A fixed LNG production facility is described. The LNG production facility is positioned in a body of water at a production location, the facility comprising a plurality of spaced-apart modules, each module provided with plant equipment related to a pre-determined function associated with the production of LNG, and wherein at least one of the spaced-apart modules is arranged to provide a breakwater for at least one other module.
**LNG PRODUCTION FACILITY**

**FIELD OF THE INVENTION**
The present invention relates to a liquefied natural gas ("LNG") production facility combining upstream gas receiving facilities along with downstream LNG processing facilities offshore. The LNG production facility of the present invention is particularly suited for remote gas fields. The present invention relates to both a small-scale and or full scale fixed LNG production facility located offshore or near shore.

**BACKGROUND TO THE INVENTION**
Natural gas ("NG") is routinely transported from one location to another location in its liquid state as "Liquefied Natural Gas ("LNG"). Liquefaction of the natural gas makes it more economical to transport as LNG occupies only about 1/600th of the volume that the same amount of natural gas does in its gaseous state. After liquefaction, LNG is typically stored in cryogenic containers either at or slightly above atmospheric pressure. LNG is regasified before distribution to end users through a pipeline or other distribution network at a temperature and pressure that meets the delivery requirements of the end users. Regasification of the LNG is most commonly achieved by raising the temperature of the LNG above the LNG boiling point for a given pressure. Transportation of LNG from one location to another is most commonly achieved using ocean-going vessels with cryogenic storage capability referred to as "LNG Carriers" or "tankers". It is common for a LNG Carrier to berth at a pier or jetty of an import terminal and offload the LNG as a liquid to an onshore storage and regasification facility. The regasification facility typically comprises a plurality of heat exchangers or vaporisers, pumps and compressors.

Conventional LNG production from offshore gas fields involves the use of upstream receiving facilities which deliver treated wellhead gas through large diameter gas pipelines to shore, onshore LNG plants, onshore storage terminals and deepwater export terminal jetties. Commonly there is further treatment of the gas onshore. Typically the only offshore treatment is drying and sometimes removal of liquids. Further treatment (removal of acid gases, drying to < 1 ppm water, mercury removal and removal of LPGs to obtain desired heating value) is generally done onshore. These conventional facilities are typically large and the costs associated with building and operating such facilities are significant. One of the most significant development costs
associated with conventional onshore LNG production is the cost of laying and maintaining the offshore pipeline that links the offshore gas field with the onshore LNG production facility, some of which can be more than 400 km in length.

Various offshore development concepts have been considered in the past that combine upstream receiving facilities along with downstream processing facilities on a singular offshore facility to process stranded gas.

For example, US Publication Number 2006/0000615 describes a method for developing a sub-sea hydrocarbon field. Sub-sea flow lines convey the natural gas output from a sub-sea oil/gas separator to a Floating Production Storage Shuttle Vessel (FPSSV). Natural gas is liquefied using an LNG Production Facility located aboard the FPSSV, the LNG so produced being stored in storage tanks onboard the FPSSV. When the storage tanks are full, the FPSSV transports the LNG to an onshore terminal. At the onshore terminal, the LNG is re-gasified and a new batch of liquid nitrogen is produced using energy recovered during LNG regasification.

US Publication Number 2006/0010910 and US Publication Number 2006/0010911 A each describe methods and systems for transportation of a cryogenic fluid. The system includes a floating liquefaction unit receiving a gas from a source, a shuttle vessel for carrying liquefied gas away from the liquefaction unit, and a floating regasification unit for receiving the liquefied gas from the vessel, regasifying the liquefied gas and providing the gas to a distribution system. The cryogenic fluid is preferably LNG. The floating liquefaction unit is positioned on a body of water and is moored via a connection to a source of natural gas. This source of natural gas may be a direct pipeline connection to natural gas being produced from a well (s), a mobile vessel (s), or to storage tanks. Periodic connections could also be made to land or marine transport vessels carrying storage tanks of natural gas.

US Publication Number 2003/0226373 A describes a process and apparatus for exploitation and liquefaction of natural gas in offshore stranded gas reserves. Two ordinary nautical vessels are used to produce, store and unload LPG and LNG. Typical front end gas processing is performed on the first vessel to produce a treated inlet gas stream. The treated inlet gas is transported to the second vessel where the stream goes
through liquefaction and storage until the LNG can be offloaded to a transport vessel for shipment. The liquefaction process utilizes two refrigerant cycles that utilize two expanded refrigerants, at least one of which is circulated in a gas phase refrigeration cycle. The refrigerants and the inlet gas stream are transported between the two vessels by the use of piping.

US Patent 6,003,603 (Breivik) teaches the use of two ships for the processing and storage of offshore natural gas. The first ship includes the field installation for gas treatment. The treated gas is then transferred in compressed form to an LNG Carrier for conversion to a liquefied form, which is stored on the LNG Carrier. Breivik utilizes a single refrigerant for cooling purposes within the liquefaction process, which is either in a liquid phase or a mixed phase. Once the LNG Carrier storage vessels are full, the LNG Carrier is disconnected from a buoy to which it is attached and sets sail. Another LNG Carrier takes its place to receive the treated inlet gas for liquefaction. The LNG Carrier is required to be seaworthy in order to transport the LNG product from the stranded reserves to facilities for further use.

International Patent Publication Number WO 1996/036529 describes a method of loading and treatment of a gaseous or liquid hydrocarbon mixture produced on an offshore production platform, a production vessel or a well installation when producing oil and gas from a reservoir, wherein the mixture is supplied to a gas treatment vessel via a buoy loading system comprising a buoy of the STL/STP type, and is treated on board the vessel for producing liquefied natural gas (LNG) or an LPG mixture stored in tanks on the vessel. Simultaneously with the supply of the hydrocarbon mixture, oil is also supplied to the vessel via the same buoy, the buoy including a multi-course STP connector, the oil being transferred directly from the STP connector via a pipeline and an unloading means on the vessel to a tanker for storage and transport of the supplied oil.

GB Patent 1596330 relates to a process for the production of a liquefied natural gas, preferably offshore, which process comprises the steps of supplying gaseous natural gas to a sea-going vessel which is adapted to store and transport LNG, and passing the said gaseous natural gas and a liquefied gas through a heat exchanger situated on board the said sea-going vessel so that the said gaseous natural gas is liquefied and the said liquefied gas is gasified, the said liquefied gas having a boiling point at atmospheric
pressure which is lower than the critical temperature of methane. Liquid air or nitrogen is produced on shore and transported in a tanker to the field. The tanker is equipped with heat exchangers and other equipment for gas liquefaction. At the field are one or more mooring terminals to which the tanker can be moored and connected to a supply of gas from the production facilities, most probably via a subsea flowline, buoy riser, and loading hose. After mooring, gas is admitted to the liquefaction plant on or in the tanker and liquefied by heat exchange with the liquid air/nitrogen. Before its liquefaction each gas has to be pretreated to remove therefrom impurities, such as water and carbon dioxide, to an extent which is sufficient to avoid blockages. The liquefied gas is then stored in the cryogenic tanks on the tanker until a full or substantial load is achieved. The tanker unmoors and returns to port. Here, LNG is discharged, liquid air/nitrogen reloaded, and the cycle re-commenced. By the use of more than one tanker and mooring terminal, continuous gas liquefaction can be achieved by the field.

International Patent Publication Number WO2002/021060 describes a floating plant for liquefying natural gas comprising a barge which is provided with a liquefaction plant, means for receiving natural gas, means for storing LNG and means for discharging LNG. The liquefaction plant includes a heat exchanger in which heat removed when liquefying natural gas is transferred to water. The liquefied natural gas is stored in the barge and it can be discharged into a vessel suitable for transporting the liquefied natural gas to shore.

European Patent Publication Number EP1 30066 relates generally to a method and system for producing natural gas from wells located offshore, and making it available to a terminal installation. This patent describes transporting pressure vessel means mounted on watercraft, which are utilized to recover raw natural gas from shut-in offshore wells. After a discrete batch of raw gas is contained within the transporting pressure vessel means, the watercraft is moved to a processing station, also preferably located on a platform offshore. At the processing station, liquids are separated from the natural gas, and then the natural gas is passed through a dehydrator and compressor before entering a pipeline.

In all of these prior art offshore concepts, the LNG production facilities are floating, with the plant equipment for liquefaction located onboard the same barge or vessel within
which the LNG is stored. The power generation facilities, the vents, the flares, and the crew accommodation facilities are all located on the same barge or vessel which results in an unacceptable risk in the event of an incident, accident or mishap at sea. Another drawback with these prior art offshore concepts is that the LNG production facility is designed to fit within the compact footprint of a barge or vessel and is restricted to a particular fixed size. This makes it difficult to accommodate changes in design or processing, resulting in unacceptable risk being carried. The fixed size also means that these concepts lack economies of scale and expandability in that if greater capacity is required or an extra LNG train is later needed, an extra self contained barge is generally required. There are also large loads placed on plant equipment on such barges as a consequence of wave motion upon these floating structures.

There remains a need to explore alternative designs for LNG production facilities.

SUMMARY OF THE INVENTION

According to one aspect of the present invention there is provided a fixed LNG production facility positioned in a body of water at a production location, the facility comprising a plurality of spaced-apart modules, each module provided with plant equipment related to a pre-determined function associated with the production of LNG, and wherein at least one of the spaced-apart modules is arranged to provide a breakwater for at least one other module.

The overall number and type of modules may vary depending on the needs of the LNG production facility. In one embodiment, the plurality of spaced-apart modules includes:

a) at least one gas processing module for receiving raw hydrocarbons from a producing well and treating the raw hydrocarbons to remove contaminants therefrom to produce a stream of treated gas;

b) at least one liquefaction modules for receiving the stream of treated gas from a gas processing module and liquefying the natural gas to produce LNG;

c) at least one storage modules operatively associated with the liquefaction module for receiving and storing LNG; and,

d) at least one berthing module including LNG transfer facilities to transfer the LNG from a storage module to an LNG Carrier.
The type of module used to provide shelter to another module can vary. In one embodiment, the at least one storage module is arranged to provide a breakwater for the at least one liquefaction module. Alternatively or additionally, the at least one gas processing module is arranged to provide a breakwater for the at least one liquefaction module. In another embodiment, the at least one gas processing module is arranged to provide a breakwater for the at least one berthing module. Alternatively or additionally, the at least one storage module is arranged to provide a breakwater for the at least one berthing module.

The at least one storage module may be the at least one berthing module.

To provide greater flexibility to the LNG production facility, the spaced-apart modules may have adjustable ballast such that the modules are transportable from a first location to a second location. Advantageously, the first location may be a construction location and the second location may be a production location, allowing the modules to be constructed at a plurality of construction locations before assembly at the production location. The LNG production facility is relocatable in that first location may be a first production location and the second location may be a second production location.

For greater flexibility in construction, the each module may comprise a plurality of similarly-sized sub-modules. Advantageously, the spaced-apart modules or sub-modules may be constructed at one or more independent construction locations and integrated at the production location or at an independent assembly location. The LNG production facility has a production capacity and the production capacity may be increased by adding additional modules or sub-modules to the LNG production facility or decreased by removing modules from the LNG production facility.

The modules may be constructed as jackets or gravity based structures, depending in part on the contour of the production location. When a first portion of the production location is in deepwater, a module located in the first portion of the production location is preferably a jacket structure. When a second portion of the production location is in shallow water, a module located in the second portion of the production location is preferably a gravity based structure. Advantageously, the gravity based structure may include a ballast storage compartment and one or more liquids selected from the group
consisting of: water; condensate; monoethylene glycol; methanol; diesel; demineralised water; diesel; and, LPG, may be stored in the ballast storage compartment.

In one embodiment, the LNG production facility further comprises a spaced-apart utility module and the utility module shares power between the liquefaction module and the gas processing module.

Carbon dioxide is one of the contaminants removed from the raw hydrocarbons by the gas processing module and the carbon dioxide may be re-injected into the reservoir to reduce greenhouse gas emissions.

In one embodiment, at least a portion of a bottom surface of each liquefaction module rests upon a portion of a bottom of the body of water for greater stability and to reduce environmental loading on the liquefaction module. Alternatively or additionally, at least a portion of a bottom surface of each gas processing module rests upon a portion of a bottom of the body of water. Depending on the contours of the production location, at least a portion of a bottom surface of each module may rest upon a portion of a bottom of the body of water for greater stability in use.

The LNG production facility may further comprise an accommodation module spaced apart from the storage module and the liquefaction module to provide a safe haven for personnel operating the LNG production facility. This is highly advantageous in that it removes the need to provide lifeboats to evacuate personnel in the event of a mishap such as fire or an explosion.

In one embodiment, the storage module comprises at least one cryogenic tank for storing LNG from the liquefaction module and at least one non-cryogenic tank for storing a liquid from the gas processing module selected from the group consisting of: natural gas liquids, condensate, water or LPG.

The production location may be an offshore location or a near-shore location.

According to a second aspect of the present invention there is provided a method of using the LNG production facility of the first aspect of the invention, the method
comprising the steps of:

a) receiving natural gas from a well;
b) liquefying the natural gas to form LNG;
c) transferring the LNG from the liquefaction module to a storage module;
d) storing the liquefied natural gas in the storage module; and

5 e) loading the LNG from the storage module onto an LNG Carrier.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to facilitate a more detailed understanding of the nature of the invention several embodiments of the present invention will now be described in detail, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic plan view of one embodiment of the present invention;

Figure 2 is a process diagram illustrating the use of a plurality of independent construction locations, an assembly location and relocatability of the LNG production facility from a first location to a second location;

Figure 3 is a side view of one embodiment of the present invention illustrating the use of jacket structures in deepwater and gravity based structures in shallow water; and,

Figure 4 is a schematic view of another embodiment of the present invention.

DETAILED DESCRIPTION OF PARTICULAR EMBODIMENTS

Particular embodiments of the present invention are now described. The terminology used herein is for the purpose of describing particular embodiments only, and is not intended to limit the scope of the present invention. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art to which this invention belongs.

With reference to FIG.1, the present invention relates to a fixed LNG production facility 10 positioned in a body of water 12 at a production location 14, such as an offshore or near shore gas field. The term "fixed" as used throughout this specification means "set in position at a predetermined or prearranged location". It is to be clearly understood that this does not imply that the production facility must remain at a given production
facility permanently. The LNG production facility 10 comprises a plurality of spaced-apart modules 16, each module having a pre-determined function associated with the production of LNG. The production location 14 can be remote offshore or near-shore.

The LNG production facility includes at least the following modules:

a) at least one gas processing module 18 for receiving raw hydrocarbons from a producing well and treating the raw hydrocarbons to remove contaminants therefrom to produce a stream of treated gas;

b) at least one liquefaction module 20 for receiving the stream of treated gas from a gas processing module 18 and liquefying the natural gas to produce LNG;

c) at least one storage module 22 operatively associated with the liquefaction module 20 for receiving and storing LNG; and,

d) at least one berthing module 24 including LNG transfer facilities 26 to transfer the LNG from a storage module 22 to an LNG Carrier 28 on an as-needs basis.

Other additional modules may be included in the fixed LNG production facility 10 of the present invention. Advantageously, utilities may be shared using a separate spaced-apart utility module 32 which acts as a hub servicing some or all of the other modules in the LNG production facility 10. Alternatively, each other module may be associated with its own separate utility module. The utility module 32 provides such services as power, compressed air, nitrogen, and heated water to the liquefaction module 20 and/or the gas processing module 18. When the LNG production facility 10 is manned, accommodation for the personnel may be provided on the gas processing or liquefaction modules 18 and 20 respectively, or a separate spaced-apart accommodation module 34 can be used for greater safety as discussed in greater detail below. A supply system 30 in the form of piping and associated pumps, manifolds and valves etc is also provided for transferring treated gas from a gas processing module 18 to a liquefaction module 20 and for transferring LNG from a liquefaction module 20 to a storage module 22.

The fixed LNG production facility 10 of the present invention is designed to accommodate severe weather conditions such as hurricanes, tropical depressions, tsunamis or tidal waves, and/or electrical storms. During severe weather conditions, large waves may impact the LNG production facility and green water may flow over the substructure of the modules (with the topside plant equipment being raised high enough
to avoid green water). At least one meter of water present on a horizontal face of the structure may be classified as green water. The specific layout of the LNG production facility may account for severe weather conditions by arranging at least one of the modules 36 as a breakwater to reduce the impact of wave forces on at least one other module 38. For example, a storage module 22 may be arranged at the production location 14 in such as way so as to provide a breakwater to reduce the force of wave impact on the liquefaction module 20 and/or gas processing module 18. As another example, a storage module may be arranged so as to provide shelter for one or more of the LNG Carrier berthing module(s) 24.

With reference to FIG. 2, the modules 16 can be separately constructed at one or more independent construction location(s) 40 and then transported to the production location 14, where the modules are installed and operatively linked to produce and store LNG. Constructing the modules at a plurality of separate independent construction locations 40 provides a number of advantages over prior art methods. Construction of each type of module can occur at different construction locations to take advantage of expertise of different suppliers located at different construction locations. Similarly, construction can occur at different times to allow overall construction time to be fast-tracked. For example, the construction of the liquefaction modules can take place in the Middle East, with construction of the storage modules taking place in South East Asia and the construction of the gas processing module can occur in Australia, all to service the needs of a production location off the coast of Africa or the Gulf of Mexico.

Each module 16 may comprise a plurality of similarly-sized sub-modules 42, which can be integrated at the production location or at an independent assembly location 44. The sub-modules 42 may be constructed a separate construction locations 40 and towed to a common assembly location 44 for integration. This option is particularly attractive if there is a restriction on the space available at the dry dock or "graving dock" or restrictions on the towable or installable size of a given module. Advantageously, once the sub-modules 42 have been assembled to form a module 16 at the assembly location 44, testing or commissioning of the module 16 can be conducted before transportation of the module to the production location 14. It is particularly advantageous when such commissioning can be done at an assembly location onshore prior to transportation of the module to a production location offshore.
The present invention provides significant advantages over prior art offshore LNG plants in terms of flexibility. The modular construction allows for additional modules or sub-modules 42 to be added or removed, if applicable due to late changes to the process functionality. The number and size of the various modules 16 and/or sub-modules 42 can be tailored to suit the changing needs of a particular site or to suit the changing flow from a reservoir over its production life cycle of a gas reservoir - for example, the number of liquefaction modules 20 may vary from time to time. The flexibility of the LNG production facility of the present invention allows economic exploitation of small offshore gas fields that would otherwise not be developed. This significantly increases the number of gas reserves around the world that can be developed as LNG, particularly those that are far from the mainland or those which would require onshore plants with significant civil engineering, environmental or social challenges.

Moreover, the operating capacity of the LNG production facility 10 may change overtime based on a number of factors including depletion of hydrocarbons in the field over time, changes in the storage capacity of the LNG Carriers into which the LNG produced at the facility is loaded, the desired peak production capacity of the production facility, the rate at which LNG from a storage module is transferred to an LNG Carrier, and/or costs associated with operating the LNG production facility. Additional storage modules 22 may be added at a later date if it becomes apparent that production is higher than anticipated or loading schedules are longer than anticipated. In some cases, the production capability need only be small, for example, in the range of one to two million tonnes a year. When supply of gas at a particular location diminishes or increases or stops, the size and location of the modular LNG plant can change to suit the change in conditions. In one embodiment, the modules 16 are transportable in that they are movable from the construction location(s) 40 to the production location 14 by towing or on floating barges 46. This feature not only allows the modules to be deployed where required but is also advantageous when maintenance or upgrading is required. To reduce frictional drag on the modules 16 during transport, the bow section of the substructure of the module 16 can be shaped (in an analogous manner to the bow of a ship).

The various modules 16 can equally be re-deployed at different locations at different times to suit LNG supply and demand. Similarly individual modules 16 or sub-modules
42 can be moved to another location where demand is higher. In one embodiment, individual modules 16 or sub-modules 42 can be reused or relocated or replaced at a point in time when they are no longer required due to changes in the production capacity of the facility 10 or towards the end of the field life. Thus with reference to FIG. 2, one or more of the modules 16 can be moved from a first production location 14' to a second production location 14".

The modules 16 comprising the LNG processing facility 10 of the present invention may take the form of fixed platforms or "jacket structures" 60 or a gravity based structure 62, depending on such relevant factors as the contours and depth of the bottom of the body of water at the production location and the type of module. In another embodiment, one or more of the modules are arranged on one or more steel or concrete barges or "bricks". Irrespective of the depth of the body of water, a gravity based structure is preferred for some types of modules for maximum safety and stability against extreme weather conditions. By way of example, it is preferable to construct the sub-structure of the liquefaction module(s) as a concrete gravity base structure using sub-modular construction and assembly for the topside equipment arranged on that substructure. The gravity based structure is constructed using lightweight or semi-lightweight concrete (having a density of less than about 2000kg/m³). A key advantage of the use of a gravity-based liquefaction module is that it provides a stable base which allows the LNG plant to continue production in extreme weather conditions. Thus for greater stability, the spaced-apart modules are arranged at the production location 14 such that at least a portion of a bottom surface 48 of each gas processing module 18 and/or each liquefaction module 20 rests upon a portion of a bottom 50 of the body of water 12.

With reference to FIG. 3, for modules which are intended to be located in deep water at the production location, such modules may be constructed in the form of a fixed platform, semi-submersible platforms (such as a tension-leg platform or a "SPAR") or "jacket" structure 60. These deep water modules are arranged to support the various equipment used for the function of the given module above the waterline 62 (for ease of operation and to reduce damage from overtopping waves and/or green water) with the base of the structure being secured in position relative to the bottom 50 of the body of water 12 at the production location 14.

In one embodiment of the present invention, at least a portion of the production location
is located in shallow water. The water depth at the shallow water production location may be in the range of 2 to 50 meters, preferably 10 to 35 meters, more preferably 15 to 30 meters or 2 to 20 meters. Each transportable module 16 is towed from the construction or assembly location 40 or 44 respectively, to the production location 14 and then arranged in a suitable pre-determined position to suit the needs of the LNG production facility 10. If the pre-determined position is located in shallow water, settling is achieved by adjusting the ballast or buoyancy of each transportable module 16, for example through the addition of water, iron ore or other suitable ballasting material. The transportable modules are settled into the shallow water such that at least a portion of the base 48 of each module 16 rests on the bottom 50 of the body of shallow water 12 to secure the position of the module 16. This provides the shallow water modules with greater stability.

To facilitate the ballasting process, the shallow water modules are provided with a ballast storage compartment 52 arranged around the periphery or toward the base 48 of the module 16 for ballasting. In use, the ballast storage compartment 52 is at least partially filled with solid and/or liquid ballast material. For example, in certain embodiments, sand and/or iron ore may be used as solid ballast material. The amount of ballast required to secure the shallow water modules depends on a number of relevant factors including but not limited to the shear strength of the underlying clay or silt material found at the bottom of the body of water. In some embodiments of the present invention, water, condensate, monoethylene glycol (MEG), methanol, diesel, demineralised water, diesel, LPG or combinations thereof are stored in the ballast storage compartments 52 to supplement the permanent liquid or solid ballast used to ground the shallow water module 16. This reduces the number of additional storage tanks which would otherwise be needed and allows much larger quantities of the liquids to be stored at the LNG production facility 10 (enhancing facility operability) at minimal extra cost.

Combining the upstream gas receiving facilities and the downstream LNG processing facilities at a single production location has a number of advantages. Firstly, the need to install, operate, maintain and pay tariffs on an expensive gas pipeline to shore is removed, making production of stranded gas fields economically feasible. More importantly, combining these facilities at a single production location provides a number of synergistic benefits. The upstream and downstream facilities are able to share
personnel, consumables and power to reduce overall operating costs associates with the LNG production facility. A common utility module 32 is used to provide power to both the gas processing module 18 and the liquefaction module 20 to reduce overall sparing. Similarly, the common utility module 32 is arranged to distribute air, water and nitrogen between the gas processing 18 and liquefaction module 20. Excess heat from power generation associated with the utility module 32 can be used to provide heating to the MEG (monoethyleneglycol) recovery system.

The proximity of the liquefaction module 20 to the wellhead 54 results in an increase in the throughput of the liquefaction module 20 allowing for an increase in throughput through the liquefaction module 20, compared the prior art in which the gas pressure is reduced during transport of the gas through a pipeline to an onshore LNG plant. Another advantage of receiving gas at wellhead pressures is that as the pressure of the reservoir drops over its life, less compression of the gas is required to remove residual gas from the reservoir.

Exemplary examples of embodiments of the fixed LNG production facility of the present invention are now described with reference to FIG. 1 and FIG. 2 for which like reference numerals refer to like parts. In each of FIG. 1 and FIG. 2, a specific number of modules is shown with “future” modules associated with potential future process functionality shown in ‘dotted’ lines. However, it is to be understood that the specific number of each type of module may vary depending on the production capacity of the LNG production facility and may also vary over the production life of the field.

A first embodiment of the present invention is illustrated in FIG. 1 which illustrates a fixed LNG production facility which includes two gas processing modules 18 for conditioning the wellhead gas, two liquefaction modules 20 for liquefying treated natural gas to form LNG, a single utility module 32 including power generation, two storage modules 22 for receiving and storing LNG from the liquefaction modules 20, two berthing modules 24, two spaced-apart flares 56 and a supply system 30. In this embodiment, the accommodation module 34 is adjacent to the utility module 32 but is still spaced-apart at a safe distance from both the gas processing module 18 and the liquefaction module 20 and the flares 56 to maximize safety. The utility module 32 can be arranged to provide a breakwater for the accommodation module 34 or vice versa if desired.
In FIG.1 the contours of the production location 14 are such that the gas processing modules 18, the flares 56, the utility module 32 and the accommodation module 34 are arranged in deepwater and are constructed using 'jacket' substructures with plant equipment arranged on the platform topsides. The liquefaction modules 20 and storage modules 22 are constructed in shallow water and are concrete gravity based structures. The storage modules 22 are arranged to act as a breakwater to reduce environmental loads on the liquefaction modules 20.

In use, wellhead hydrocarbons are delivered to the gas processing modules via a flow line from one or more wellhead located either sub-sea or on a production platform. The wellhead hydrocarbons may be passed through a slug-catcher 55 to ensure a steady flow of gas entering the gas processing modules. The gas processing modules include a separator for effecting initial separation of natural gas from particulates, natural gas liquids (NGL) and condensate. The NGL and condensate streams can be subjected to further fractionation to produce LPG, if desired.

The separated natural gas is then subjected to conditioning to remove contaminants prior to liquefaction. More specifically, hydrogen sulphide and carbon dioxide can be removed using a suitable process such as amine adsorption. Advantageously, due to the proximity of the reservoir, the carbon dioxide so removed can be dewatered, compressed, liquefied and re-injected into the reservoir to reduce greenhouse gas emissions. The natural gas is subjected to further conditioning to remove water and other contaminants, such as mercury and heavy hydrocarbons prior to liquefaction.

The treated natural gas from the gas processing modules is delivered to one or more liquefaction modules. The liquefaction module is designed to receive natural gas from the gas processing module and liquefy the natural gas to produce LNG which is sent out to the storage module(s). Liquefaction is achieved onboard each liquefaction module using methods of well established in the art which typically involve compression and cooling. Such processes include the APCI C3/MR™ or Split MR™ or AP-X™, processes, the Phillips Optimized Cascade Process, the Linde Mixed Fluid Cascade process or the Shell Double mixed Refrigerant or Parallel Mixed Refrigerant process.
In this embodiment, the storage modules are positioned to provide a breakwater for the liquefaction modules so as to at least partially protect the liquefaction modules from wave impacts during production. Moreover, the liquefaction module and gas processing module share common storage modules, the storage module being arranged to accommodate at least one cryogenic storage tank 80 for storing LNG and at least one non-cryogenic storage tank 82 for storing other liquids including but not limited to water, condensate, monoethylene glycol (MEG), methanol, diesel, demineralised water, diesel, LPG or combinations thereof.

The storage module(s) 22 are hydrostatically stable when partially filled to reduce sloshing. To reduce the effects of sloshing, in certain instances the storage tanks are provided with a plurality of internal baffles and has a supporting hull structure capable of withstanding the loads imposed from intermediate filling levels when the module is subject to harsh, multi-directional environmental conditions. The cryogenic storage tank may be a double containment, full containment, or membrane system with a primary tank constructed from, by way of example, but not limited to stainless steel, aluminum, and/or 9%-nickel steel. The cryogenic storage tanks may include pre-tensioned concrete to provide structural resistance to the stored LNG, boil off gas pressure loads and to external hazards.

With reference to FIG. 1, the offshore LNG production facility includes two berthing modules 24 each arranged in sufficiently deep water to allow an LNG Carrier 28 to berth directly alongside to load LNG transferred from the storage module(s) 22. In use, the LNG Carriers 28 berth at regular intervals at the LNG production facility 10 so as to receive a cargo of LNG and may approach the berthing modules 24 from either direction depending on the prevailing weather conditions. Depending on the size of the LNG Carrier 28, the stern of the LNG Carrier 28 may extend beyond an end of the berthing module 24 when the LNG Carrier is berthed alongside the berthing module 24. This overhang of the LNG Carrier's stern beyond the berthing module may expose the LNG Carrier to adverse environmental conditions. To minimize this effect, the berthing module 28 has at least one lateral side which has a length of a sufficient size to allow a range of sizes of LNG carrier to be moored alongside without overhang of the stern.
The berthing module 24 can be fitted with fendering equipment (not shown) arranged to absorb a substantial portion of a load generated by impact of the LNG Carrier 28 with the berthing module 24 during berthing. The berthing module may be designed to allow an LNG Carrier to moor on one or more lateral sides of the berthing module. In one embodiment, the berthing module is arranged to allow bi-directional berthing of an LNG Carrier with the longitudinal axis of the berthing module aligned to be substantially parallel to the direction of the predominant current.

Loading of LNG from the storage modules 22 to the LNG Carrier 28 is achieved using any of the loading methods well established in the industry.

The berthing module 24 includes LNG transfer equipment 26 to transfer LNG from the storage module 22 to the storage tanks (not shown) onboard the LNG Carrier 28. Any suitable LNG transfer equipment may be used such as a fixed or swivel joint loading arm, preferably fitted with an emergency release system. Between loading operations, the LNG transfer equipment 26 may be kept cold by re-circulation of a small quantity of LNG. The LNG transfer equipment 26 may include an emergency safety system to allow loading to be stopped if required in a quick, safe, and controlled manner by closing the isolation valves on the unloading and tank fill lines and stopping the cargo pumps of the LNG carrier. The emergency safety system may be designed to allow LNG transfer to be restarted with minimum delay after corrective action has been taken.

After receiving its cargo of LNG, the LNG Carrier 28 travels to a delivery location (not shown) where the LNG is offloaded and regasified. The LNG Carrier can dock at an import terminal associated with an onshore regasification facility or transfer the LNG to a second LNG Carrier with onboard regasification capability or deliver the LNG to any other suitable offshore storage and regasification facility.

A second embodiment of the present invention is illustrated in Figure 2 for which like reference numerals refer to like parts. In this embodiment, the LNG production facility 10 is arranged such that the storage modules 22 are integrated with the berthing modules 24. The storage module(s) 22 are further arranged to provide a breakwater to protect the LNG Carrier 28 from wave impact whilst berthed during berthing loading. This embodiment is more suited for use in deepwater. The accommodation module 34 is
arranged at a safe distance from the gas processing module 18, the flares 56, and the liquefaction modules 20.

Now that several embodiments of the invention have been described in detail, it will be apparent to persons skilled in the relevant art that numerous variations and modifications can be made without departing from the basic inventive concepts. For example, a LNG Carrier with onboard storage and regasification capability may be used as the storage module and operate for a period of time as part of the LNG production facility. When the LNG Carrier is full, the LNG Carrier disconnects and travels to a mooring location where the LNG stored onboard the LNG Carrier is regasified onboard the LNG Carrier to form natural gas (NG) which is then transferred to an onshore gas distribution facility. The LNG Carrier then returns to pick up another load of LNG from the loading modules or another export terminal. In the meantime, another LNG Carrier is temporarily stationed at the production location forming part of the LNG production facility. In one embodiment, the LNG Carrier serves the function of a storage module. The LNG Carrier may have an onboard regasification facility. All such modifications and variations are considered to be within the scope of the present invention, the nature of which is to be determined from the foregoing description and the appended claims.

It will be clearly understood that, although a number of prior art publications are referred to herein, this reference does not constitute an admission that any of these documents forms part of the common general knowledge in the art, in Australia or in any other country. In the summary of the invention, the description and claims which follow, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.
Claims defining the Invention:

1. A fixed LNG production facility positioned in a body of water at a production location, the facility comprising a plurality of spaced-apart modules, each module provided with plant equipment related to a pre-determined function associated with the production of LNG, and wherein at least one of the spaced-apart modules is arranged to provide a breakwater for at least one other module.

2. The LNG production facility of claim 1 wherein the plurality of modules includes:
   a) at least one gas processing module for receiving raw hydrocarbons from a producing well and treating the raw hydrocarbons to remove contaminants therefrom to produce a stream of treated gas;
   b) at least one liquefaction modules for receiving the stream of treated gas from a gas processing module and liquefying the natural gas to produce LNG;
   c) at least one storage modules operatively associated with the liquefaction module for receiving and storing LNG; and,
   d) at least one berthing module including LNG transfer facilities to transfer the LNG from a storage module to an LNG Carrier.

3. The LNG production facility of claim 2 wherein the at least one storage module is arranged to provide a breakwater for the at least one liquefaction module.

4. The LNG production facility of claim 2 wherein the at least one gas processing module is arranged to provide a breakwater for the at least one liquefaction module.

5. The LNG production facility of claim 2 wherein the at least one gas processing module is arranged to provide a breakwater for the at least one berthing module.

6. The LNG production facility of claim 2 wherein the at least one storage module is arranged to provide a breakwater for the at least one berthing module.

7. The LNG production facility of claim 2 wherein the at least one storage module is the at least one berthing module.
8. The LNG production facility of any one of the preceding claims wherein the spaced-apart modules have adjustable ballast such that the modules are transportable from a first location to a second location.

9. The LNG production facility of claim 8 wherein the first location is a construction location and the second location is a production location.

10. The LNG production facility of claim 8 wherein the first location is a first production location and the second location is a second production location.

11. The LNG production facility of any one of the preceding claims wherein each module comprises a plurality of similarly-sized sub-modules.

12. The LNG production facility of any one of the preceding claims wherein the spaced-apart modules or sub-modules are constructed at one or more independent construction locations and integrated at the production location or at an independent assembly location.

13. The LNG production facility of any one of the preceding claims wherein the LNG production facility has a production capacity and the production capacity is increased by adding additional modules or sub-modules to the LNG production facility or decreased by removing modules from the LNG production facility.

14. The LNG production facility of any one of the preceding claims wherein a first portion of the production location is in deepwater and a module located in the first portion of the production location is a jacket structure.

15. The LNG production facility of any one of the preceding claims wherein a second portion of the production location is in shallow water and a module located in the second portion of the production location is a gravity based structure.

16. The LNG production facility of claim 15 wherein the gravity based structure includes a ballast storage compartment and one or more liquids selected from the group consisting of: water; condensate; monoethylene glycol; methanol; diesel; demineralised
water; diesel; and, LPG, is stored in the ballast storage compartment.

17. The LNG production facility of any one of the preceding claims further comprising a utility module and the utility module shares power between the liquefaction module and the gas processing module.

18. The LNG production facility of any one of claims 2 to 17 wherein carbon dioxide is one of the contaminants removed from the raw hydrocarbons by the gas processing module and the carbon dioxide is re-injected into the reservoir to reduce greenhouse gas emissions.

19. The LNG production facility of any one of claims 2 to 18 wherein at least a portion of a bottom surface of each liquefaction module rests upon a portion of a bottom of the body of water.

20. The LNG production facility of any one of claims 2 to 19 wherein at least a portion of a bottom surface of each gas processing module rests upon a portion of a bottom of the body of water.

21. The LNG production facility of any one of claims 2 to 18 wherein at least a portion of a bottom surface of each module rests upon a portion of a bottom of the body of water.

22. The LNG production facility of any one of the preceding claims further comprising an accommodation module spaced apart from the storage module and the liquefaction module.

23. The LNG production facility of any one of claims 2 to 22 wherein the storage module comprises at least one cryogenic tank for storing LNG from the liquefaction module and at least one non-cryogenic tank for storing a liquid from the gas processing module selected from the group consisting of: natural gas liquids, condensate, water or LPG.
24. The LNG production facility of any one of the preceding claims wherein the production location is an offshore location.

25. The LNG production facility of any one of the preceding claims wherein the production location is a near-shore location.

26. A method of using a LNG production facility described in any one of claims 1 to 25 comprising the steps of:
   a) receiving natural gas from a well;
   b) liquefying the natural gas to form LNG;
   c) transferring the LNG from the liquefaction module to a storage module;
   d) storing the liquefied natural gas in the storage module; and
   e) loading the LNG from the storage module onto an LNG Carrier.

27. An LNG production facility substantially as herein described with reference to and as illustrated in the accompanying drawings.

28. Use of an LNG production facility substantially as herein described with reference to and as illustrated in the accompanying drawings.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.
F25J 1/00 (2006.01)  F27C 5/02 (2006.01)

According to International Patent Classification (IPC) or both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DWPI: (LNG or LPG or Natural(s) Gas or Methane) and (modul+ or transport+ or demount+) and (liqui+ or lique+)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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See patent family annex

* Special categories of cited documents:
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T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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K member of the same patent family

Date of the actual completion of the international search
13 June 2007

Date of mailing of the International search report
21 June 2007

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END OF ANNEX