “consisting essentially of” as used herein means the composition, feed, effluent, product, or stream includes a given component at a concentration of at least 60 mol%, preferably at least 70 mol%, more preferably at least 80 mol%, more preferably at least 90 mol%, still more preferably at least 95 mol%, based on the total weight of the composition, feed, effluent, product, or other stream in question.

[0020] The term “rich” when used in phrases such as “X-rich” or “rich in X” means, with respect to an outgoing stream obtained from a device, that the stream comprises material X at a concentration higher than in the feed material fed to the same device from which the stream is derived.

[0021] The term “ideal stage” means a hypothetical zone or stage in a distillation column in which a liquid phase and a vapor phase reaches an equilibrium.

[0022] The term “LNG” means liquefied natural gas; “NGL” means natural gas liquids; and “NG” means natural gas. An NG consists essentially of methane. An NGL consists essentially of C₂+ hydrocarbons. An LNG comprises methane and optionally C₂+ hydrocarbons. An LNG comprising both methane and NGL can be separated to obtain an NG fraction and an NGL fraction.

[0023] As used herein, “wt%” means percentage by weight, “vol%” means percentage by volume, “mol%” means percentage by mole, “ppm” means parts per million, and “ppm wt” “wppm”, and “ppm by weight” are used interchangeably to mean parts per million on a weight basis. All concentrations herein are expressed on the basis of the total amount of the composition in question, unless specified otherwise. Thus, the concentrations of the various components of the “feed mixture” are expressed based on the total weight of the feed mixture.

All ranges expressed herein should include both end points as two specific embodiments unless specified or indicated to the contrary.

[0024] As used herein, “kPa-a” means absolute pressure in kilopascal; and “kPa-g” means gauge pressure in kilopascal.

[0025] Nomenclature of elements and groups thereof used herein are pursuant to the Periodic Table used by the International Union of Pure and Applied Chemistry after 1988. An example of the Periodic Table is shown in the inner page of the front cover of Advanced Inorganic Chemistry, 6th Edition, by F. Albert Cotton et al. (John Wiley & Sons, Inc., 1999).

[0026] This disclosure proposes simplified and energy efficient processes and systems for separating an LNG stream comprising methane and C2+ hydrocarbons. The processes and systems, if integrated with a petroleum refinery, a petrochemical production plant, a chemical plant, and the like, can achieve tremendous energy and material synergies.

[0027] The LNG stream can comprise any LNG that may be transported from one port to another. The LNG stream comprises methane, preferably at a concentration thereof ≥ 50 mol% (e.g., $\geq 55, 60, 65, 70, 75, 80, 85, 90, 95, 96, 97, 98$ mol%), based on the total moles in the LNG stream. The LNG comprises ethane, preferably at a concentration thereof ≥ 1 mol% (e.g., $\geq 2, 3, 4, 5, 6, 7, 8, 9, 10$ mol%) and ≤ 12 mol% (e.g., $\leq 11, 10, 9, 8, 7, 6, 5, 4$ mol%), based on the total moles in the LNG stream. The LNG may further comprise C3+ hydrocarbons, preferably at a concentration in total thereof ≤ 5 mol% (e.g., $\leq 4, 3, 2, 1, 0.5, 0.2$ mol%), based on the total moles in the LNG stream. The LNG may further comprise non-hydrocarbon molecules such as N₂, preferably at a total concentration thereof ≤ 10 mol% (e.g., $\leq 9, 8, 7, 6, 5, 4, 3, 2, 1, 0.8, 0.6, 0.5, 0.4, 0.2, 0.1$ mol%), based on the total moles in the LNG stream.

[0028] The LNG is preferably a liquid stream. The LNG may be a liquid/vapor mixture stream. For example, the LNG may comprise vapor at a total concentration thereof ≤ 10 mol% (e.g., $\leq 9, 8, 7, 6, 5, 4, 3, 2, 1, 0.8, 0.6, 0.5, 0.4, 0.2, 0.1$ mol%), based on the total moles in the LNG stream.

[0029] The LNG stream can be drawn from an LNG vessel or a LNG storage, of a mixture of multiple streams drawn from different sources. The LNG stream can have a temperature varying in a large range. Preferably, the LNG stream has a temperature $\leq -80^\circ\text{C}$ (e.g., $\leq -90, -100, -110, -120, -130, -140, -150^\circ\text{C}$). Preferably, the LNG stream has a temperature $\geq -180^\circ\text{C}$ (e.g., $\geq -170, -160, -150, -140, -130, -120, -110, -100^\circ\text{C}$). The LNG stream can be a low-temperature stream drawn from a vessel and/or a storage which has been optionally heated by a heating source. In general, it is highly desirable that the LNG stream has a temperature no

higher than its bubble point in embodiments of the process of the first and second aspects of this disclosure.

[0030] In certain embodiments of the various aspects of this disclosure, the LNG stream may be provided by pumping a precursor LNG stream having a pressure from atmospheric pressure to 300 kPa-a and a temperature from -160 to -80 °C.

The Processes of the First Aspect of This Disclosure

[0031] The process according to the first aspect of this disclosure for separating an LNG stream can comprise one or more of: (I) providing an LNG stream comprising methane, ethane, and optionally C3+ hydrocarbons having a temperature ≤ 80 °C, and an absolute pressure of ≥ 500 kPa-a; (II) feeding the LNG stream into a distillation column at the top-most ideal stage of the distillation column; (III) supplying heat to the distillation column; (IV) obtaining an overhead stream from the distillation column comprising methane at a concentration ≥ 70 wt%, based on the total weight of the hydrocarbons in the overhead stream, without using an overhead compressor, an overhead condenser, and an overhead reflux stream; and (V) obtaining a bottoms stream from the distillation column comprising C2+ hydrocarbons and from 0.01 to 10 wt% methane, based on the total weight of the bottoms stream.

[0032] In certain embodiments of the processes of the first aspect, the distillation column can have 2 to 20 (e.g., 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or 20) ideal stages. More stages can result in better separation, but requires taller column and are more expensive to build. Preferably, the distillation column has 5 to 15, preferably 8 to 12, preferably 9 to 11 ideal stages.

[0033] In various embodiments of the processes of the first aspect, the LNG stream as fed into the distillation column has a pressure $\geq 2,000$ kPa-a (e.g., $\geq 3,000$ kPa-a, $\geq 4,000$ kPa-a, $\geq 5,000$ kPa-a). The LNG stream can have a pressure $\leq 11,000$ kPa-a (e.g., $\leq 10,000$ kPa-a; $\leq 8,000$ kPa-a, $\leq 6,000$ kPa-a, $\leq 5,000$ kPa-a, $\leq 4,000$ kPa-a). Such relatively high pressure of the LNG can enable the direct supply of the NG stream produced from the top of the distillation column into a natural gas delivery network without further compression.

[0034] In various embodiments of the processes of the first aspect, the LNG stream as fed into the distillation column has a pressure from 500 to 1,500 kPa-a (e.g., 600 to 1,200 kPa-a, or 800 to 1,000 kPa-a). In such case, the overhead stream, having similar pressure, can be directly fed into an industrial fuel system, e.g., the fuel system of a steam cracker furnaces.

[0035] In various embodiments of the processes of the first aspect, the process further comprises (VI) heating the overhead stream to obtain a superheated natural gas stream; and (VII) supplying the superheated natural gas stream to a natural gas delivery network without

further compression or a fuel system. It is highly desirable that the overhead stream, when supplied to the natural gas network or its end use in a fuel system, it is superheated such that no condensation may form in the supply line. Such heating can be advantageously effected by using a first heat source having a relatively low temperature, e.g., a temperature ≤ 150 °C (e.g., $\leq 140, 120, 100, 90, 80, 70, 60, 50, 40$ °C), preferably via a first heat exchanger. The first heat source can have a temperature ≥ 30 °C (e.g., $\geq 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100$ °C). As a result of the heating, the superheated natural gas stream can have a temperature ≥ 5 °C (e.g., $\geq 6, 7, 8, 9, 10, 12, 14, 15, 16, 18, 20, 22, 24, 25$ °C). Preferably the superheated natural gas stream has a temperature close to ambient temperature to facilitate delivery in a pipeline. Preferably the first heat source is an industrial stream in need of cooling. One example of the first heat source is a warm cooling water stream having a temperature higher than the overhead stream. Upon cooling by the overhead stream, the cooling water stream, with or without additional cooling, can be used to cool down another process stream in need of cooling. Another example of the first heat source is steam condensate produced in any industrial processes. Still another example of the first heat source is an excess low pressure steam stream. The overhead stream can cool down the excess low pressure steam stream to obtain a steam condensate. Yet another example of the first heat source is a heat medium that comprises at least a portion thereof a heat medium used in a heat exchanger other than the heat exchanger used the relevant step (VI). Thus, the heat medium exiting another heat exchanger, or a mixture of the heat media exiting two or more other heat exchangers, may be combined and used as the heat source. Any combination or mixture of two or more of the exemplary first heat sources described above in this paragraph may be used the first heat source to heat the overhead stream. Such first heat sources can be readily available in petroleum refineries, petrochemical production plants, chemical production plants, and the like. By using such low-temperature heat sources, which are in need of cooling, to heat the overhead stream, the “cold energy” stored in the overhead stream can be advantageously captured and utilized in useful industrial processes, achieving a high degree of energy efficiency.

[0036] In various embodiments of the processes of the first aspect, the process can further comprise (VI') heating the overhead stream to obtain an un-superheated heated natural gas stream having an absolute pressure ≥ 200 kPa-a; (VII') compressing without after-cooling the un-superheated heated natural gas stream to obtain a compressed superheated natural gas stream having an absolute pressure ≥ 400 kPa-a; and (VII'') supplying without further compression the compressed superheated natural gas stream to a natural gas delivery network and/or an industrial fuel system. Such heating can be advantageously effected by using a second

heat source having a relatively low temperature, e.g., a temperature ≤ 150 °C (e.g., $\leq 140, 120, 100, 90, 80, 70, 60, 50, 40$ °C), preferably via a first heat exchanger. The second heat source can have a temperature ≥ 30 °C (e.g., $\geq 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100$ °C). As a result of the heating and compression, the compressed superheated natural gas stream can have a temperature ≥ 5 °C (e.g., $\geq 6, 7, 8, 9, 10, 12, 14, 15, 16, 18, 20, 22, 24, 25$ °C). Any of the first heat source described in the preceding paragraph may be advantageously used as the second heat source.

[0037] In various embodiments of the processes of the first aspect of this disclosure, step (III) can comprise: (IIIa) drawing a recycle stream from the distillation column; (IIIb) heating the recycle stream by using a third heat source having a temperature ≤ 150 °C (e.g., $\leq 140, 120, 100, 90, 80, 70, 60, 50, 40$ °C), preferably via a second heat exchanger; and (IIIc) feeding at least a portion of the heated recycle stream obtained from step (IIIb) into the distillation column. The recycle stream can be a side stream drawn from the side of the distillation column. Alternatively, the recycle stream is a split stream from the bottom stream. The third heat source can have a temperature ≥ 30 °C (e.g., $\geq 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100$ °C). Any of the first heat source described in the earlier paragraph may be advantageously used as the third heat source.

[0038] In various embodiments of the processes of the first aspect of this disclosure, the process can further comprise (VIII) heating at least a portion of the bottoms stream using a fourth heat source to obtain a heated bottoms stream, preferably via a third heat exchanger; and (IX) conducting away the heated bottoms stream. Any of the first heat source described in the earlier paragraph may be advantageously used the fourth heat source.

[0039] In various embodiments of the processes of the first aspect of this disclosure, the process can further comprise: (X) supplying at least a portion of the bottoms stream to one or more of the following: (a) a pyrolysis reactor, preferably a steam cracker; (b) a dehydrogenation reactor; (c) a separation column; and (d) an LPG blending stage for blending with another hydrocarbon stream. The C₂+ hydrocarbons in the bottoms stream can be advantageously converted into more valuable chemicals such as olefins by pyrolysis such as steam cracking or dehydrogenation. By further separation and/or blending with other streams, more valuable products may be produced. In embodiments where the bottoms stream or a portion thereof is fed into a pyrolysis reactor (e.g., a steam cracker) and cracked for making products such as olefins, the bottoms stream can comprise, e.g., 0.1 to 5 mol% of methane. Thus a high-degree of separation of methane and C₂+ hydrocarbons is not required in the process, which makes it

possible to utilize a relatively inexpensive and relatively short distillation column having, e.g., < 10 (e.g., 2-8, 2-6, 3-5) ideal stages.

[0040] In one particularly advantageous embodiment, an LNG receiving port is located in proximity to one or more of a petroleum refining plant, a petrochemical production plant, a chemical production plant, and the like, so that convenient heat integration utilizing the first, second, third, or fourth heat sources described above available from the plants can be implemented, and at least one of the overhead stream and the bottoms stream can be supplied to the plants as raw materials for producing value-added products.

[0041] The processes of the first aspect of this disclosure is simpler than those available in the prior art, particularly in that no overhead compressor, no overhead condenser, and no overhead reflux system is need to process the overhead stream from the distillation column. Processes in the prior art, on the contrary, typically require the use of all three. Traditional LNG distillation processes thus involve vaporization of LNG, compression of the overhead vapor, and refrigeration to condense the overhead vapor, which, taken together, is very expensive to build and operate. Moreover, a great majority of traditional LNG ports are located on the sea shore, where warm sea water is routinely used as the heating source. The sea water after being cooled by the LNG stream is routinely discharged directly into the sea. Since the low temperature of the LNG was achieved by expensing considerable amount of energy at the exporting port and on the transportation vessel, such processing using sea water results in waste of enormous amount of energy. The processes of the first aspect of this disclosure, if integrated with other industrial processes as discussed above, can capture and utilize the “cold energy” stored in the LNG and various hydrocarbon streams, resulting in much higher energy efficiency and a much lower carbon dioxide emission.

The Processes of the Second Aspect of This Disclosure

[0042] The process according to the second aspect of this disclosure for separating an LNG stream can comprise one or more of: (i) providing an LNG stream comprising methane, ethane, and optionally C3+ hydrocarbons having a temperature ≤ -80 °C and an absolute pressure of ≥ 500 kPa-a; (ii) heating the LNG stream to obtain a vapor-liquid mixture feed stream; (iii) feeding the vapor-liquid mixture feed stream into a distillation column comprising 2 to 20 ideal stages; (iv) obtaining a first overhead vapor stream from the distillation column comprising methane at a concentration ≥ 70 wt%, based on the total weight of the hydrocarbons in the overhead stream; (v) condensing at least a portion of the first overhead vapor stream, without compressing the first overhead vapor stream, to obtain a vapor-liquid mixture overhead stream; (vi) separating the vapor-liquid mixture overhead stream to obtain a liquid reflux stream and a

second vapor overhead stream; (vii) feeding at least a portion of the liquid reflux stream into the distillation column as a reflux stream; (viii) providing heat to the distillation column; and (ix) obtaining a bottoms stream from the distillation column comprising C2+ hydrocarbons and from 0.1 wt% to 10 wt% methane.

[0043] In preferred embodiments of the processes of the second aspect, step (ii) comprises: (iia) heating the LNG stream or a portion thereof by indirectly exchanging heat with at least a portion of the first overhead vapor stream; and step (v) comprises: (va) cooling the first overhead vapor stream or a portion thereof by indirectly exchanging heat with at least a portion of the LNG stream. Alternatively or additionally, the LNG stream may be heated by a heat source preferably via a heat exchanger, preferably any of the first, second, third, or fourth heat source described above in connection with the processes of the first aspect of this disclosure.

[0044] The second vapor overhead stream in the processes of the second aspect may be processed and used in the same or similar manners as for the overhead stream in the processes of the first aspect of this disclosure described above.

[0045] The bottoms stream in the processes of the second aspect may be processed and used in the same or similar manners as for the overhead stream in the processes of the first aspect of this disclosure described above.

[0046] The operation of the distillation column in the processes of the second aspect may be similar to that of the distillation column in the processes of the first aspect described above.

[0047] Similar to the processes of the first aspect, the processes of the second aspect may be advantageously integrated with other industrial processes to achieve a high degree of energy efficiency and synergy in material supply.

[0048] Compared to the processes of the first aspect of this disclosure, the processes of the second aspect are slightly more complex, but they can achieve a higher degree of separation of NG from NGLs. Compared to the processes in the prior art, the processes of the second aspect are nonetheless simpler and less complex. Similar to the processes of the first aspect, if integrated with other industrial processes, the processes of the second aspect can achieve much higher energy efficiency and a much smaller carbon dioxide emission.

The Processes of the Third Aspect of This Disclosure

[0049] The processes of the third aspect of this disclosure can include one or more of the following: (1) providing an vapor-liquid mixture LNG stream comprising methane, ethane, and optionally C3+ hydrocarbons having a temperature ≤ -80 °C and an absolute pressure of ≥ 500 kPa-a; (2) feeding the vapor-liquid mixture LNG stream into a flashing drum; (3) obtaining a flashing drum overhead vapor effluent rich in methane and a flashing drum bottoms liquid

effluent rich in ethane, wherein the flashing drum bottoms liquid effluent constitutes ≤ 50 wt% of the vapor-liquid mixture LNG stream; and (4) separating the flashing drum bottoms liquid effluent in a distillation column.

[0050] In various embodiments of the processes of the third aspect of this disclosure, step (1) can comprise: (1a) providing a precursor LNG stream having a temperature ≤ -80 °C; and (1b) heating the precursor LNG stream to obtain the vapor-liquid mixture LNG stream. Preferably, step (1b) comprises indirectly exchanging heat between the precursor LNG stream and a heat source having a temperature in a range from -50 to 150 °C. Useful heat source for step (1b) can be any of the heat sources described above in connection with the processes of the first aspect. The precursor LNG stream may be further pumped to a higher desirable pressure as in the processes in the first and second aspects described above.

[0051] The flashing drum overhead effluent, rich in methane and depleted in C₂+ hydrocarbons compared to the LNG stream fed into the drum, may be processed in a manner similar to the overhead streams from the distillation columns in the processes of the first and/or second aspect of this disclosure described above. In various embodiments of the processes of the third aspect, the flashing drum overhead vapor effluent can be supplied, upon optional compression, to an NG delivery network and/or an industrial fuel system, e.g., a fuel system for a steam cracker.

[0052] The flashing drum bottoms liquid effluent, rich in C₂+ hydrocarbons and depleted in methane compared to the LNG stream fed into the drum, can be separated by distillation using the separation processes available in the prior art, the processes of the first and/or second aspects of this disclosure, to produce a distillation column overhead stream rich in NG and a distillation column bottoms stream rich in NGL. The distillation column overhead stream may be combined with the flashing drum overhead vapor stream and then processed as described above. Alternatively, at least a portion of the distillation column overhead stream may be process separately from the flashing drum overhead vapor stream. The distillation column bottoms stream produced in the processes of the third aspect may be processed and utilized in a manner similar to the bottoms streams in the processes of the first and second aspects of this disclosure as described above.

[0053] By utilizing a flashing drum before a distillation column, the processes of the third aspect of this disclosure only needs a distillation column having a much smaller capacity than the distillation columns required in the processes in the prior art and the first and second aspects of this disclosure as described above in order to process a given quantity of LNG stream. Thus the system of the third aspect can be less expensive to build. Similar to the processes of the

first aspect, if integrated with other industrial processes, the processes of the third aspect can achieve much higher energy efficiency and a much smaller carbon dioxide emission.

[0054] Various aspects and embodiments of the processes and systems of this disclosure are schematically illustrated in FIGs. 2, 3, and 4, detailed description of which are provided below. FIG. 1 schematically illustrates a prior art process and system for separating LNG in contrast to the processes of this disclosure, a description of which is also provided below.

FIG. 1

[0055] FIG. 1 schematically illustrates an LNG separation process and system 101 utilized in the prior art for separating LNG typically at the location of an LNG receiving port. As shown, a liquid LNG feed stream 103, comprising methane, ethane, and optionally C3+ hydrocarbons, drawn from an LNG transportation vessel or a storage tank (now shown), having a temperature of, e.g., from -180 to -150 °C and a pressure of, e.g., from 100 to 300 kPa-a, is first pumped by pump 105 to form a stream 107 having an elevated pressure of, e.g., from 800 to 1,000 kPa-a. Stream 107 is then heated via heat exchanger 109 (feed/overhead exchanger) by stream 119 (described below) to form stream 111 having a higher temperature of, e.g., from -130 to -110 °C. Stream 111 is then fed into an LNG distillation column 113 having about 10 ideal stages, typically at middle location of the column rather than at the top-most ideal stage, from which an overhead vapor stream 115 rich in methane compared to stream 111 and a bottoms stream 135 rich in C2+ hydrocarbons compared to stream 111 are produced. A portion of stream 135 (an NGL stream), stream 137, is heated by a heat exchanger 139 (an LNG vaporizer) to obtain a higher-temperature stream 141, which is recycled to column 113. Another portion of stream 135, stream 143, is then pumped by pump 145 to obtain a stream 147 having a higher pressure than stream 143. Stream 147 is then heated at heat exchanger 149 (an NGL warmer) by a heat source to obtain a heated stream 151. Stream 151 can be then supplied to a steam cracker, and the like, after optional further separation, where C2+ hydrocarbons can be converted into more valuable chemicals. The overhead stream 115 in vapor phase is first compressed by a compressor 117 to obtain a stream 119 having a higher pressure, which is then cooled via the feed/overhead heat exchanger 109 by stream 107 to obtain a vapor-liquid mixture stream 123. Stream 123 can be separated to obtain a liquid stream 124 which is refluxed to the top of column 113, and a vapor stream 125 which can be further pumped by a pump 127 to form a stream 129 at a higher pressure than stream 125. Stream 129 can be further heated by a heat exchanger 131 to obtain a superheated NG stream 133. Stream 133 can be delivered to an NG delivery network.

[0056] The process and system as illustrated in FIG. 1 require 3 units of pumps, 1 unit of compressor, typically a distillation column of about 10 ideal stages, 1 unit of feed/overhead heat exchanger, 1 unit of LNG vaporizer, and 1 unit of NGL warmer. This is a very expensive system to build and operate. Using the process and system of FIG. 1, one can process an LNG feed stream 103 having a temperature of -161°C and a pressure of 1 kPa-g at 3.5 million tons per annum (“MTA”) and a composition comprising 88.2 wt% methane, 8.9 wt% ethane, 1.5 propane, and balance C4+ hydrocarbons and N_2 (“Exemplary LNG”), to produce an NG stream 133 having a temperature of 30°C and a pressure of 3500 kPa-g, an NGL stream having a temperature of 29°C and a pressure of 4000 kPa-g, with a utility consumption of about 4200 kW shaft power and 89 megawatt of heat input. Typically, the heat input is provided from sea water available at the LNG port. The thus chilled sea water is then discharged into the sea, representing a loss of at least 89 megawatt of energy because the low temperature of the feed stream 103 was achieved by cooling natural gas from a high temperature to -161°C . Given a great majority of the many LNG ports in the world are located on sea shores, a large amount of energy can be wasted to using sea water as the heating source to heat the various low-temperature hydrocarbon streams in the LNG separation process. It would be highly desirable the 89 megawatt “cold” energy is captured and utilized to drive useful processes.

FIG. 2

[0057] FIG. 2 schematically illustrates a process and system 201 of this disclosure for separating LNG, which is much simpler than the process of FIG. 1 and much more energy efficient. As shown in FIG. 2, a liquid LNG feed stream 203, comprising methane, ethane, and optionally C3+ hydrocarbons, drawn from an LNG transportation vessel or a storage tank (now shown), having a temperature of, e.g., from -180 to -150°C and a pressure of, e.g., from 100 to 300 kPa-a, is pumped by pump 205 to form a stream 207 having an elevated pressure of ≥ 500 kPa-a, e.g., from 500 to 1500 kPa-a (or from 600 to 1200 kPa-a; or from 800 to 1000 kPa-a). Stream 207 is then fed into the top-most ideal stage of an LNG distillation column 209 having from, e.g., 2 to 20 (preferably 5 to 10, preferably 8 to 12, and preferably 9 to 11) ideal stages, from which an overhead vapor stream 211 rich in methane compared to stream 207 and a bottoms stream 221 rich in C2+ hydrocarbons compared to stream 207 are produced.

[0058] A portion of stream 221 (an NGL stream), stream 223, is heated by a heat exchanger 225 (an LNG vaporizer) to obtain a higher-temperature stream 227, which is recycled to column 209. Another portion of stream 221, stream 229, is then pumped by pump 231 to obtain a stream 233 having a higher pressure than stream 229. Stream 233, or a portion thereof after optional additional separation, can be supplied to a pyrolysis reactor such as a steam cracker, a

dehydrogenation reactor, a separation column, a liquefied petroleum gas (“LPG”) blending stage for blending with another hydrocarbon stream, and the like, where C2+ hydrocarbons can be separated and/or converted into more valuable chemicals.

[0059] In certain embodiments, the overhead stream 211 in vapor phase can be, upon optional compression by a low-duty compressor (not shown), heated by a heat exchanger 213 to obtain a superheated NG stream 215. Preferably stream 215 has a pressure $\geq 2,000$ kPa-a (e.g., $\geq 2,500, 3,000, 3,500, 4,000$ kPa-a). Preferably stream 215 has a pressure $\leq 6,000$ kPa-a (e.g., $\leq 5,500, 5,000, 4,500, 4,000$ kPa-a). Stream 215 can be delivered to an NG delivery network or an industrial fuel system, with or without further compression. In other embodiments, stream 211 may be heated to obtain an un-superheated heated natural gas stream having an absolute pressure ≥ 200 kPa-a, which is then compressed without after-cooling to obtain a compressed superheated natural gas stream having an absolute pressure ≥ 400 kPa-a, which can then be supplied to a LNG delivery network or an industrial fuel system without further compression.

[0060] The process and system as illustrated in FIG. 2 require only 3 units of pumps, a distillation column, 1 unit of LNG vaporizer, and 1 unit of NGL warmer. No compressor or condenser is required to process the overhead stream. Thus the system of FIG. 2 is much simpler than that of FIG. 1, much less costly to construct, and much less costly to operate.

[0061] Using the process and system of FIG. 2, one can process a feed stream 203 comprising the same Exemplary LNG described in connection with FIG. 1, having a temperature of -161°C and a pressure of 1 kPa-g at 3.5 MTA, to produce an NG stream 219 having a temperature of 30°C and a pressure of 3500 kPa-g, an NGL stream having a temperature of 29°C and a pressure of 4000 kPa-g, with a utility consumption of about 890 kW shaft power, which is merely 21% of the shaft power consumed by the process of FIG. 1, and 93 megawatt of heat input, comparable to that which is required by the process of FIG. 1.

[0062] In the process illustrated in FIG. 2, while it would be feasible to utilize warm sea water to provide the heat source for the various heat exchangers (213, 225) to heat the various hydrocarbon streams, preferably other heat source in need of cooling in an industrial process is utilized so that the “cold energy” stored in the low-temperature hydrocarbon streams are captured by the heat source and used for useful industrial purposes. Such other heat source can be preferably provided from, e.g., a petrochemical plant, a petroleum refinery plant, a chemical plant, and the like. Such other heat source can preferably have a low temperature $\leq 150^{\circ}\text{C}$ (e.g., $\leq 140, 120, 100, 90, 80, 70, 60, 50$, or 40°C). Such other heat source can preferably have a temperature $\geq 30^{\circ}\text{C}$ (e.g., $\geq 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 100^{\circ}\text{C}$). The relatively

low temperature of such other heat source makes the economic utilization of the residual heat energy therein difficult in traditional processes and systems. In the process of FIG. 2, however, the residual heat energy in such other low-temperature heat stream can be conveniently harnessed in the relevant heat exchangers (e.g., heat exchangers 217 and 225) to raise the temperatures of the relatively low-temperature hydrocarbon streams. Non-limiting examples of such other heat sources include: a warm cooling water stream; a steam condensate stream; an excess low pressure steam stream; a hydrocarbon stream having a temperature higher than the hydrocarbon stream to be heated in the process of FIG. 2; a heat medium that comprises at least a portion thereof a heat medium used in another heat exchanger; and combinations and mixtures thereof. These streams can be readily available from a chemical plant, a petrochemical plant, a petroleum refinery plant, and the like. Thus, the process of FIG. 2 allows for highly energy efficient heat integration between and among an LNG separation process, a petroleum refining process, a petrochemical production process, a chemical production process, and the like. Such integration can achieve tremendous energy savings and significant reduction in CO₂ emissions.

[0063] The methane-rich stream 215 or a portion thereof can be supplied to as a fuel to a fuel system, such as a fuel system needed in a petrochemical production plant, a petroleum refinery plant, a chemical production plant, and the like. For example, an olefins production plant typically comprises one or more steam crackers, each comprising a furnace in which a plurality of burners are operated to combust a fuel supplied from a steam cracker fuel system to provide the heat energy required for cracking hydrocarbon molecules inside one or more tube reactors located inside the furnace. Stream 215 or a portion thereof can be advantageously supplied into such a steam cracker fuel system. In addition, stream 233 or a portion thereof may be used as a feed to a steam cracker, where it is converted into high-value hydrocarbons such as ethylene, propylene, butenes, and the like. The synergy of co-locating an LNG separation system as illustrated in FIG. 2 with a petroleum refinery, a petrochemical production plant, a chemical production plant, and the like, can be enormous.

FIG. 3

[0064] FIG. 3 schematically illustrates another LNG separation process and system 301 of this disclosure, which is also simpler and more energy efficient than those of FIG. 1. As shown, a liquid LNG feed stream 303, comprising methane, ethane, and optionally C₃+ hydrocarbons, drawn from an LNG transportation vessel or a storage tank (now shown), having a temperature of, e.g., from -180 to -150 °C and a pressure of, e.g., from 100 to 300 kPa-a, is first pumped by pump 305 to form a stream 307 having an elevated pressure of, e.g., from 500 to 1,500 kPa-a.

Stream 307 is then heated via heat exchanger 309 (e.g., a feed/overhead exchanger) by a heating stream (e.g., preferably stream 317 described below) to form stream 311 having a higher temperature. Stream 311 is then fed into an LNG distillation column 313 having about 2-20 ideal stages, from which an overhead vapor stream 315 rich in methane compared to stream 311 and a bottoms stream 333 rich in C2+ hydrocarbons compared to stream 311 are produced.

[0065] A portion of stream 333 (an NGL stream), stream 335, is heated by a heat exchanger 337 (an LNG vaporizer) to obtain a higher-temperature stream 339, which is recycled to column 313. Another portion of stream 333, stream 341, is then pumped by pump 343 to obtain a stream 345 having a higher pressure than stream 341. Stream 345 is then heated at heat exchanger 347 (an NGL warmer) by a heat source to obtain a heated stream 349. Stream 349, or a portion thereof after optional additional separation, can be then supplied to a pyrolysis reactor such as a steam cracker, a dehydrogenation reactor, a separation column, a liquefied petroleum gas ("LPG") blending stage for blending with another hydrocarbon stream, and the like, where C2+ hydrocarbons can be separated and/or converted into more valuable chemicals.

[0066] The overhead stream 315 in vapor phase is first cooled via heat exchanger (e.g., the feed/overhead heat exchanger 309) 319 by a cooling stream (e.g., preferably stream 307) to obtain a vapor-liquid mixture stream 321. Stream 321 can be separated to obtain a liquid stream 124 which is refluxed to the top of column 313, and a vapor stream 323. Stream 323, upon optional compression by preferably a low-duty compressor (not shown), can be further heated by heat exchanger 325 to obtain a superheated NG stream 327. Preferably stream 327 has a pressure $\geq 2,000$ kPa-a (e.g., $\geq 2,500, 3,000, 3,500, 4,000$ kPa-a). Preferably stream 327 has a pressure $\leq 6,000$ kPa-a (e.g., $\leq 5,500, 5,000, 4,500, 4,000$ kPa-a). Stream 327 can be delivered to an NG delivery network or a fuel system, such as the fuel system for the burners of a steam cracker cracking hydrocarbons such as those from stream 349. In other embodiments, stream 323 may be heated to obtain a saturated natural gas stream having an absolute pressure ≥ 200 kPa-a, which is then compressed without after-cooling to obtain a compressed superheated natural gas stream having an absolute pressure ≥ 400 kPa-a, which can then be supplied to a LNG delivery network or an industrial fuel system without further compression.

[0067] The process and system as illustrated in FIG. 3 can require only 2 units of pumps, no compressor, a distillation column, 1 unit of feed/overhead heat exchanger, 1 unit of LNG vaporizer, and 1 unit of NGL warmer. The process and system of FIG. 3 is still simpler and less costly than those of FIG. 1 to construct and operate.

[0068] Similar to the process of FIG. 2, in the process illustrated in FIG. 3, while it would be feasible to utilize warm sea water to provide the heat source for the various heat exchangers

(309, 325, 337, and 347) to heat the various hydrocarbon streams, preferably other heat source in need of cooling in an industrial process is utilized so that the “cold energy” stored in the low-temperature hydrocarbon streams are captured by the heat source and used for useful industrial purposes. Such other heat source can be preferably provided from, e.g., a petrochemical plant, a petroleum refinery plant, a chemical plant, and the like. Such other heat source can preferably have a low temperature $\leq 150^{\circ}\text{C}$ (e.g., $\leq 140, 120, 100, 90, 80, 70, 60, 50$, or 40°C). Such other heat source can preferably have a temperature $\geq 30^{\circ}\text{C}$ (e.g., $\geq 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 100^{\circ}\text{C}$). The relatively low temperature of such other heat source makes the economic utilization of the residual heat energy therein difficult in traditional processes and systems. In the process of FIG. 3, however, the residual heat energy in such other low-temperature heat stream can be conveniently harnessed in the relevant heat exchangers to raise the temperatures of the relatively low-temperature hydrocarbon streams. Non-limiting examples of such other heat sources include: a warm cooling water stream; a steam condensate stream; an excess low pressure steam stream; a hydrocarbon stream having a temperature higher than the hydrocarbon stream to be heated in the process of FIG. 2; a heat medium that comprises as at least a portion thereof a heat medium used in another heat exchanger; and combinations and mixtures thereof. These streams can be readily available from a chemical plant, a petrochemical plant, a petroleum refinery plant, and the like. Thus, the process of FIG. 2 allows for highly energy efficient heat integration between and among an LNG separation process, a petroleum refining process, a petrochemical production process, a chemical production process, and the like. Such integration can achieve tremendous energy savings and significant reduction in CO_2 emissions.

[0069] Similar to the process of FIG. 2, the methane-rich stream 327 or a portion thereof can be supplied to as a fuel to a fuel system, such as a fuel system needed in a petrochemical production plant, a petroleum refinery plant, a chemical production plant, and the like. Stream 327 or a portion thereof can be advantageously supplied into a steam cracker fuel system. In addition, stream 349 or a portion thereof may be used as a feed to a steam cracker, where it is converted into high-value hydrocarbons such as ethylene, propylene, butenes, and the like. Likewise, the synergy of co-locating an LNG separation system as illustrated in FIG. 3 with a petroleum refinery, a petrochemical production plant, a chemical production plant, and the like, can be enormous.

FIG. 4

[0070] FIG. 4 schematically illustrates another LNG separation process and system 401 of this disclosure, which is also more energy efficient than those of FIG. 1. As shown, a liquid

LNG feed stream 403, comprising methane, ethane, and optionally C3+ hydrocarbons, drawn from an LNG transportation vessel or a storage tank (now shown), having a temperature of, e.g., from -180 to -150 °C and a pressure of, e.g., from 100 to 300 kPa-a, is first pumped by pump 405 to form a stream 407 having an elevated pressure of, e.g., from 500 to 1500 kPa-a. Stream 407 is then heated via heat exchanger 409 (e.g., a feed/overhead exchanger) by a heating stream (e.g., preferably stream 433 described below) to form a vapor/liquid mixture stream 411 having a higher temperature. Stream 411 is then fed into a flashing drum 413, where it is separated into an overhead vapor stream 415 rich in methane and a bottoms liquid stream 425 rich in C2+ hydrocarbons. Stream 415 can be, upon optional compression by a compressor (not shown), heated by a heat exchanger 417 to form a higher-temperature (e.g., a superheated) stream 419. Preferably stream 419 has a pressure $\geq 2,000$ kPa-a (e.g., $\geq 2,500, 3,000, 3,500, 4,000$ kPa-a). Preferably stream 419 has a pressure $\leq 6,000$ kPa-a (e.g., $\leq 5,500, 5,000, 4,500, 4,000$ kPa-a). Stream 419 can be delivered to an NG delivery network or a fuel system, such as the fuel system for the burners of a steam cracker cracking hydrocarbons such as those from stream 467. In other embodiments, stream 410 may be heated to obtain a saturated natural gas stream having an absolute pressure ≥ 200 kPa-a, which is then compressed without after-cooling to obtain a compressed superheated natural gas stream having an absolute pressure ≥ 400 kPa-a, which can then be supplied to a LNG delivery network or an industrial fuel system without further compression.

[0071] Stream 425 can still comprise substantial quantity of methane. Stream 425 is then separated in a separation system similar to that of FIG. 1 to obtain another NG stream 449 and an NGL stream 467. Specifically, stream 425 is fed into a distillation column 427, from which an overhead vapor stream 429 rich in methane and a bottoms stream 451 rich in C2+ hydrocarbon are obtained. A portion of stream 451 (an NGL stream), stream 453, is heated by a heat exchanger 455 (an LNG vaporizer) to obtain a higher-temperature stream 457, which is recycled to column 427. Another portion of stream 451, stream 459, is then pumped by pump 461 to obtain a stream 463 having a higher pressure than stream 459. Stream 463 is then heated at heat exchanger 465 (an NGL warmer) by a heat source to obtain a heated stream 467. Stream 467, or a portion thereof after optional additional separation, can be then supplied to a steam cracker, and the like, where C2+ hydrocarbons can be converted into more valuable chemicals. The overhead stream 429 in vapor phase is first compressed by a compressor 431 to obtain a stream 433 having a higher pressure, which is then cooled via a heat exchanger 435 to obtain a vapor-liquid mixture stream 437. Stream 437 can be separated to obtain a liquid stream 439 which is refluxed to the top of column 427, and a vapor stream 441 which can be further

pumped by a pump 443 to form a stream 445 at a higher pressure than stream 441. Stream 445 can be further heated by a heat exchanger 447 to obtain a superheated NG stream 449. Stream 449 can be delivered to an NG delivery network or a fuel system, with or without being combined with stream 423. In certain preferred embodiments, stream 415 is at least partly combined with stream 441, optionally compressed by a common compressor (not shown), and then heated by the same heat exchanger (i.e. 421 and 447 being the same) as well.

[0072] By utilizing the flashing drum 413 upstream of the distillation column 427, a significant portion of methane can be separated from stream 411 efficiently and at low cost from the drum as stream 415. Only the bottoms stream 425, which can represent a very small portion of stream 411, is subjected to conventional distillation separation in column 427. Thus, compared to the process and system of FIG. 1, to process the same quantity of LNG feed having the same composition, the process and system of FIG. 4 require a much smaller capacity distillation separation system, which translates a much smaller distillation column 427, a much smaller-duty compressor 431, smaller pumps and smaller-duty heat exchangers, which can more than compensate the low-cost flashing drum 413.

[0073] Similar to the processes and systems illustrated in FIGs. 2 and 3, the process and system of FIG. 4 can be integrated with a chemical production plant, a petroleum refinery plant, a petrochemical production plant, and the like, to achieve significant energy savings and CO₂ emission reductions.

[0074] This disclosure can further include one or more of the following non-limiting aspects and/or embodiments:

[0075] A1. A process for separating an LNG stream, the process comprising:

(I) providing an LNG stream comprising methane, ethane, and optionally C₃+ hydrocarbons having a temperature ≤ -80 °C, and an absolute pressure of ≥ 500 kPa-a;

(II) feeding the LNG stream into a distillation column at the top-most ideal stage of the distillation column;

(III) supplying heat to the distillation column;

(IV) obtaining an overhead stream from the distillation column comprising methane at a concentration ≥ 70 wt%, based on the total weight of the hydrocarbons in the overhead stream, without using an overhead compressor, an overhead condenser, and an overhead reflux stream; and

(V) obtaining a bottoms stream from the distillation column comprising C₂+ hydrocarbons and from 0.01 to 10 wt% methane, based on the total weight of the bottoms stream.

[0076] A2. The process of A1, wherein the distillation column has from 2 to 20 (preferably 5 to 15, preferably 8 to 12, preferably 9 to 11) ideal stages.

[0077] A3. The process of A1 or A2, wherein the LNG stream has an absolute pressure of $\geq 2,000$ kPa-a, preferably $\geq 4,000$ kPa-a.

[0078] A4. The process of any of A1 to A3, further comprising:

(VI) heating the overhead stream to obtain a superheated natural gas stream; and

(VII) supplying the superheated natural gas stream to a natural gas delivery network without further compression or a fuel system.

[0079] A5. The process of A4, wherein in step (VI), the overhead stream is heated by a first heat source having a temperature $\leq 150^{\circ}\text{C}$ (e.g., $\leq 140, 120, 100, 90, 80, 70, 60, 50, 40^{\circ}\text{C}$), preferably via a first heat exchanger.

[0080] A6. The process of A4 or A5, wherein in step (VI), the overhead stream is heated by a first heat source having a temperature $\geq 30^{\circ}\text{C}$ (e.g., $\geq 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100^{\circ}\text{C}$).

[0081] A7. The process of any of A4, A5, and A6, wherein the superheated natural gas stream has a temperature $\geq 5^{\circ}\text{C}$ (e.g., $\geq 6, 7, 8, 9, 10, 12, 14, 15, 16, 18, 20, 22, 24, 25^{\circ}\text{C}$).

[0082] A8. The process of any of A1 to A3, further comprising:

(VI') heating the overhead stream to obtain an un-superheated heated natural gas stream having an absolute pressure ≥ 200 kPa-a;

(VII') compressing without after-cooling the un-superheated heated natural gas stream to obtain a compressed superheated natural gas stream having an absolute pressure ≥ 400 kPa-a; and

(VII'') supplying without further compression the compressed superheated natural gas stream to a natural gas delivery network and/or an industrial fuel system.

[0083] A9. The process of A8, wherein in step (VI'), the overhead stream is heated by a second heat source having a temperature $\leq 150^{\circ}\text{C}$ (e.g., $\leq 140, 120, 100, 90, 80, 70, 60, 50, 40^{\circ}\text{C}$), preferably via a first heat exchanger.

[0084] A10. The process of A8 or A9, wherein in step (VI'), the overhead stream is heated by a second heat source having a temperature $\geq 30^{\circ}\text{C}$ (e.g., $\geq 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100^{\circ}\text{C}$).

[0085] A11. The process of any of A8, A9, and A10, wherein the compressed superheated natural gas stream has a temperature $\geq 5^{\circ}\text{C}$ (e.g., $\geq 6, 7, 8, 9, 10, 12, 14, 15, 16, 18, 20, 22, 24, 25^{\circ}\text{C}$).

[0086] A12. The process of any of A1 to A11, wherein step (III) comprises:

(IIIa) drawing a recycle stream from the distillation column;
(IIIb) heating the recycle stream by using a third heat source having a temperature ≤ 150 °C (e.g., $\leq 140, 120, 100, 90, 80, 70, 60, 50, 40$ °C), preferably via a second heat exchanger;
(IIIc) feeding at least a portion of the heated recycle stream obtained from step (IIIb) into the distillation column.

[0087] A13. The process of A12, wherein in step (IIIb), the third heat source has a temperature ≥ 30 °C (e.g., $\geq 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100$ °C).

[0088] A14. The process of any of A1 to A13, further comprising:
(VIII) heating at least a portion of the bottoms stream using a fourth heat source to obtain a heated bottoms stream, preferably via a third heat exchanger; and
(IX) conducting away the heated bottoms stream.

[0089] A15. The process of A14, wherein the recycle stream is a side stream or a split stream from the bottoms stream.

[0090] A16. The process of any of A5 to A15, wherein the first heat source and/or the second heat source and/or the third heat source and/or the fourth heat source is one or more of the following streams:

a warm cooling water stream;
a steam condensate;
an excess low pressure steam stream;
a warm hydrocarbon stream;
a heat medium that comprises as at least a portion thereof a heat medium used in a heat exchanger other than the heat exchanger used the relevant step (VI), (IIIb) or (VIII); and
a mixture or a combination thereof.

[0091] A17. The process of any of A1 to A16, further comprising:
(X) supplying at least a portion of the bottoms stream to one or more of the following:
(a) a pyrolysis reactor, preferably a steam cracker;
(b) a dehydrogenation reactor;
(c) a separation column; and
(d) an LPG blending stage for blending with another hydrocarbon stream.

[0092] A18. The process of any of A1 to A17, wherein step (I) comprises:
(Ia) providing a precursor LNG stream having a pressure from atmospheric pressure to 300 kPa-a and a temperature from -160 to -80 °C;
(Ib) pumping the precursor LNG stream to obtain the LNG stream.

[0093] A19. The process of any of A1 to A18, wherein the LNG stream has an absolute pressure of from 500 to 1500 kPa, and at least a portion of the overhead stream is supplied as fuel to a furnace of a hydrocarbon steam cracker.

[0094] A20. The process of A19, wherein the distillation column comprises from 3 to 5 ideal stages.

[0095] A21. The process of any of A1 to A20, wherein the bottoms stream comprises from 0.1 to 5 mol% of methane, and at least a portion of the bottoms stream is supplied as a hydrocarbon feed to a hydrocarbon pyrolysis reactor.

[0096] B1. A process for separating an LNG stream, the process comprising:

- (i) providing an LNG stream comprising methane, ethane, and optionally C3+ hydrocarbons having a temperature ≤ -80 °C and an absolute pressure of ≥ 500 kPa-a;
- (ii) heating the LNG stream to obtain a vapor-liquid mixture feed stream;
- (iii) feeding the vapor-liquid mixture feed stream into a distillation column comprising 2 to 20 ideal stages;
- (iv) obtaining a first overhead vapor stream from the distillation column comprising methane at a concentration ≥ 70 wt%, based on the total weight of the hydrocarbons in the overhead stream;
- (v) condensing at least a portion of the first overhead vapor stream, without compressing the first overhead vapor stream, to obtain a vapor-liquid mixture overhead stream;
- (vi) separating the vapor-liquid mixture overhead stream to obtain a liquid reflux stream and a second vapor overhead stream;
- (vii) feeding at least a portion of the liquid reflux stream into the distillation column as a reflux stream;
- (viii) providing heat to the distillation column; and
- (ix) obtaining a bottoms stream from the distillation column comprising C2+ hydrocarbons and from 0.1 wt% to 10 wt% methane.

[0097] B2. The process of B1, wherein step (ii) comprises:

- (iia) heating the LNG stream or a portion thereof by indirectly exchanging heat with at least a portion of the first overhead vapor stream;

and step (v) comprises:

- (va) cooling the first overhead vapor stream or a portion thereof by indirectly exchanging heat with at least a portion of the LNG stream.

[0098] B3. The process of B1 or B2, wherein the LNG stream has an absolute pressure of ≥ 200 kPa-a, preferably ≥ 400 kPa-a.

[0099] B4. The process of any of B1 to B3, further comprising:

- (x) heating the second vapor overhead stream to obtain a superheated natural gas stream; and
- (xi) supplying the superheated natural gas stream to a natural gas delivery network without further compression and/or an industrial fuel system.

[0100] B5. The process of B4, wherein in step (x), the second vapor overhead stream is heated by a first heat source having a temperature $\leq 150^{\circ}\text{C}$ (e.g., $\leq 140, 120, 100, 90, 80, 70, 60, 50, 40^{\circ}\text{C}$), preferably via a first heat exchanger.

[0101] B6. The process of B4 or B5, wherein in step (VI), the second vapor overhead stream is heated by a first heat source having a temperature $\geq 30^{\circ}\text{C}$ (e.g., $\geq 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100^{\circ}\text{C}$).

[0102] B7. The process of any of B4, B5, and B6, wherein the superheated natural gas stream has a temperature $\geq 5^{\circ}\text{C}$ (e.g., $\geq 6, 7, 8, 9, 10, 12, 14, 15, 16, 18, 20, 22, 24, 25^{\circ}\text{C}$).

[0103] B8. The process of any of B1 to B6, further comprising:

- (xii) heating the second vapor overhead stream to obtain an un-superheated heated natural gas stream having an absolute pressure $\geq 200\text{ kPa-a}$;
- (xiii) compressing without after cooling the un-superheated heated natural gas stream to obtain a compressed superheated natural gas stream having an absolute pressure $\geq 400\text{kPa-a}$; and
- (xiv) supplying without further compression the compressed superheated natural gas stream to a natural gas delivery network and/or an industrial fuel system.

[0104] B9. The process of B8, wherein in step (xii), the second vapor overhead stream is heated by a first heat source having a temperature $\leq 150^{\circ}\text{C}$ (e.g., $\leq 140, 120, 100, 90, 80, 70, 60, 50, 40^{\circ}\text{C}$), preferably via a first heat exchanger.

[0105] B10. The process of B8 or B9, wherein in step (xii), the second vapor overhead stream is heated by a first heat source having a temperature $\geq 30^{\circ}\text{C}$ (e.g., $\geq 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100^{\circ}\text{C}$).

[0106] B11. The process of any of B8, B9, and B10, wherein the compressed superheated natural gas stream has a temperature $\geq 5^{\circ}\text{C}$ (e.g., $\geq 6, 7, 8, 9, 10, 12, 14, 15, 16, 18, 20, 22, 24, 25^{\circ}\text{C}$).

[0107] B12. The process of any of B1 to B11, wherein step (viii) comprises:

- (viii a) drawing a recycle stream from the distillation column;
- (viii b) heating the recycle stream by using a heat source having a temperature $\leq 150^{\circ}\text{C}$ (e.g., $\leq 140, 120, 100, 90, 80, 70, 60, 50, 40^{\circ}\text{C}$), preferably via a second heat exchanger;
- (viii c) feeding at least a portion of the heated side stream obtained from step (IIIb) into the distillation column.

[0108] B13. The process of B12, wherein in step (viii), the second heat source has a temperature $\geq 30^{\circ}\text{C}$ (e.g., $\geq 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100^{\circ}\text{C}$).

[0109] B14. The process of any of B1 to B13, further comprising:

(xv) heating at least a portion of the bottoms stream using a third heat source to obtain a heated bottoms stream, preferably via a third heat exchanger; and

(xvi) conducting away the heated bottoms stream.

[0110] B15. The process of any of B1 to B14, wherein the first heat source and/or the second heat source and/or the third heat source is one or more of the following streams:

a warm cooling water stream;

a steam condensate;

an excess low pressure steam stream;

a warm hydrocarbon stream;

a heat medium that comprises as at least a portion thereof a heat medium used in a heat exchanger other than the heat exchanger used the relevant step (VI), (IIIb) or (VIII); and

a mixture or a combination thereof.

[0111] B16. The process of B14 or B15, wherein the recycle stream is a side stream or a split stream from the bottoms stream.

[0112] B17. The process of any of B1 to B16, further comprising:

(xvii) supplying at least a portion of the bottoms stream to one or more of the following:

(a) a pyrolysis reactor, preferably a steam cracker

(b) a dehydrogenation reactor;

(c) a separation column; and

(d) an LPG blending stage for blending with another hydrocarbon stream.

[0113] B18. The process of any of B1 to B17, wherein step (i) comprises:

(ia) providing a precursor LNG stream having a pressure from atmospheric pressure to 300 kPa-a and a temperature from -160 to -80°C ;

(ib) pumping the precursor LNG stream to obtain the LNG stream.

[0114] B19. The process of any of B1 to B18, wherein the LNG stream has an absolute pressure of from 500 to 1500 kPa, and at least a portion of the overhead stream is supplied as fuel to a furnace of a hydrocarbon steam cracker.

[0115] B20. The process of B19, wherein the distillation column comprises from 2 to 20 (preferably 5 to 15, preferably 8 to 12, preferably 9 to 11) ideal stages.

[0116] B21. The process of any of B1 to B20, wherein the bottoms stream comprises from 0.01 to 10 wt% of methane, based on the total weight of the bottoms stream, and at least a

portion of the bottoms stream is supplied as a hydrocarbon feed to a hydrocarbon pyrolysis reactor.

[0117] C1. A process for separating an LNG stream, the process comprising:

- (1) providing an vapor-liquid mixture LNG stream comprising methane, ethane, and optionally C3+ hydrocarbons having a temperature ≤ -80 °C and an absolute pressure of ≥ 500 kPa-a;
- (2) feeding the vapor-liquid mixture LNG stream into a flashing drum;
- (3) obtaining an flashing drum overhead vapor effluent rich in methane and a flashing drum bottoms liquid effluent rich in ethane, wherein the flashing drum bottoms liquid effluent constitutes ≤ 50 wt% of the vapor-liquid mixture LNG stream; and
- (4) separating the flashing drum bottoms liquid effluent in a distillation column.

[0118] C2. The process of C1, wherein step (1) comprises:

[0119] (1a) providing a precursor LNG stream having a temperature ≤ -80 °C; and

[0120] (1b) heating the precursor LNG stream to obtain the vapor-liquid mixture LNG stream.

[0121] C3. The process of C2, wherein step (1b) comprises indirectly exchange heat between the precursor LNG stream with a heat source having a temperature in a range from -50 to 150 °C.

[0122] C4. The process of C3, wherein the heat source is one or more of the following streams:

a warm cooling water stream;

a steam condensate;

an excess low pressure steam stream;

a warm hydrocarbon stream;

a heat medium that comprises as at least a portion thereof a heat medium used in a heat exchanger other than the heat exchanger used the relevant step (VI), (IIIb) or (VIII); and

a mixture or a combination thereof.

[0123] C5. The process of any of C1 to C4, wherein at least a portion of the flashing drum overhead vapor effluent is supplied as a fuel to a furnace of a hydrocarbon steam cracker.

[0124] C6. The process of any of C1 to C5, wherein step (4) comprises:

(4a) obtaining an overhead NG stream rich in methane from the distillation column; and

(4b) obtaining a bottoms LPG stream rich in ethane from the distillation column.

[0125] C7. The process of any of C1 to C6, further comprising:

(5) heating the flashing drum overhead vapor effluent and/or the overhead NG stream to obtain a superheated natural gas stream; and

(6) supplying the superheated natural gas stream to a natural gas delivery network with or without further compression and/or an industrial fuel system.

[0126] C8. The process of any of C1 to C7, wherein step (iv) comprises:

(ivc) drawing a recycle stream from the distillation column;

(ivd) heating the recycle stream by using a heat source having a temperature no higher than 150 °C; and

(ive) feeding at least a portion of the heated recycle stream obtained from step (ivd) into the distillation column.

[0127] C9. The process of C8, wherein the heat source is one or more of the following streams:

a warm cooling water stream;

a steam condensate;

an excess low pressure steam stream;

a warm hydrocarbon stream;

a heat medium that comprises as at least a portion thereof a heat medium used in a heat exchanger other than the heat exchanger used the relevant step (VI), (IIIb) or (VIII); and

a mixture or a combination thereof.

[0128] C10. The process of C9 or C10, wherein the recycle stream is a side stream or a split stream from the bottoms stream.

[0129] C11. The process of any of C6 to C10, further comprising:

(7) supplying at least a portion of the bottoms stream to one or more of the following:

(a) a pyrolysis reactor;

(b) a dehydrogenation reactor;

(c) a separation column; and

(d) an LPG blending stage for blending with another hydrocarbon stream.

CLAIMS

What is claimed is:

1. A process for separating an LNG stream, the process comprising:
 - (I) providing an LNG stream comprising methane, ethane, and optionally C3+ hydrocarbons having a temperature ≤ -80 °C, and an absolute pressure of ≥ 500 kPa-a;
 - (II) feeding the LNG stream into a distillation column at the top-most ideal stage of the distillation column;
 - (III) supplying heat to the distillation column;
 - (IV) obtaining an overhead stream from the distillation column comprising methane at a concentration ≥ 70 wt%, based on the total weight of the hydrocarbons in the overhead stream, without using an overhead compressor, an overhead condenser, and an overhead reflux stream; and
 - (V) obtaining a bottoms stream from the distillation column comprising C2+ hydrocarbons and from 0.01 to 10 wt% methane, based on the total weight of the bottoms stream.
2. The process of claim 1, wherein the distillation column has from 2 to 20 ideal stages.
3. The process of claim 1 or claim 2, wherein the LNG stream has an absolute pressure of $\geq 2,000$ kPa-a, preferably $\geq 4,000$ kPa-a.
4. The process of any of the preceding claims, further comprising:
 - (VI) heating the overhead stream by a first heat source, preferably via a first heat exchanger, to obtain a superheated natural gas stream; and
 - (VII) supplying the superheated natural gas stream to a natural gas delivery network without further compression or a fuel system.
5. The process of any of the preceding claims, further comprising:
 - (VI') heating the overhead stream by a second heat source, preferably via a second heat exchanger, to obtain an un-superheated heated natural gas stream having an absolute pressure ≥ 200 kPa-a;

(VII') compressing without after-cooling the un-superheated heated natural gas stream to obtain a compressed superheated natural gas stream having an absolute pressure ≥ 400 kPa-a; and

(VII'') supplying without further compression the compressed superheated natural gas stream to a natural gas delivery network and/or an industrial fuel system.

6. The process of any of the preceding claims, wherein step (III) comprises:

(IIIa) drawing a recycle stream from the distillation column;

(IIIb) heating the recycle stream by using a third heat source, preferably via a third heat exchanger;

(IIIc) feeding at least a portion of the heated recycle stream obtained from step (IIIb) into the distillation column.

7. The process of claim 6, wherein the recycle stream is a side stream or a split stream from the bottoms stream.

8. The process of any of the preceding claims, further comprising:

(VIII) heating at least a portion of the bottoms stream using a fourth heat source, preferably via a fourth heat exchanger, to obtain a heated bottoms stream, preferably via a third heat exchanger; and

(IX) conducting away the heated bottoms stream.

9. The process of any of claims 4 to 8, wherein at least one of the first heat source, the second heat source, the third heat source, and the fourth heat source has a temperature $\leq 150^\circ\text{C}$ (e.g., $\leq 140, 120, 100, 90, 80, 70, 60, 50, 40^\circ\text{C}$).

10. The process of any of the preceding claims, wherein at least one of the first heat source, the second heat source, the third heat source, and the fourth heat source has a temperature $\geq 30^\circ\text{C}$ (e.g., $\geq 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100^\circ\text{C}$).

11. The process of any of claims 4 to 10, wherein the first heat source and/or the second heat source and/or the third heat source and/or the fourth heat source is one or more of the following streams:

a warm cooling water stream;

a steam condensate;
an excess low pressure steam stream;
a warm hydrocarbon stream;
a heat medium that comprises as at least a portion thereof a heat medium used in a heat exchanger other than the heat exchanger used the relevant step (VI), (IIIb) or (VIII); and
a mixture or a combination thereof.

12. The process of any of the preceding claims, further comprising:
(X) supplying at least a portion of the bottoms stream to one or more of the following:
a pyrolysis reactor, preferably a steam cracker;
a dehydrogenation reactor;
a separation column; and
an LPG blending stage for blending with another hydrocarbon stream.
13. The process of any of the preceding claims, wherein the bottoms stream comprises from 0.1 to 5 mol% of methane, and at least a portion of the bottoms stream is supplied as a hydrocarbon feed to a hydrocarbon pyrolysis reactor.
14. A process for separating an LNG stream, the process comprising:
(i) providing an LNG stream comprising methane, ethane, and optionally C3+ hydrocarbons having a temperature ≤ -80 °C and an absolute pressure of ≥ 500 kPa-a;
(ii) heating the LNG stream to obtain a vapor-liquid mixture feed stream;
(iii) feeding the vapor-liquid mixture feed stream into a distillation column comprising 2 to 20 ideal stages;
(iv) obtaining a first overhead vapor stream from the distillation column comprising methane at a concentration ≥ 70 wt%, based on the total weight of the hydrocarbons in the overhead stream;
(v) condensing at least a portion of the first overhead vapor stream, without compressing the first overhead vapor stream, to obtain a vapor-liquid mixture overhead stream;
(vi) separating the vapor-liquid mixture overhead stream to obtain a liquid reflux stream and a second vapor overhead stream;
(vii) feeding at least a portion of the liquid reflux stream into the distillation column as a reflux stream;
(viii) providing heat to the distillation column; and

(ix) obtaining a bottoms stream from the distillation column comprising C2+ hydrocarbons and from 0.1 wt% to 10 wt% methane.

15. The process of claim 14, wherein step (ii) comprises:

(iia) heating the LNG stream or a portion thereof by indirectly exchanging heat with at least a portion of the first overhead vapor stream;

and step (v) comprises:

(va) cooling the first overhead vapor stream or a portion thereof by indirectly exchanging heat with at least a portion of the LNG stream.

16. The process of claim 14 or claim 15, further comprising:

heating the second vapor overhead stream by a first heat source, preferably via a first heat exchanger, to obtain a superheated natural gas stream; and

supplying the superheated natural gas stream to a natural gas delivery network without further compression and/or an industrial fuel system.

17. The process of any of claims 14 to 16, further comprising:

(x) heating the second vapor overhead stream by a second heat source, preferably via a second heat exchanger, to obtain an un-superheated heated natural gas stream having an absolute pressure ≥ 200 kPa-a;

(xi) compressing without after cooling the un-superheated heated natural gas stream to obtain a compressed superheated natural gas stream having an absolute pressure ≥ 400 kPa-a; and

(xii) supplying without further compression the compressed superheated natural gas stream to a natural gas delivery network and/or an industrial fuel system.

18. The process of any of claims 14 to 17, wherein step (viii) comprises:

(viiiia) drawing a recycle stream from the distillation column;

(viiiib) heating the recycle stream by using a third heat source, preferably via a third heat exchanger;

(viiiic) feeding at least a portion of the heated side stream obtained from step (IIIb) into the distillation column.

19. The process of any of claims 14 to 18, further comprising:
heating at least a portion of the bottoms stream using a fourth heat source, preferably via a fourth heat exchanger, to obtain a heated bottoms stream; and
conducting away the heated bottoms stream.
20. The process of any of claims 16 to 19, wherein at least one of the first heat source, the second heat source, the third heat source, and the fourth heat source has a temperature $\leq 150^{\circ}\text{C}$ (e.g., $\leq 140, 120, 100, 90, 80, 70, 60, 50, 40^{\circ}\text{C}$), preferably $\geq 30^{\circ}\text{C}$ (e.g., $\geq 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100^{\circ}\text{C}$).
21. The process of any of claims 16 to 20, wherein at least one of the first heat source, the second heat source, the third heat source, and the fourth heat source is one or more of the following streams:
a warm cooling water stream;
a steam condensate;
an excess low pressure steam stream;
a warm hydrocarbon stream;
a heat medium that comprises at least a portion thereof a heat medium used in a heat exchanger other than the heat exchanger used in the relevant step (VI), (IIIb) or (VIII); and
a mixture or a combination thereof.
22. A process for separating an LNG stream, the process comprising:
(1) providing an vapor-liquid mixture LNG stream comprising methane, ethane, and optionally C3+ hydrocarbons having a temperature $\leq -80^{\circ}\text{C}$ and an absolute pressure of ≥ 500 kPa-a;
(2) feeding the vapor-liquid mixture LNG stream into a flashing drum;
(3) obtaining an flashing drum overhead vapor effluent rich in methane and a flashing drum bottoms liquid effluent rich in ethane, wherein the flashing drum bottoms liquid effluent constitutes ≤ 50 wt% of the vapor-liquid mixture LNG stream; and
(4) separating the flashing drum bottoms liquid effluent in a distillation column.

23. The process of claim 22, wherein step (1) comprises:
- (1a) providing a precursor LNG stream having a temperature ≤ -80 °C; and
 - (1b) heating the precursor LNG stream to obtain the vapor-liquid mixture LNG stream by indirectly exchanging heat between the precursor LNG stream with a heat source having a temperature in a range from -50 to 150 °C.
24. The process of claim 23, wherein the heat source is one or more of the following streams:
- a warm cooling water stream;
 - a steam condensate;
 - an excess low pressure steam stream;
 - a warm hydrocarbon stream;
 - a heat medium that comprises at least a portion thereof a heat medium used in a heat exchanger other than the heat exchanger used in the relevant step (VI), (IIIb) or (VIII); and
 - a mixture or a combination thereof.
25. The process of any of the preceding claims, wherein the process is integrated with a process in a petrochemical plant and a petroleum refining plant.