Energy efficient LNG technology for recovery of flare gas

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• Significant amounts of natural gas is flared or vented in relation to oil production
• Reserves of “stranded” natural gas abandoned due to lack of profitability
• Considerable amounts of methane is produced as biological material is broken down
• Lack of infrastructure prevents natural gas recovery
• Liquefaction of natural gas to LNG is a viable and interesting alternative
  – Volume reduction of 600 times
  – Cost efficient shipment around the world
• LNG is a flexible product – can be transported to markets paying the highest price
The Pre-treatment Challenge

Gas sources

- **Coal Bed Methane/Coal Mine Methane**
  - C1: 90 – 95%
  - C2+: 0 - 3%
  - CO2: 0 - 3%
  - N2: 0 – 3%
  - H2O: Saturated

- **Biogas**
  - C1: 50 – 65%
  - C2+: 0%
  - CO2: 35-50%
  - H2O: Saturated

- **Landfill gas**
  - C1: 35 – 65%
  - C2+: 0%
  - CO2: 15 - 50%
  - N2: 15 – 50 %
  - O2: 0 – 5%

- **Flare Gas / Associated gas**
  - C1: 60 – 95%
  - C2+: 3 - 30%
  - CO2: 0 - 5%
  - N2: 0 – 5%
  - H2S: 0 – 2%

- **Pipeline gas**
  - C1: 87 – 98%
  - C2+: 1 - 9%
  - CO2: 0 - 2.5%
  - N2: 0 – 2%
The Pretreatment Challenge

• Requirements to gas entering liquefier
  - CO$_2$  50 ppm
  - H$_2$O  1 ppm
  - H$_2$S  4 ppm

• Pretreatment dependent on gas source:
  - Batch processes, e.g. active carbon
  - Amine systems (CO$_2$ and H$_2$S)
  - Mol sieve (CO$_2$, H$_2$O, N$_2$, O$_2$,..)
  - CO$_2$ Wash (CO$_2$, siloxanes, HFC’s ...)
  - Membrane technology (CO$_2$ and N$_2$)

• High H$_2$S content => potentially cost driving

• Energy consumption
  - Dependent of level of contaminants
  - To a large extent covered by heat
MiniLNG™

A unique mini-scale LNG technology
MiniLNG™

Characteristics
- MiniLNG™: Capacity up to 15 tons LNG / day
- Based on patented technology developed by SINTEF
- Hamworthy holds an exclusive license
- Fits to small gas sources: biogas, landfill, coal mine methane
- Based on mixed refrigerant technology

Benefits:
- Use of standard components
  - Low price
  - Short delivery time
- Low energy consumption
  - 0.6 kWh/kg LNG
MiniLNG™ – Pilot Plant

- Storage tank
- Pre-cooling
- Liquefier
- Pre-treatment
- Power supply
MiniLNG™

- Standardization:
  - Capacities: 6 and 15 tons LNG / day
  - Containerization
  - Options for customer:
    - Storage tank
    - Type of pretreatment
    - Electric power supply
- Manufactured at assembly site
- Easy shipment
- Plug and play philosophy
- Relocation possible
- Prototype operated since 2003
- Full scale demonstration plant to be launched
Small and medium scale LNG
Based on reversed Brayton technology
Offshore installations

- Strong limitations on:
  - Volume
  - Weight
  - Footprint

- Restrictions to gas processing
  Typical products:
  - Commercial LNG
  - Heavy hydrocarbons
  - LPG or NGL

- Low specific energy consumption
  - Reduces CAPEX and OPEX

- Strong focus on safety
- Flexible to gas composition changes
- Power production required
- Mechanical drives

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Onshore installations

- Electric power
  - Can be available for smaller plants
  - Production necessary for larger plants
- Low or negligible building lot cost
  - Limited weight, footprint and volume restrictions
- Distance to sea might be a challenge
- Low specific energy consumption
  - Reduces CAPEX and OPEX
Hamworthy Experience

- First free-standing small scale LNG plant in Northern Europe delivered March 2003.
- Hamworthy EPCIC contract with GASNOR.
- Technology feasibility and robustness thoroughly and successfully demonstrated.

35 LNG BOG Reliquefaction systems

Kollsnes II LNG
- 2 x capacity of existing Linde plant (Kollsnes I).
- Hamworthy EPCIC contract with GASNOR.
- Full production August 2007.

Snurrevarden LNG Plant, Norway (22,000 TPA)

Kollsnes II LNG Plant, Norway (84,000 TPA)

Al Gattara (Hyundai) BOG Reliquefaction System (58,000 TPA)
Nitrogen Expander Cycle

- Non-combustible and non-toxic cooling medium locally generated
- Robustness; single phase, single component, few or no splitting of streams
- Can be ramped quickly up and down in capacity, also fully automatic
- Can operate on optimum design point over a wide range of feed gas properties

Well proven process and equipment from onshore and marine LNG applications!
New and efficient LNG production

• Novel and improved Brayton technology
  – Based on proven technology
  – Patent pending
  – Low specific energy consumption: \( \sim 0.35 \) kWh/kg LNG
  – Adaptable to varying gas compositions
  – Compact system – small footprint
  – Capacities increased to 1.0 MTPA per train
  – Waste heat recovery feasible \( \Rightarrow \) energy consumption further reduced
  – Successful offshore engineering studies for varying capacities carried out – to be followed by contract
3D model 26,000 TPA
3D model FLNG 2 MTPA
Concluding Remarks

- Efficient LNG technology for hydrocarbon gas recovery available today
- Unique MiniLNG™ technology for biogas, landfill gas and coal mine methane – up to 5.500 TPA
- Novel and compact nitrogen Brayton technology developed for onshore and offshore flare gas recovery – 1.000.000 TPA

“Hamworthy wants to work with you to understand your needs and customize your solution”