CLAIMS

1. A liquefied natural gas production system using liquid nitrogen as a primary refrigerant, the system comprising:

a natural gas stream from a supply of natural gas;

a liquefied nitrogen stream from a supply of liquefied nitrogen;

at least one heat exchanger that exchanges heat between the liquefied nitrogen stream and the natural gas stream to at least partially vaporize the liquefied nitrogen stream and at least partially condense the natural gas stream; and

a greenhouse gas removal unit comprising a distillation column having a heat pump condenser and reboiler system, the greenhouse gas removal unit configured to remove greenhouse gas from the at least partially vaporized nitrogen stream, wherein the heat pump condenser and reboiler system further comprises a compressor that increases a pressure and condensing temperature of an overhead stream of the distillation column, a heat pump heat exchanger to cross-exchange the overhead stream of the distillation column and a bottom stream of the distillation column to affect both an overhead condenser duty and a bottom reboiler duty of the distillation column, a pressure reduction device, connected to an output of the heat pump heat exchanger, and configured to reduce a pressure of the distillation column overhead stream after the distillation column overhead stream has passed through the heat pump heat exchanger, and a separator, connected to an output of the pressure reduction device, and configured to produce a first separator overhead stream, wherein the first separator overhead stream is gaseous nitrogen that exits the greenhouse gas removal unit having greenhouse gases removed therefrom;

at least one expander service that reduces the pressure of the at least partially vaporized nitrogen stream; and

a controller that adjusts an inlet temperature of a first of the at least one expander service to affect an overhead condenser duty and a bottom reboiler duty of the distillation column.

2. The liquefied natural gas production system of claim 1, wherein the liquefied nitrogen stream is circulated through one of the at least one heat exchanger at least three times.

3. The liquefied natural gas production system of claim 1, further comprising at least one expander service that reduces the pressure of the at least partially vaporized nitrogen stream, wherein an inlet stream of the distillation column is an outlet stream of a first of the at least one expander service.

4. The liquefied natural gas production system of claim 1, wherein an increase of the inlet temperature of the first of the at least one expander service increases the overhead condenser duty and decreases the reboiler duty, and further wherein and a decrease of the inlet temperature of the first of the at least one expander service decreases the overhead condenser duty and increases the boiler duty.

5. The liquefied natural gas production system of claim 1, wherein the controller is further configured to control the compressor to adjust the increase in the pressure of the overhead stream of the distillation column, thereby changing overall heat transfer in the heat pump heat exchanger.

6. The liquefied natural gas production system of claim 1, further comprising a nitrogen vent system that vents the first separator overhead stream to atmosphere.

7. The liquefied natural gas production system of claim 6, further comprising a second heat exchanger in which the first separator overhead stream exchanges heat with the natural gas stream to increase a temperature of the first separator overhead stream to at least ambient temperature prior to the first separator overhead stream entering the nitrogen vent system.

8. The liquefied natural gas production system of system of claim 1, wherein the pressure reduction device is a first pressure reduction device, and further comprising a second pressure reduction device that reduces a pressure of the at least partially condensed natural gas stream.

9. The liquefied natural gas production system of claim 8, wherein the second pressure reduction device is one or more of a hydraulic turbine and a Joule-Thomson valve.

10. The liquefied natural gas production system of claim 1, further comprising a pump that pumps the liquefied nitrogen stream to a pressure of at least 20 bara.

11. The liquefied natural gas production system of claim 1, wherein the greenhouse gases removed from the at least partially vaporized nitrogen stream comprise a greenhouse gas product stream, and further comprising a greenhouse gas pump that increases a pressure of the greenhouse gas product stream.

12. The liquefied natural gas production system of claim 11, wherein the greenhouse gas product stream is combined with the at least partially condensed natural gas stream.

13. The liquefied natural gas production system of claim 1, further comprising a heat pump system through which the at least partially vaporized nitrogen stream flows after flowing through a first of the at least one expander service.

14. The liquefied natural gas production system of claim 13, wherein the heat pump system includes a nitrogen compressor, a nitrogen cooler, and a feed-effluent heat exchanger.

15. The liquefied natural gas production system of claim 1, wherein the greenhouse gas comprises at least one of methane, ethane, propane, butane, ethene, propene, and butene.

16. The liquefied natural gas production system of claim 1, further comprising a psychometric heat exchanger that uses the at least partially vaporized nitrogen stream to pre-chill the natural gas stream prior to the natural gas stream entering the at least one heat exchanger.

17. The liquefied natural gas production system of claim 16, wherein a specific gravity of the at least partially vaporized nitrogen stream is reduced by at least 0.2% by the psychometric heat exchanger.

18. A method of producing liquefied natural gas (LNG) using liquid nitrogen as a primary refrigerant, the method comprising:

providing a natural gas stream from a supply of natural gas;

providing a liquefied nitrogen stream from a supply of liquefied nitrogen;

passing the natural gas stream and the liquefied nitrogen stream through a first heat exchanger that exchanges heat between the liquefied nitrogen stream and the natural gas stream to at least partially vaporize the liquefied nitrogen stream and at least partially condense the natural gas stream; and

removing greenhouse gas from the at least partially vaporized nitrogen stream using a greenhouse gas removal unit, wherein the greenhouse gas removal unit comprises a distillation column and a heat pump condenser and reboiler system;

increasing a pressure and condensing temperature of an overhead stream of the distillation column;

cross-exchanging the overhead stream of the distillation column and a bottoms stream of the distillation column to affect both an overhead condenser duty and a bottom reboiler duty of the distillation column;

reducing a pressure of the distillation column overhead stream after the cross-exchanging step to produce a reduced-pressure distillation column overhead stream; and

separating the reduced-pressure distillation column overhead stream to produce a first separator overhead stream, wherein the first separator overhead stream is gaseous nitrogen that exits the greenhouse gas removal unit having greenhouse gases removed therefrom;

providing a second heat exchanger in which the first separator overhead stream exchanges heat with the natural gas stream to increase a temperature of the first separator overhead stream to at least ambient temperature prior to the first separator overhead stream being vented to atmosphere;

reducing a pressure of the at least partially vaporized nitrogen stream using at least one expander service; and

controlling an inlet temperature of the at least one expander service to affect the overhead condenser duty and the bottom reboiler duty of the distillation column.

19. The method of claim 18, further comprising venting the first separator overhead stream to atmosphere.

20. The method of claim 18, further comprising controlling the increase in the pressure and condensing temperature of the overhead stream of the distillation column, thereby changing overall heat transfer during the cross-exchanging step.

21. The method of claim 18, further comprising combining the greenhouse gas removed from the at least partially vaporized nitrogen stream with the natural gas stream.

22. The method of claim 18, further comprising flowing the at least partially vaporized nitrogen stream through a heat pump system after flowing through a first of the at least one expander service.

23. The method of claim 18, wherein the liquefied nitrogen stream is circulated through the first heat exchanger at least three times.