



## The Other Gas Trades: LPG and CNG

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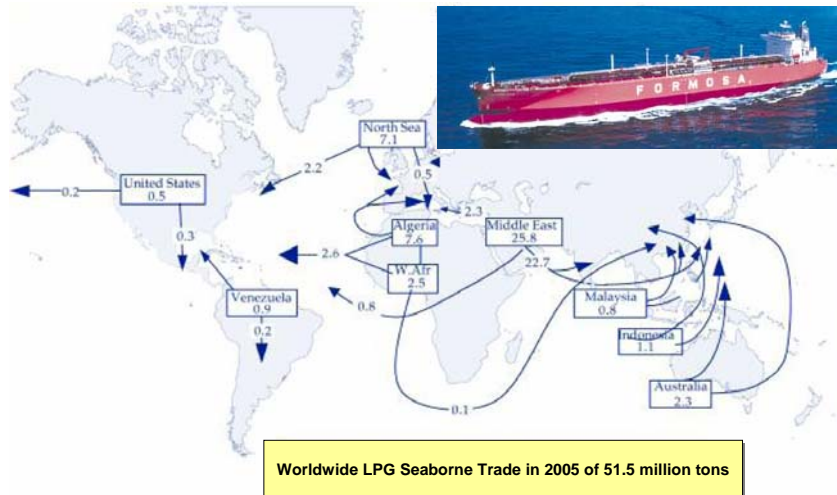


## Liquefied Petroleum Gas



- LPG – odorless and colorless hydrocarbons comprising propane and butane. Produced in 3 ways:
  - as impurities removed from natural gas
  - removing the volatile compounds from crude oil
  - distillation or cracking
- LPG is a liquid and has a volumetric efficiency of ~270:1
- Used as a petrochemical feedstock for producing petrochemical gases such as Ethylene, Propylene and Ammonia, which may also be shipped in LPGC's.
- Petrochemical gases account for just 10% of LPG carrier demand – balance is generally for domestic consumption
- LPG prices are directly proportional to oil prices (similar drivers).
- Environmental concerns driving LPG demand as an energy source

## Seaborne LPG trade



## LPG trends

- 23% of total LPG production is shipped by sea
- LPG seaborne trade is forecasted to grow to 68 m t by 2010 and to 98 m t by 2015\*
- Where will the LPG go ?
- LPG is mainly used as an energy source
- demand will be principally dependant upon the retail market
- petrochemical plants with flexible feed-stocks are a possible alternative
- can these markets absorb the increase ?
- and if not, what then ?



## LPG fleet

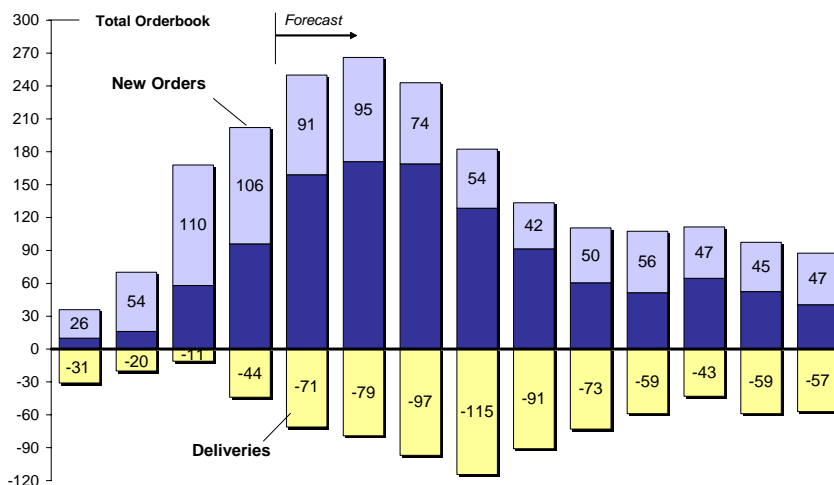
| Category, k Cu. m. | Existing          |             |             | On order   |                  | Totals      |                   |             |
|--------------------|-------------------|-------------|-------------|------------|------------------|-------------|-------------------|-------------|
|                    | Capacity          | No.         | Av. age     | No.        | Capacity         | Total no.   | Total capacity    | % of total  |
| <9.9k              | 2,396,183         | 787         | 18.2        | 72         | 406,276          | 859         | 2,802,459         | 12%         |
| 10-19.9            | 808,887           | 60          | 17.5        | 11         | 166,000          | 71          | 974,887           | 4%          |
| 20-29.9            | 821,937           | 36          | 13.6        | 18         | 387,600          | 54          | 1,209,537         | 5%          |
| 30-39.9            | 1,115,298         | 31          | 9.3         | 18         | 642,000          | 49          | 1,757,298         | 8%          |
| 40-49.9            | 43,671            | 1           | 24          | 0          | 0                | 1           | 43,671            | 0%          |
| 50-59.9            | 1,463,488         | 26          | 16.7        | 0          | 0                | 26          | 1,463,488         | 6%          |
| 60-69.9            | 120,000           | 2           | 1.5         | 6          | 360,000          | 8           | 480,000           | 2%          |
| 70-79.9            | 6,296,704         | 82          | 15.8        | 11         | 849,000          | 93          | 7,145,704         | 31%         |
| > 80k              | 2,322,689         | 28          | 11.1        | 55         | 4,538,200        | 83          | 6,860,889         | 30%         |
| <b>Totals</b>      | <b>15,388,857</b> | <b>1053</b> | <b>17.3</b> | <b>191</b> | <b>7,349,076</b> | <b>1244</b> | <b>22,737,933</b> | <b>100%</b> |



Source: Fairplay Jan 2007

## LPG Carrier – New Construction Outlook

Number of Ships (All Sizes) – Reference (Base) Case



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| YE Orderbk | 2003   | 2004  | 2005   | 2006  | 2007 | 2008 | 2009  | 2010   | 2011   | 2012   | 2013  | 2014 | 2015   | 2016   |
|------------|--------|-------|--------|-------|------|------|-------|--------|--------|--------|-------|------|--------|--------|
| % Growth   | -12.2% | 94.4% | 140.0% | 36.9% | 8.7% | 6.4% | -8.6% | -24.9% | -26.9% | -17.2% | -2.7% | 3.7% | -12.6% | -10.3% |

## Shipowners

- Of the nearly 80 shipowners involved in LPG, the top ten control just under 50% of the total fleet capacity:

| Shipowner             | Total capacity in cu. m. |
|-----------------------|--------------------------|
| BW SHIPPING GROUP LTD | 1,894,552                |
| NAFTOMAR SHIPPING     | 753,883                  |
| MITSUI OSK LINES LTD  | 740,371                  |
| YUYO STEAMSHIP        | 624,897                  |
| SANKO STEAMSHIP       | 624,239                  |
| SOLVANG               | 519,522                  |
| KAWASAKI KISEN KAISHA | 466,636                  |
| KUMIAI SENPAKU        | 461,672                  |
| KUWAIT PETROLEUM      | 453,744                  |
| CMB                   | 437,776                  |



Source: Fairplay Jan 2007

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## Shipbuilders

- There are 56 shipbuilders involved in this business of which the top eight are building just under 70% of the total order book:

| Shipyards   | Total | Capacity  |
|---|-------|-----------|
| Mitsubishi Heavy Industries Ltd.-Nagasaki               | 43    | 3,072,420 |
| Kawasaki Heavy Industries, Ltd.                         | 36    | 2,515,940 |
| Hyundai Heavy Industries Co., Ltd. -Ulsan               | 26    | 1,096,041 |
| Ch. Nav. de La Ciotat -La Ciotat                        | 8     | 553,401   |
| Oy Wartsila Ab -Turku                                   | 8     | 482,449   |
| Nippon Kokan K.K. (NKK Corp.) -Tsu                      | 6     | 455,022   |
| N.V. Boelwerf S.A. -Temse                               | 10    | 421,216   |
| Daewoo Shipbuilding & Marine Engineering Co., Ltd.-Okpo | 8     | 382,244   |



Source: Fairplay Jan 2007

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## LPG Ship Types

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### Type A - Independent Tanks

#### Tank Type:

Self supported, independent prismatic tanks

Tanks designed to Class Rules

Complete secondary barrier required

Cargo boil-off cannot be utilized on board

Re-liquefaction redundancy required

**Carriage Pressure/Temperature: <0.7 bar/0 to-104°C**

**Size Range: > 10,000 m<sup>3</sup> (typical)**



### Type C - Fully Pressurized Tanks

#### Tank Type:

Cylinders or spheres built in accordance with a recognized pressure vessel code

(ASME DIV I or II, BS 5500, TUV, etc)

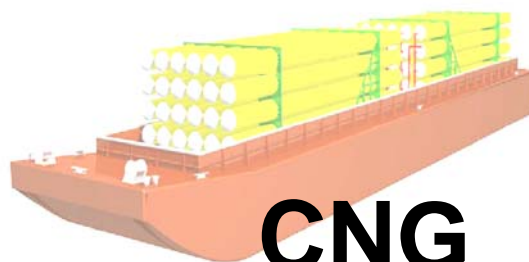
**Carriage Pressure/Temperature: 18 bar/ambient (typ)**

**Size Range :< 10,000 m<sup>3</sup> (typical but can be up to 35,000 cu.m.l)**



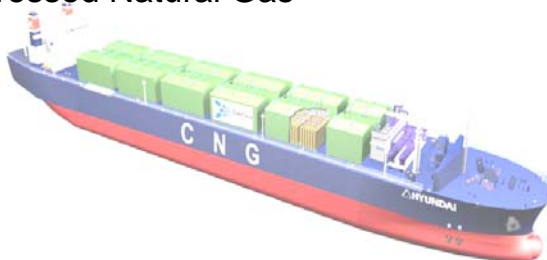
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# CNG

Compressed Natural Gas





## Compressed Natural Gas

- CNG is obtained by:
  - compressing natural gas
  - directly from a pipeline – after some cleaning
  - from LNG vaporized at high pressure – (CLNG)
- CNG is a gas not liquid
- CNG has a volumetric efficiency of 200 – 300:1 (LNG is about 615:1)
- Temperature: Atmospheric to -40°C
- Pressure: 100 – 250 bar (1500 – 3600 psi)



## Why CNG ?

- The liquefaction process for Natural Gas is labor intensive and expensive
- The gas must be very pure and free of unwanted products such as:
  - water
  - mercury
  - carbon dioxide
- Why do we liquefy only to return the liquid to a gas at the receiving terminal?

## Why CNG ?

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- Targeting large potential savings if the liquefaction process is omitted:
  - purification plant
  - reliquefaction plant
  - re-gasification plant
- So where's the problem ?
  - traditional pressure vessels were too heavy
  - the gas industry is very conservative
  - LNG has been the preferred way for many years

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## Why CNG ?

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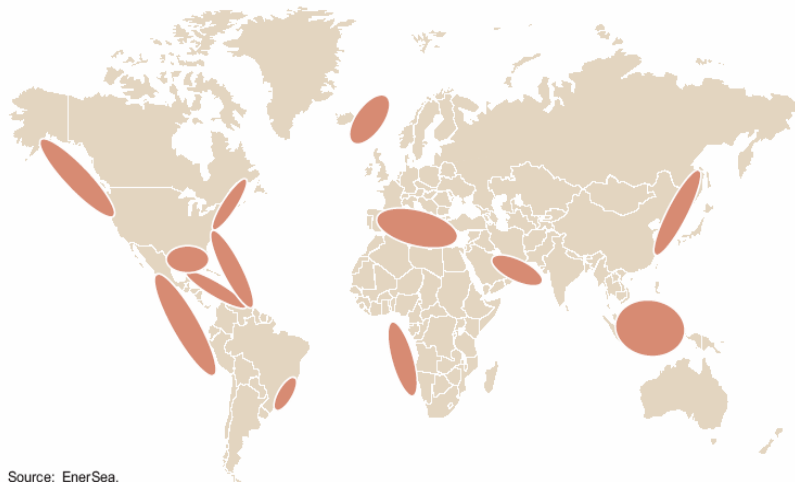


- Offshore field associated gas with no flaring
- Stranded gas exploitation with lack of available infrastructure supporting alternatives
- Need commitment from both supply and demand side of project to support investment in ships
- Scalable technology

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## Prospective CNG Source/Market areas



Source: EnerSea.

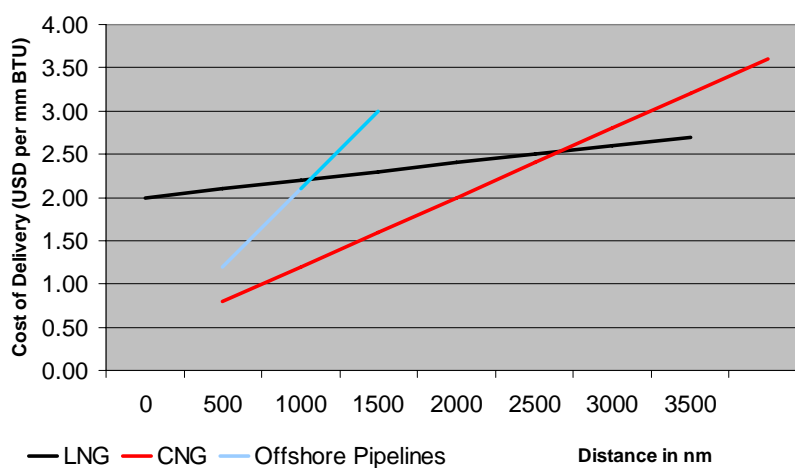
Trade generally limited to about 2500 nautical miles



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## Why CNG ?



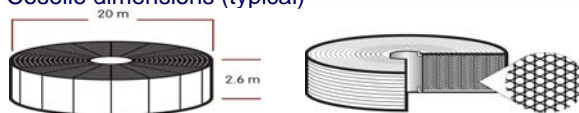
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## Sea NG Ship – 16-Coselle Design

Length - 114 m / 472 ft  
 Beam (Width) - 24 m / 78 ft  
 Depth – 6.5 m / 21 ft  
 Gas Capacity – 1.4 Mm<sup>3</sup> / 48 MMscf  
 Speed - 13 Knots / 15 MPH  
 Fuel - 92% CNG, 8% MDO



Coselle dimensions (typical)



## EnerSea CNG Carrier

Gas Port



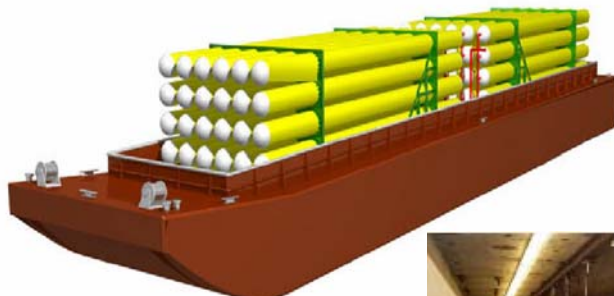
Liquid Port

- ✓ Maximizes gas delivery efficiency
- ✓ Accept wide range of gas compositions
- ✓ Minimal dehydration required (6-7 lbs/mmscf)
- ✓ Eliminates heat of compression
- ✓ Eliminates Joules-Thompson cooling in containment
- ✓ No liquid dropout in storage
- ✓ Complements VOTRANS Optimization principles



## TransCanada

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## Transocean Gas - CNG transportation

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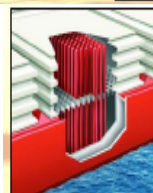
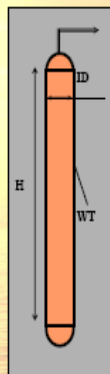


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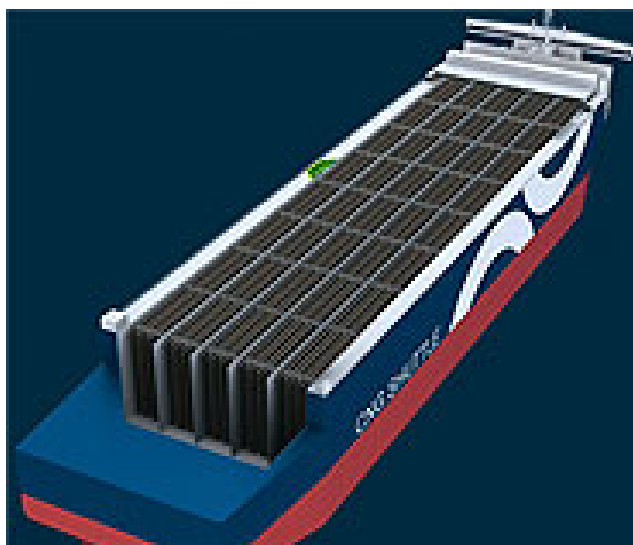
## Knutsen PNG

### Characteristics:

- Operating pressure, 250 barg
- Typical heel pressure, 25-30 barg
- Cylinder height 12 – 38 meters
- Diameter, about 1 meter
- Steel quality , high strength (X-80)
- Wall thickness 33.5 mm
- Operating temperature, -25 to 50 °C
- 40 year lifetime



## CETech – Compressed Energy Technology



## CNG Designs

| System         | Sea NG            | EnerSea           | Trans Canada                           | Trans Ocean                            | Knutsen           | CE Tech           |
|----------------|-------------------|-------------------|--|--|-------------------|-------------------|
| Type           | Coiled pipe       | Cylindrical PV    | Cylindrical PV                         | Cylindrical PV                         | Cylindrical PV    | Cylindrical PV    |
| PV Orientation | H Coils           | V                 | H                                      | V                                      | V                 | H                 |
| Material       | <b>Steel Pipe</b> | <b>Steel Pipe</b> | <b>Composite Reinforced Steel Pipe</b> | <b>Composite Glass or carbon fiber</b> | <b>Steel Pipe</b> | <b>Steel Pipe</b> |
| PV diameter    | 150mm             | 1040mm            | 1040mm                                 | 1040mm                                 | 1040mm            | 1040 or 1220mm    |
| PV length      | 18KM              | 24 to 36M         | 24M                                    | 12M                                    | 18 to 36M         | 220M              |
| Pressure       | 200 Bar           | 90-130 Bar        | 200 Bar                                | 240 Bar                                | 250 Bar           | 250 Bar           |
| Temperature    | 10° C             | -20° C to -40° C  | Ambient                                | -40° C                                 | Ambient           | Ambient           |



## Hybrid: SeaOne - Compressed Gas Liquid



## ABS Approach to New Concepts

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- Understand the Concept
- Identify All Hazards
- Look to Apply Existing Requirements
- Look to for Equivalents
- Identify Concerns Not Covered
- Special Analyses, Tests, Studies
- Define Parameters for Safety Assessment

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## ABS Requirements

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- **Apply IMO Gas Code as Applicable**
  - Type 2 G Ship / Intact and Damage Stability
  - Vessel Arrangements
  - Hazardous Areas
  - Containment Systems
  - Fire Protection
- **Use API Codes for:**
  - System Safety Approach
  - Gas Depressurization Arrangements
  - Gas Dispersion
  - Radiant Heat Levels
  - Fire Protection

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## Special Testing

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- Material Properties
- Monitor Fabrication
- Demonstrate Relative Motion Effects
- Installation of Completed Containment System
- Effectiveness of Proposed In-service Inspection Methods



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