General introduction:

Höegh LNG is leader in developing the marine natural gas chain

The shipping company Höegh LNG introduces challenging project topics to 5th grade students at NTNU, 2010-2011, to be continued as Master thesis.

We are seeking NTNU students in 4th grade, who are interested in collaborating with us, first as a summer student this year, continuing with the Project and the Master thesis next year.

Background

World wide today, the most significant way to transport natural gas is by pipeline in gaseous form. However, LNG is the fastest growing energy transportation scheme in the world, and ship based transport of LNG is expected to become as important as pipeline transport. In this market, Höegh LNG is today operating LNG carriers and a floating delivery terminal while the company at the same time looks at new and innovative solutions in the marine chain of production – shipping – delivery of natural gas.

Höegh LNG’s main objective is to provide the complete “marine LNG value chain”. And by continuous technical developments, to stay in the forefront of the international natural gas logistics, both regarding liquefied (LNG) and compressed (CNG) natural gas.

The marine value chain starts with floating production (FPSO; Floating Production, Storage and Offloading), continues with the ship based transport (LNG carrier) and ends with the floating re-gasification terminal, either as shuttling SRV ships (Shuttle and Re-gasification Vessel) targeting medium gas volumes and short to medium transport distances, or as a permanently located FSRU vessel (Floating Storage Re-gasification Unit) for medium to large gas volumes.

On the drawing board is our first floating LNG production vessel, the FPSO, with a complete LNG process plant on deck and large storage containments in the ship hull. With this unit in operation within the next years, Höegh LNG provides a complete marine value chain.

As an alternative to LNG, we are exploring CNG (Compressed Natural Gas) as a business opportunity in transportation of natural gas over shorter distances and in smaller volumes. We are now in the stage of finalizing our patented technology within CNG and are planning a pilot demonstration. Other businesses of gas transport may be in developing CO₂ transportation.

Höegh pioneered the transportation of liquefied natural gas (LNG) when contracting the world's first LNG carriers with special Norwegian developed spherical tanks (the Moss type) delivered to the company in 1973. Today, Höegh LNG operates four LNG carriers including the two new vessels delivered in 2006 for the world’s northernmost Snøhvit LNG operation. The same year Höegh LNG ordered two LNG re-gasification vessels for a deepwater port offshore Boston, USA which will come into service this year.
Summary of NTNU Project topics (autumn 2010)

(No.1 – HLNG-pt-2010):

The energy system onboard an LNG FPSO

Objective:
Design the energy (power and heat) system for an LNG FPSO. Identify selection criteria for a wide range of operations. Particularly select a system to suit extreme conditions regarding high CO2 content and low feed gas pressure.

(No.2 – HLNG-pt-2010):

The natural gas liquefaction process onboard an LNG FPSO

Objective:
Design the natural gas liquefaction process (LNG) for an LNG FPSO. Scan publications on LNG processes. Pay particular attention to the environmental profile related to Höegh’s corporate objectives. Identify selection criteria and make comparisons with different concepts based on key selection criteria for offshore and floating application.

(No.3 – HLNG-pt-2010):

The natural gas pre-processing of carbon dioxide removal onboard an LNG FPSO

Objective:
Design the natural gas CO2 purification process to meet specifications of the liquefaction process (LNG). Scan the market for different concepts. Identify critical parameters to suit the application on an FPSO. Identify selection criteria and make comparisons of concepts based on key selection criteria for offshore and floating application.

(No.4 – HLNG-pt-2010):

The carbon foot-print of the maritime LNG value chain from production to gas grid

Objective:
Analyse the overall fuel and energy balance in the present Höegh LNG designed marine value chain. Pay particular attention to the environmental profile related to Höegh’s corporate objectives. Make proposals to the Höegh design and operations. Suggest global optimization principles to the present logistic chain.
(No.5 – HLNG-pt-2010):

The offloading systems of cryogenic product from an LNG FPSO

Objective:
The offloading systems onboard an LNG FPSO is designed either as an offloading side-by-side or as a tandem concept. In the overall LNG maritime chain there are several loading and off-loading systems (FPSO / SRV / FSRU / LNG carrier / LPG). The selection of the systems are related to a series of operational concerns such as loading ratio / regularity-availability / safety aspects / wind and waves / weather-vaning versus fixed location / cost and carrier vessels flexibility. Scan the market for different concepts, Analyse the experience of the Höegh’s ship-to-ship pilot test experience. Identify critical parameters to suit the application on an LNG FPSO. Identify selection criteria and make comparisons of concepts based on key selection criteria for different services and locations.

(No.6 – HLNG-pt-2010):

The re-gasification process for LNG onboard a SRV / FSRU vessel

Objective:
Design the LNG re-gasification process of the SRV / FSRU vessel producing natural gas at pipeline conditions. Scan publications on re-gasification concepts, closed – open –fiired designs, and relate different flag state constraints to most optimal process selection. Pay particular attention to the environmental profile related to Höegh’s corporate objectives. Identify selection criteria and make comparisons with different concepts based on key selection criteria for offshore and floating application.

(No.7 – HLNG-pt-2010):

The carbon foot-print of the maritime CNG (Compressed Natural Gas) value chain

Objective:
Design the natural gas compression process (CNG) for a CNG Shuttle, including the land based process infrastructure. Scan publications on CNG processes. Analyse the overall fuel and energy balance in the present Höegh/CETech designed marine value chain. Pay particular attention to the environmental profile related to Höegh’s corporate objectives. Make proposals to the Höegh/CETech process design and chain operations. Identify selection criteria and make comparisons with different concepts based on key selection criteria. Suggest global optimization principles to the present logistic chain.

Attached:
Project topics 2010 (complete text proposal)
NTNU Project topic (autumn 2010)

No.1: Energy system onboard an LNG FPSO

Objective:
Design the energy (power and heat) system for an LNG FPSO. Identify selection criteria for a wide range of operations. Particularly select a system to suit extreme conditions regarding high CO2 content and low feed gas pressure.

Project tasks:
1. Make a literature survey including Höegh FPSO documents and NTNU reports
2. Relate the energy system to key parameters of the marine LNG value chain
3. Analyse the power and heat systems for extreme conditions and identify limitations
4. Identify improvements to the Höegh FPSO present design and engineering
5. Simulate the selected energy system efficiency
6. Conclusion and recommendation
7. Master thesis objective

Information:
In LNG power and heat systems, the balance of demand is dependant of the feed gas and on the location of the production vessel. Further, the power and heat balance is dependant of the feed gas, the gas processing efficiencies and the air and water temperatures. Space and weight requirements and environmental factors may impact the concept selection.

In floating LNG liquefaction process there are different driver concepts available. The main concepts are:
- Electrical power production by onboard power module producing power necessary for all topside and marine systems. The electrical distribution system could be combined with electrical power from shore.
- Gas turbine direct drive of electrical power generators and gas turbine direct drive of liquefaction compressors.
- Steam turbine direct drive of electrical power generators and steam turbine direct drive of liquefaction compressors.
- Combination of alternative 2 and 3 in order to achieve optimum use of fuel.

Depending of the feed gas composition with respect to CO2 and N2 content the amount of heat in the gas pre-treatment process will vary. An indication of the power and heat demands:
- Marine and topside utility electrical power 40 - 55 MW
- Liquefaction compression and expansion power 105 - 150 MW
- Thermal power for acid gas removal and other consumers 40 - 75 MW

When analyzing the different alternatives the total need for power onboard both thermal power and rotational power are evaluated as part of the same complete power and heat scheme.
Höegh LNG - shipping company
Introducing challenging topics for 5th grade students at NTNU

NTNU Project topic (autumn 2010)

No.2: Natural gas liquefaction process onboard an LNG FPSO

Objective:
Design the natural gas liquefaction process (LNG) for an LNG FPSO. Scan publications on LNG processes. Pay particular attention to the environmental profile related to Höegh’s corporate objectives. Identify selection criteria and make comparisons with different concepts based on key selection criteria for offshore and floating application.

Project tasks:
1. Make a literature survey including Höegh FPSO documents and NTNU reports
2. Relate the process energy demand to key parameters of the marine LNG value chain
3. Analyse the liquefaction process system for extreme conditions and identify limitations
4. Simulate the selected liquefaction process efficiency
5. Identify improvements to the Höegh FPSO present design and engineering
6. Conclusion and recommendation
7. Master thesis objective

Information:
In the LNG industry the liquefaction processes are most commonly patented and information protected. Some typical liquefaction processes are: Single cycles, Cascades, Cycles with N2 expanders, Dual Mixed Refrigerants (DMR), SMR(Prico/Linde), C3-MR(APCI) etc.

When selecting the right process, some of the critical parameters are: different compositions over time, lean-rich gas composition (GCV), nitrogen content, thermodynamic efficiency etc. Other problems relates to: power and heat system under extreme conditions regarding high CO2 content and low feed gas pressure.

Further relevant analysis:
1) Optimization of liquefaction system when utilizing direct drives. Different approach than for el drives. Start with a given turbine (LM 2500 or LM 6000) and optimization of throughput e.g. equal load on both refrigerant cycles, sensitivity wrt ambient temperature and sea water temperature
2) Optimization of current LPG/ NGL extraction system, literature research and simulation
3) Research motions and column performance. Literature research. Could also include an evaluation of amine process vs. membrane technology for CO2 removal (sensitivity wrt CO2 content)
4) Develop the LNG Liquefaction process to include LPG extraction/condensation in a lean feed gas avoiding separate LPG extraction/condensation systems (the C3+ can be extracted from the liquefaction system downstream the methane expander). Determine maximum levels of C3+ levels to be processed for avoiding freezing at cryogenic conditions. (include also max combination of Iso and N-butane etc). Evaluate also effects of aromatics and acceptable levels of impurities.
5) Evaluate caisson type riser systems for sea water cooling. Energy consumption/mechanical integrity of such systems, literature research and simulation
6) Evaluate a modified Niche liquefaction technology, other refrigerant medium etc.
No.3: Natural gas pre-processing of carbon dioxide removal onboard an LNG FPSO

Objective:
Design the natural gas CO2 purification process to meet specifications of the liquefaction process (LNG). Scan the market for different concepts. Identify critical parameters to suit the application on an FPSO. Identify selection criteria and make comparisons of concepts based on key selection criteria for offshore and floating application.

Project tasks:
1) Make a literature survey including Höegh FPSO documents and NTNU reports
2) Relate the process energy demand to key parameters of the marine LNG value chain
3) Analyse the purification process system for extreme conditions and identify limitations
4) Simulate the selected process system for different CO2 concentrations
5) Identify improvements to the Höegh FPSO present design and engineering
6) Conclusion and recommendation
7) Master thesis objective

Information:
Before LNG liquefaction, gas purification processing is required upstream the liquefaction process itself. One important aspect is CO2 removal. The feed-gas to the liquefaction process needs to contain minimal amount of CO2 to avoid freeze out and subsequently blocking of the passes in the main LNG heat exchanger. There are different concepts for cleaning CO2:

- Amine process with regeneration
- Membrane process
- Mol sieve process with regeneration
- Combined Membrane and Amine process

Evaluation of the feasibility of CO2 removal processes (or combination) applied on an offshore LNG FPSO. Typical range of CO2 concentration in the feed gas is 1-20 mol%. Which processes fit best to different CO2 concentrations (ex. 1-5 mol%, 5-10mol%, 10-15mol%, 15-20mol%).

The following aspects shall be used in the argumentation:
- Heat demand. Determine the heat demand of each CO2 removal process (or combination), correlated to different CO2 concentrations.
- Environmental impact. What is the condition of the process stream containing CO2 downstream the CO2 removal process? Should the stream be vented to the atmosphere or combusted? What is the implication (energy consumption) of re-injection?
- Weight and Footprint. Determine the weight and footprint of each CO2 removal process (or combination), correlated to different CO2 concentrations. Both weight of equipment (dry weight) and weight of the inventory in the process streams shall be determined.
- Implications of the marine environment on the process.
- Movement of vessels, corrosion protection of materials etc.
NTNU Project topic (autumn 2010)

No.4: Carbon foot-print of the maritime LNG value chain from production to gas grid

Objective:
Analyse the overall fuel and energy balance in the present Höegh LNG designed marine value chain. Pay particular attention to the environmental profile related to Höegh’s corporate objectives. Make proposals to the Höegh design and operations. Suggest global optimization principles to the present logistic chain.

Project tasks:
1. Make a literature survey including Höegh documents and NTNU reports
2. Relate the fuel and energy demand to key parameters of the marine LNG value chain
3. Analyse the logistics chain, its machinery and processes in today’s design, and identify trade-offs between commercial and legal (tax) conditions related to carbon foot-print
4. Analyse the carbon foot print for different gas compositions and different fuels
5. Identify improvements to Höegh’s present design and operations
6. Conclusion and recommendation
7. Master thesis objective

Information:
There is increasing focus world wide on the carbon foot-print from marine transportation. Carbon dioxide emissions in each step in the marine LNG chain must be minimized.

The main sources of emission are:
- CO2 removal from the feed-gas
- Power generation for pre-treatment and liquefaction process
- Power generation for transportation
- Power generation for re-gasification.

The CO2 foot-print can be reduced by a combination of operational optimisation and design improvements.
No.5: Off-loading systems of cryogenic product from an LNG FPSO

Objective:
The offloading systems onboard an LNG FPSO is designed either as an offloading side-by-side or as a tandem concept. In the overall LNG maritime chain there are several loading and off-loading systems (FPSO / SRV / FSRU / LNG carrier / LPG). The selection of the systems are related to a series of operational concerns such as loading ratio / regularity-availability / safety aspects / wind and waves / weather-vaning versus fixed location / cost and carrier vessels flexibility. Scan the market for different concepts, Analyse the experience of the Höegh’s ship-to-ship pilot test experience. Identify critical parameters to suit the application on an LNG FPSO. Identify selection criteria and make comparisons of concepts based on key selection criteria for different services and locations.

Project tasks:
1. Make a literature survey including Höegh FPSO documents and NTNU reports
2. Analyse loading/offloading systems in the LNG chain and find limitations for each system
3. Analyse the regularity of different Höegh FPSO / SRV / FSRU vessels and today’s LNG carrier design and LPG vessels
4. Analyse the experience of the Höegh’s ship-to-ship pilot test experience.
5. Identify improvements to the Höegh vessels’ present design and operation
6. Conclusion and recommendation
7. Master thesis objective

Information:
Offshore ship to ship transfer of LNG has not been done yet as a full scale commercial operation. Hence for the development of LNG FPSO projects this is considered as one of the main bottlenecks.

These transfer operations will involve novel equipment that needs to be qualified in addition to the operations itself. The supplier's progress in equipment qualification and certification will impact the selection for projects with early start-up.

The required availability for an LNG FPSO project is very high, hence it must be proven that the ship-to-ship transfer operations will can meet such availability requirements.
NTNU Project topic (autumn 2010)

No.6: Re-gasification process for LNG onboard a SRV / FSRU vessel

Objective:
Design the LNG re-gasification process of the SRV / FSRU vessel producing natural gas at pipeline conditions. Scan publications on re-gasification concepts, closed – open –fired designs, and relate different flag state constraints to most optimal process selection. Pay particular attention to the environmental profile related to Höegh’s corporate objectives. Identify selection criteria and make comparisons with different concepts based on key selection criteria for offshore and floating application.

Project tasks:
1. Make a literature survey including Höegh documents and NTNU reports
2. Relate the process energy demand to key parameters of the marine LNG value chain
3. Analyse the re-gasification system for extreme conditions and identify limitations
4. Simulate the selected re-gasification process total system efficiency
5. Identify improvements to the Höegh SRV / FSRU design and engineering
6. Conclusion and recommendation
7. Master thesis objective

Information:

The SRV (Shuttle Regas Vessel) is an LNG vessel with onboard LNG re-gasification systems. The SRV will connect to an offshore unloading buoy and mooring system before the evaporated LNG is discharged via the turret and the connected riser and subsea pipeline. As soon as the LNG cargo is discharged the SRV will disconnect and operate as a traditional LNG carrier.

An enlarged version of the SRV can also operate as a Floating, Storage and Re-gasification Unit (FSRU). A stationary FSRU requires offshore side-by-side LNG discharge from traditional LNG carriers.

The re-gasification system for the two vessel concepts are in principle based on the same technology, but the continuous re-gasification of the stationary FSRU is in general considered more demanding with regard to maintainability, availability and even environmental and safety requirements from the shelf state.

Höegh LNG has taken delivery of the first SRV “Suez Neptune” and the second SRV “Suez Cape Ann”, to be delivered to operation in 2Q 2010.

Höegh LNG is also currently developing a FSRU concept in a Joint Venture with Gaz de France Suez (Triton). The Triton FSRU will be located in the Adriatic Sea, 30 km off the coast of Italy.

In addition Höegh LNG has received the licence for two re-gasification terminals; Port Meridian in UK and Port Dolphin in Florida. These two projects will be based on the re-gasification technology as mentioned above.
NTNU Project topic (autumn 2010)

**No.7: Carbon foot-print of the maritime CNG (Compressed Natural Gas) value chain**

**Objective:**
Design the natural gas compression process for a CNG Shuttle, including the land based process infrastructure. Scan publications on CNG processes. Analyse the overall energy balance in the present Höegh/CETech designed value chain. Pay particular attention to the environmental profile related to Höegh’s corporate objectives and compare CNG and LNG chains. Make proposals to the Höegh/CETech process and chain design. Identify selection criteria and make comparisons with different concepts based on key selection criteria. Suggest global optimization principles to the present logistic chain.

**Project tasks:**
1. Make a literature survey including Höegh/CETech documents and NTNU reports
2. Relate the CNG process energy demand to key parameters of an LNG value chain
3. Analyse the Höegh/CETech present design and engineering
4. Simulate the compression process system to find the total system efficiency
5. Environmental impact of the CNG chain compared to LNG
6. Conclusion and recommendation
7. Master thesis objective

**Information:**
As a complementary scheme to LNG in marine transportation of natural gas, Höegh/CETech is exploring CNG (Compressed Natural Gas) as a business opportunity in transportation of natural gas over shorter distances and in smaller volumes.

The CNG Shuttle concept is developed for two main applications:
- Transport natural gas from a supply location to a receiving terminal pipeline
- Transport of associated gas from an oil producing unit to a receiving/processing terminal

The gas is stored in the tanks at an operational pressure of 150 bars. The tanks are designed with two piping connections. Although the need for processing facilities on each ship is kept to a minimum, most business cases / studies have included for a small onboard processing unit. This is used for continuous cooling of the gas during transit and transfer to control the temperature of the composite tanks at pressure drops. The heating cycle also reduces the offloading time.

Typically the compressors will operate at 150 bars continuously and the gas will be allowed to expand into the tanks in order to minimize storage temperature. Typical storage temperature achieved for a gas application is in the range of -30°C. Liquids that are separated from the gas can either be stored on separate tanks or they can be “spiked” into the tanks together with the gas. This increases the cargo capacity of the system due to the increased density of the gas in the tanks.

The tank arrangement on the CNG Shuttle is segmented to accommodate a constant unloading rate from the ship depending on the requirements of the receiving terminal. The terminal compressors is used to lower the tank pressure down to 20 bar (empty tank) when the receiving terminal pressure is higher than this.