CLAIMS

1. A liquefied natural gas production system, the system comprising:

a natural gas stream from a supply of natural gas;

a liquid nitrogen stream from a liquid nitrogen supply;

a natural gas compressor that compresses the natural gas stream to a pressure of at least 135 bara to form a compressed natural gas stream;

a natural gas cooler that cools the compressed natural gas stream by indirect heat exchange with an ambient fluid to form a cooled compressed natural gas stream;

a first heat exchanger that exchanges heat between an at least partially vaporized nitrogen stream and the cooled compressed natural gas stream to form an additionally cooled compressed natural gas stream;

a work-producing natural gas expander that expands the additionally cooled compressed natural gas stream to a pressure less than 200 bara, but no greater than the pressure to which the natural gas compressor compresses the natural gas stream, to thereby form a chilled natural gas stream; and

a second heat exchanger that at least partially condenses the chilled natural gas stream by exchanging heat between the chilled natural gas stream and the liquid nitrogen stream to form the at least partially vaporized nitrogen stream, wherein the at least partially vaporized nitrogen stream passes through the first heat exchanger.

2. The liquefied natural gas production system of claim 1, wherein the natural gas compressor compresses the natural gas stream to a pressure greater than 200 bara.

3. The liquefied natural gas production system of either claims 1 or 2, wherein the natural gas expander expands the additionally cooled compressed natural gas stream to a pressure less than 135 bara.

4. The liquefied natural gas production system of any of claims 1-3, wherein the liquid nitrogen supply is produced at a different location of the liquefied natural gas production system and transported as a liquid to the liquefied natural gas production system.

5. The liquefied natural gas production system of any of claims 1-4, wherein the at least

partially vaporized nitrogen stream is released to environment as a vapor after passing through the first heat exchanger.

6. The liquefied natural gas production system of claim 1, wherein the first heat exchanger comprises at least one printed circuit heat exchanger.

7. The liquefied natural gas production system of claim 1, further comprising a greenhouse gas removal unit configured to remove greenhouse gas from the at least partially vaporized nitrogen stream, wherein the greenhouse gas removal unit comprises a distillation column having a heat pump condenser and reboiler system, and 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, and 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, the heat pump system including a heat pump compressor, a heat pump cooler, and a feed-effluent heat exchanger.

8. The liquefied natural gas production system of any one of claims 1-7, further comprising a psychrometric 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 first heat exchanger.

9. The liquefied natural gas production system of any one of claims 1-8, wherein the natural gas cooler is configured to cool the compressed natural gas stream to near ambient temperature after being compressed by the natural gas compressor.

10. The liquefied natural gas production system of any one of claims 1-9, further comprising a first nitrogen expander that expands the at least partially vaporized nitrogen stream to form a first cool nitrogen gas stream;

wherein the first cool nitrogen gas stream is passed through the second heat exchanger to at least partially condense the chilled natural gas stream and form a first warm nitrogen gas stream.

11. The liquefied natural gas production system of claim 10, further comprising a second nitrogen expander that expands the first warm nitrogen gas stream to form a second cool nitrogen gas stream;

wherein the second cool nitrogen gas stream is passed through the second heat exchanger to at least partially condense the chilled natural gas stream and form a second warm

nitrogen gas stream.

12. The liquefied natural gas production system of claim 11, further comprising:

a nitrogen compressor that compresses the second warm nitrogen gas stream to form a compressed nitrogen gas stream;

a nitrogen cooler that cools the compressed nitrogen gas stream by indirect heat exchange with an ambient temperature fluid to form a cool compressed nitrogen gas stream; and

a third nitrogen expander that expands the cool compressed nitrogen gas stream to form a third cool nitrogen gas stream;

wherein the third cool nitrogen gas stream is passed through the second heat exchanger to at least partially condense the chilled natural gas stream and form a third warm nitrogen gas stream; and

wherein the third warm nitrogen gas stream is the at least partially vaporized nitrogen stream that exchanges heat with the cooled compressed natural gas stream in the first heat exchanger to form the additionally cooled compressed natural gas stream.

13. The liquefied natural gas production system of any of claims 1-12, wherein the first heat exchanger comprises at least two heat exchangers, and wherein the second heat exchanger comprises at least two heat exchangers.

14. A method of producing liquefied natural gas (LNG), the method comprising:

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

providing a liquid nitrogen stream from a liquid nitrogen supply;

compressing the natural gas stream in a natural gas compressor to a pressure of at least 135 bara to form a compressed natural gas stream;

cooling, through indirect heat exchange with an ambient fluid in a natural gas cooler, the compressed natural gas stream to form a cooled compressed natural gas stream;

passing the cooled compressed natural gas stream and an at least partially vaporized nitrogen stream through a first heat exchanger that exchanges heat between the at least partially vaporized nitrogen stream and the cooled compressed natural gas stream to additionally cool the cooled compressed natural gas stream to form an additionally cooled compressed natural gas stream;

expanding, in a work producing natural gas expander, the additionally cooled compressed natural gas stream to a pressure less than 200 bara, but no greater than the pressure to which the natural gas compressor compresses the natural gas stream, to thereby produce a chilled natural gas stream; and

liquefying the chilled natural gas stream by passing the chilled natural gas stream and the liquefied nitrogen stream through a second heat exchanger that exchanges heat therebetween, wherein the liquefied nitrogen stream passes through the second heat exchanger to form the at least partially vaporized nitrogen stream.

15. The method of claim 14, wherein the natural gas compressor compresses the natural gas stream to a pressure greater than 200 bara, and wherein the natural gas expander expands the additionally cooled compressed natural gas stream to a pressure less than 135 bara.

16. The method claim 14 or claim 15, further comprising:

expanding the at least partially vaporized nitrogen stream in a first nitrogen expander to form a first cool nitrogen gas stream;

passing the first cool nitrogen gas stream through the second heat exchanger to at least partially condense the chilled natural gas stream and form a first warm nitrogen gas stream;

expanding the first warm nitrogen gas stream in a second nitrogen expander to form a second cool nitrogen gas stream;

passing the second cool nitrogen gas stream through the second heat exchanger to at least partially condense the chilled natural gas stream and form a second warm nitrogen gas stream;

compressing the second warm nitrogen gas stream in a nitrogen compressor to form a compressed natural gas stream;

cooling the compressed nitrogen gas stream by indirect heat exchange with an ambient temperature fluid in a nitrogen cooler to form a cool compressed nitrogen gas stream;

expanding the cool compressed nitrogen gas stream in a third nitrogen expander to form a third cool nitrogen gas stream; and

passing the third cool nitrogen gas stream through the second heat exchanger to at least partially condense the chilled natural gas stream and form a third warm nitrogen gas stream.

17. The method of claim 16, wherein the third warm nitrogen gas stream is the at least partially vaporized nitrogen stream that exchanges heat with the cooled compressed natural gas

stream in the first heat exchanger to form the additionally cooled compressed natural gas stream.

18. The method of claim 16, further comprising 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, and further comprising:

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; and

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.

19. The method of any one of claims 14-18, wherein the natural gas cooler cools the compressed natural gas stream to near ambient temperature after being compressed by the natural gas compressor.

20. A method of removing greenhouse gas contaminants in a liquid nitrogen stream used to liquefy a natural gas stream, comprising:

compressing the natural gas stream in a natural gas compressor to a pressure of at least 135 bara to form a compressed natural gas stream;

cooling, in a natural gas cooler, the compressed natural gas stream to form a cooled compressed natural gas stream;

passing the cooled compressed natural gas stream and an at least partially vaporized nitrogen stream through a first heat exchanger that exchanges heat between the at least partially vaporized nitrogen stream and the cooled compressed natural gas stream to additionally cool the cooled compressed natural gas stream to form an additionally cooled compressed natural

gas stream;

expanding, in a natural gas expander, the additionally cooled compressed natural gas stream to a pressure less than 200 bara, but no greater than the pressure to which the natural gas compressor compresses the natural gas stream, to thereby form a chilled natural gas stream;

passing the cooled compressed natural gas stream and the liquefied nitrogen stream through a second heat exchanger that exchanges heat between the liquefied nitrogen stream and the chilled natural gas stream to form the at least partially vaporized nitrogen stream and to at least partially liquefy the chilled natural gas stream, wherein the liquefied nitrogen stream is circulated through the second heat exchanger at least three times, and wherein the at least partially vaporized nitrogen stream passes through the first heat exchanger;

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

providing a greenhouse gas removal unit that includes a distillation column and 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 overhead stream 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;

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; and

venting the first separator overhead stream to atmosphere.