



The Other Gas Trades: LPG and CNG

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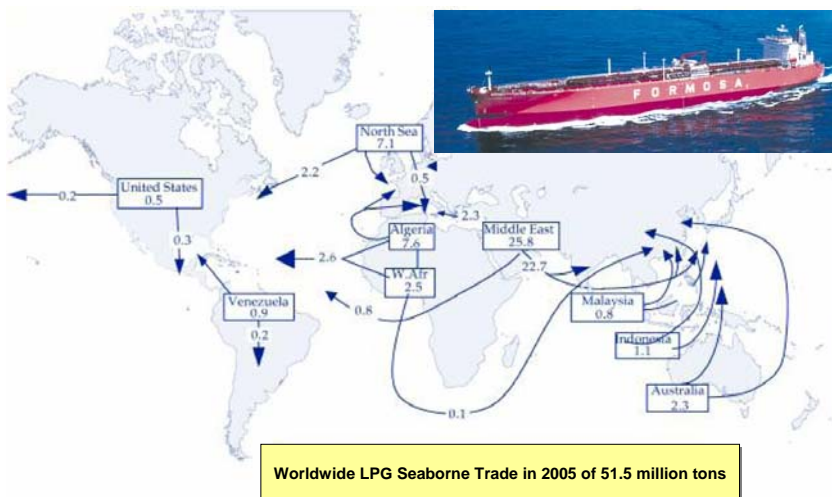


Liquefied Petroleum Gas



- 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%
Totals	15,388,857	1053	17.3	191	7,349,076	1244	22,737,933	100%



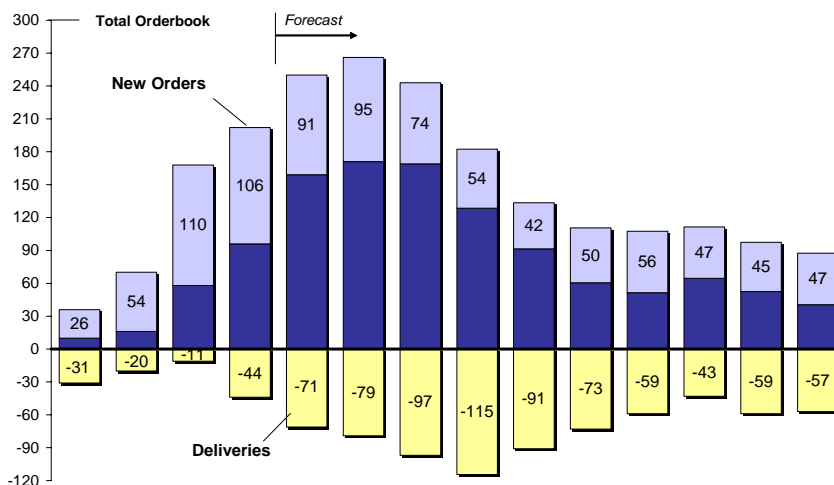
Source: Fairplay Jan 2007



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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%



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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



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



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 m³ (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)

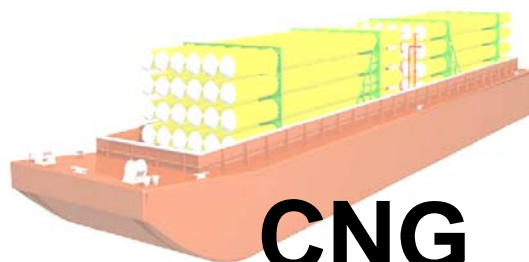
Carriage Pressure/Temperature: 18 bar/ambient (typ)

Size Range :< 10,000 m³ (typical but can be up to 35,000 cu.m.l)



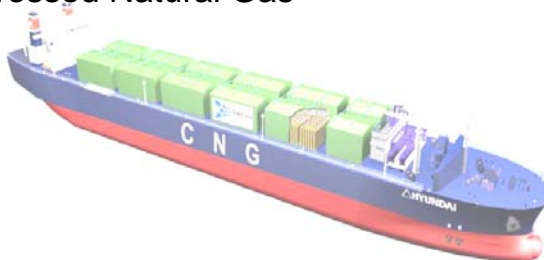
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CNG

Compressed Natural Gas



Compressed Natural Gas

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- 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)

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Why CNG ?

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- 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?

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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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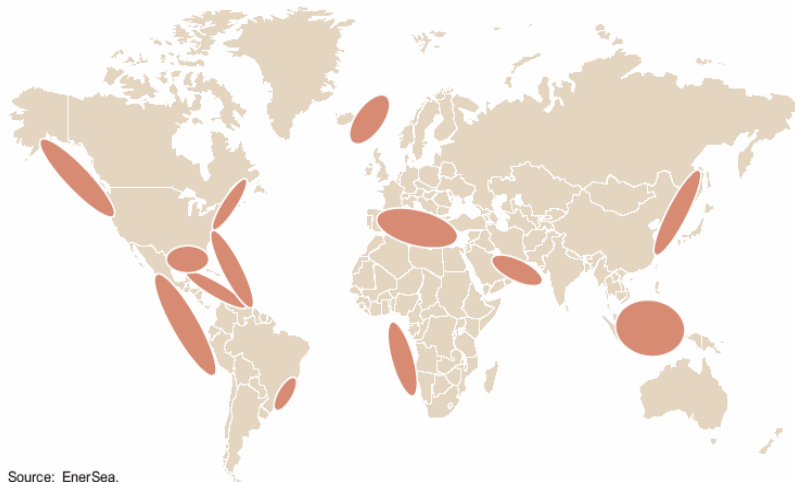


- Offshore field associated gas with no flaring
- Stranded gas exploitation with lack of available infrastructure supporting alternatives
- Need commitment from both supply and demand side of project to support investment in ships
- Scalable technology

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Prospective CNG Source/Market areas



Source: EnerSea.

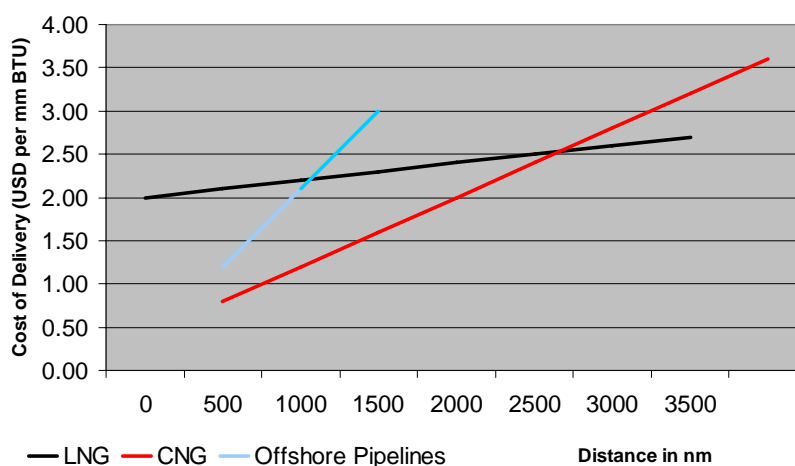
Trade generally limited to about 2500 nautical miles



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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 Mm³ / 48 MMscf
 Speed - 13 Knots / 15 MPH
 Fuel - 92% CNG, 8% MDO



Coselle dimensions (typical)



EnerSea CNG Carrier

Gas Port



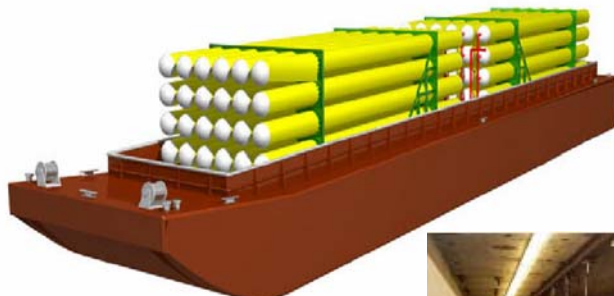
Liquid Port

- ✓ 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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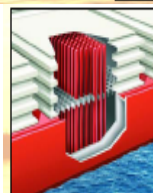
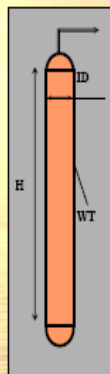


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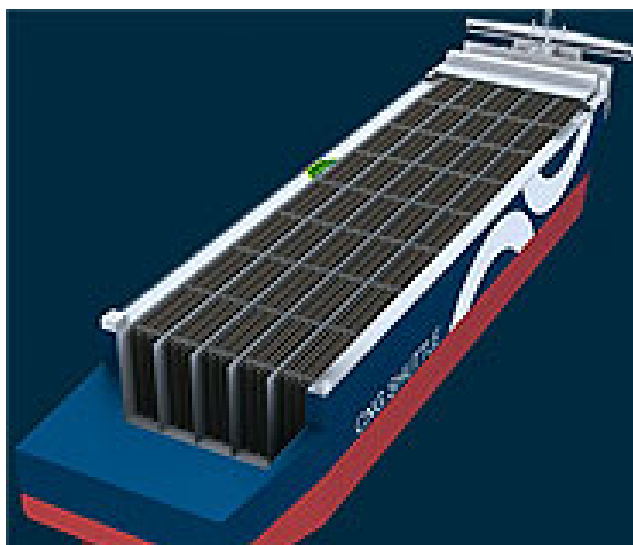
Knutsen PNG

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	Steel Pipe	Steel Pipe	Composite Reinforced Steel Pipe	Composite Glass or carbon fiber	Steel Pipe	Steel Pipe
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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