Turning the page in ship propulsion, by switching to LNG

Oskar Levander
Director R&D
Operational Performance / Ship Power R&D

Gas as fuel for propulsion of ships - status and perspectives
Copenhagen, March 3rd, 2008
• Environmental drivers
• LNG as marine fuel
• DF engines
• LNG cruise ship
• Running on gas in port
• Turning the page in propulsion
  – Example: The next generation ferry
Development driver for ship propulsion

- Environment
  - Emission reduction
    - NO$_x$ emissions
    - SO$_x$ emissions
      - SECA areas
      - EU ports
  - The next step will be climate change
    - Greenhouse gases
      - Focus on CO$_2$ emissions
    - Particles

- Fuel cost
  - Increasing oil prices
CO₂ emission reduction:
- Reduce power demand
  - Ship and propulsion design
  - Auxiliary power demand
  - Operation profile
- Improve efficiency
  - Propulsion optimisation
  - Engine technology
  - Waste energy recovery
- Change to alternative fuels
  - Fuels with less carbon
Ferry efficiency

Utilised energy (32.5%)

Energy in fuel 100%

Brake power 46.5%

Transmission losses 1.2%

Heat and losses 53.5%

Electric power 4.2%

Utilised exhaust heat recovery 2.8%

Utilised HT water heat recovery 1.9%

Surplus recoverable exhaust heat 8.0%

Surplus recoverable HT water heat 12.0%

Losses 28.8%

Propulsion losses 14.0%

Additional resistance from waves, wind and hull fouling 3.5%

Effective power 23.6%

Losses and unused energy

Estimation for sea mode at 22 knots
Alternatives to oil

What are the alternatives to oil?

- Biofuel
- Hydrogen
- Synthetic fuels
- Natural gas
What is natural gas?

- Natural gas is mostly methane (CH$_4$)

- **Methane** contains the highest amount of energy per unit of carbon of any fossil fuel
  
  - Carbon to hydrogen ratio 1 / 4 (gasoline: 1 / 2.25)
  
  - Lower CO$_2$ emissions

- Natural gas is:
  
  - A very safe fuel
  - Non-toxic
  - Lighter than air

Methane (CH$_4$)

Ethane (C$_2$H$_6$)
Cleaner Exhaust Emissions with LNG

- 30% lower CO$_2$
  - Thanks to low carbon to hydrogen ratio of fuel
- 85% lower NO$_X$
  - Lean burn concept (high air-fuel ratio)
- No SO$_X$ emissions
  - Sulphur is removed from fuel when liquefied
- Very low particulate emissions
- No visible smoke
- No sludge deposits
Fuel prices

Today LNG is cheaper than HFO (Price / energy content)

Sources: www.lngoneworld.com, www.bunkerworld.com, LR Fairplay
Dual-fuel engine characteristics

- High efficiency
- Low gas pressure
- Low emissions, due to:
  - High efficiency
  - Clean fuel
  - Lean burn combustion
- Fuel flexibility
  - Gas mode
  - Diesel mode
- Two engine models
  - Wärtsilä 34DF
  - Wärtsilä 50DF
DF Engines - Operating modes

Gas mode:
- Otto principle
- Low-pressure gas admission
- Pilot diesel injection

Diesel mode:
- Diesel principle
- Diesel injection
Engine characteristics - Operating mode changes

**Diesel mode**
- Running on HFO or MDO and MDO pilot fuel injection
- Transfer to gas operation at loads up to 80%
- Pilot fuel injection in operation

**Gas mode**
- Automatic and instant trip to diesel operation in alarm situations
- Trip to diesel operation on request at any load
- Automatic trip to diesel mode after 3 minutes at engine loads below 15%
DF – concept benefits

- Reliability
- Efficiency
- Low gas pressure
- Fuel flexibility
  - MDO as a backup
  - HFO as option
- System configuration
  - Single storage tank is allowed
  - Single engine installations allowed
Dual-fuel engine range

**Wärtsilä 34DF**
- 6L34DF: 2.7 MW
- 9L34DF: 4.0 MW
- 12V34DF: 5.4 MW
- 16V34DF: 7.2 MW
- 20V34DF: 9.0 MW

**Wärtsilä 50DF**
- 6L50DF: 5.7 MW
- 8L50DF: 7.6 MW
- 9L50DF: 8.6 MW
- 12V50DF: 11.4 MW
- 16V50DF: 15.2 MW
- 18V50DF: 17.1 MW
Dual-fuel engine references at sea

**Petrojarl 1**
- FPSO Petrojarl
- 2x 18V32DF
- 2x 32'000 running hours

**Sendje Ceiba**
- FPSO Bergesen
- 1x 18V32DF
- 18’000 running hours

**Viking Energy**
- DF-electric offshore supply vessel
  - Eidesvik
  - Kleven Verft
  - 4x 6R32DF
  - 4x 19’500 running hours

**Stril Pioner**
- DF-electric offshore supply vessel
  - Simon Møkster
  - Kleven Verft
  - 4x 6R32DF
  - 4x 16’500 running hours

**Viking tbn (Gass Avant) and hull 30**
- DF-electric offshore supply vessel
  - Eidesvik
  - West Contractors
  - 4x 6R32DF
  - Ship deliveries 2007 & 2008

**Provalys and Gaselys**
- DF-electric LNG Carrier
  - Gaz de France
  - Alstom Chantiers de l’Atlantique
  - 2x 12V50DF + 2x6L50DF
  - Total 20’000 running hours for 2 ships

**Gaz de France energy**
- DF-electric LNG Carrier
  - Gaz de France
  - Alstom Chantiers de l’Atlantique
  - 4x 6L50DF
  - Total 16’000 running hours

**British Emerald**
- DF-electric LNG Carrier
  - BP Shipping
  - Hyundai Heavy Industries
  - 2x 12V50DF + 2x9L50DF
  - Delivered 2007
LNG fuelled vessel: PSV Viking Energy & Stril Pioneer

PSV Viking Energy / Stril pioneer

Owners: Eidesvik AS
        Mökster Shipping
Builder: Kleven Verft

Main particulars:
- Gross 4000 GT
- Length 94.9 m
- Beam 20.4 m
- Speed 17.2 knots
- LNG tank 220 m³
- 4 x Wärtsilä 6L32DF gensets
- Power 4 x 2020 kW
  Total 8080 kW
Dual-fuel-electric LNG carrier deliveries

7 shipyards
≥ 11 ship owners
52 ships
Wärtsilä is actively developing solutions for LNG fuelled passenger vessel:

- 10 000 gt Cruise Ferry
- 30 000 gt RoPax
- BIG LNG
- 65 000 gt PaxCar Ferry
- 125 000 gt Cruise ship
Running on gas in port
LNG cruise ship
125 000 gt
LNG Cruise Ship concept

Developed by:

Wärtsilä

Aker Yards
Main Particulars

- Gross tonnage: 125 000 GT
- Length over all: 310 m
- Length, bp: 295 m
- Breadth: 40 m
- Draught, design: 8.6 m
- Deadweight: 10 000 ton
- Service speed, max: 21.0 knots
- Lower beds: 2 780 pcs
- Pax cabins: 1 390 pcs
Why bunker has to be in liquid form (LNG)

Fuel relative volume, energy content equal

- NG 1 bar
- LNG 10bar
- CNG 200bar
Energy content equal
LNG storage location

Gas storage below deck

- LNG tank
- Min. B/15 or 2 m (the lesser)
- Never less than 760 mm
- Min. B/5 or 11,5 m (the lesser)
- Never less than 760 mm
DF-electric machinery

- **Thruster integrated into skeg**
  - E-motors: 2 x 21,000 kW
- **Stern thrusters**
  - 2 x 3,000 kW
- **FPP**

**Total installed engine power**: 68,400 kW

- **3 x WÄRTSILÄ 12V50DF**
  - 11,400 kW
- **3 x WÄRTSILÄ 12V50DF**
  - 11,400 kW
- **Bow thrusters**
  - 4 x 3,000 kW
Power requirement – total plant

- Propulsion
- Hotel

<table>
<thead>
<tr>
<th>Speed (kn)</th>
<th>Port</th>
<th>Man</th>
<th>10.5 kn</th>
<th>13.5 kn</th>
<th>17.5 kn</th>
<th>18.5 kn</th>
<th>20 kn</th>
<th>21.5 kn</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10kW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>15kW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>20kW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>25kW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>30kW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>35kW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>40kW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>45kW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>50kW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Safety philosophy

- LNG is a very safe fuel for passenger vessels
  - LNG will not ignite (too cold)
  - Difficult to ignite NG
    - NG can be ignited in a very narrow fuel / air ratio range (5-15%)
  - No build up of gas in bottom of ship
  - A possible NG leak will disperse upwards (lighter than air)

- Machinery concepts adds safety
  - Gas detection – automatic gas supply shut off
  - Double wall pipes
  - Never any large quantities of NG in engine rooms
  - LNG stored is special tanks in separate compartments
LNG tanks – Location

• Rule requirements
  – From side: B/5
  – From bottom: B/15 or 2 m (the lesser)

• Novel location in cruise ships
  – In centre line casing
  – Free ventilation to open air
  – Fire insulated space
  – “Drip tray” below tanks capable of containing the fuel of an entire tank
Gas system components

- Gas valve units
- Heat exchanger for pressure build up
- LNG tanks
- Evaporator
LNG tanks – Capacity

- Daily LNG consumption:
  - 100 ton
  - 220 m³

- Capacity for 7 day cruise:
  - 1,560 m³ consumption
  - 20% margin
  - filling ratio 95%
  - 2,000 m³ tank volume

- Back-up and extended range is covered with MDO
Bunkering

- LNG Terminal
- Tanker truck
- Tanker ship / barge
- Land based storage tank
LNG bunkering from barge
LNG in Caribbean and Alaska

- Import terminal
- Export terminal
<table>
<thead>
<tr>
<th></th>
<th>USD/ton</th>
<th>EUR/ton</th>
<th>USD/MBtu</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSHFO</td>
<td>460</td>
<td>312</td>
<td>12.0</td>
</tr>
<tr>
<td>MDO</td>
<td>720</td>
<td>490</td>
<td>17.8</td>
</tr>
<tr>
<td>MGO</td>
<td>790</td>
<td>537</td>
<td>19.5</td>
</tr>
<tr>
<td>LNG</td>
<td>470</td>
<td>317</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Source: [www.bunkerworld.com](http://www.bunkerworld.com) (Rotterdam 29.1.2008), LNG price estimated

1 EUR = 1.47 USD
Fuel consumption and cost

Assumed fuel prices:
- LSHFO: 312 €/ton (460 USD/ton)
- MDO: 490 €/ton (720 USD/ton)
- LNG: 317 €/ton (10.0 USD/MBtu)
Energy consumption is lower for DF thanks to:

- Lower heat demand (no HFO)
- Lower electrical power demand (AC)
Machinery investment cost

+ 29% ≈ 12 M€

- Fuel system
- Steering
- Propulsion train
- Electric propulsion
- Propulsion engine

HFO

DF
Annual machinery related costs

Maintenance costs
Lub oil costs
Fuel oil costs
Annual capital costs

Assumed fuel prices:
- LSHFO: 312 €/ton (460 USD/ton)
- MDO: 490 €/ton (720 USD/ton)
- LNG: 317 €/ton (10.0 USD/MBtu)

Capital cost assumptions:
- Interest: 6%
- Time: 15 years

Maintenance cost:
- Calculation period: 15 years

- 7% ≈ 1.4 M€
Emissions

HFO

DF

CO₂
NOₓ
SOₓ

CO₂ -30%
NOₓ -85%
SOₓ -99.9%
## LNG challenges

### Challenges:

- **Space for tank locations**
  - Alternative locations
  - New tank types

- **Cost**
  - Investment
  - Design for actual use
  - Operation
  - LNG price can be competitive

- **Rules**
  - DNV and LR rules
  - Draft IMO rules

- **Availability of LNG**
  - Gas suppliers are interested
Running on gas in port
Why ports are going for shore power?

- Environmental pressure
- Emissions from ships (auxiliary engines running on HFO)
  - SO$_x$
  - NO$_x$
  - Particles
- Many ports are close to urban areas
  - Port emissions drifts straight to populated areas (ship funnels are lower compared to land based power plants)
- Noise pollution
Shore power features

- No **local** exhaust emissions
- Expensive comp. to HFO gensets
- Not available in all ports
- Voltages and frequencies are not standardised
- Connectors are not standardised for high voltages
- Limitations of local power-distribution network
- Risk for power loss during changeover
Alternatives to shore power

- HFO + Exhaust gas treatment
  - SCR $\rightarrow$ NO$_x$
  - Seawater Scrubbers $\rightarrow$ SO$_x$ (and Particles)

- MGO
  - Only meets the regulation for sulphur content
  - Does not comply with the demands in certain ports

- LNG
Today LNG is cheaper than HFO (Price / energy content)

Sources: [www.lngoneworld.com](http://www.lngoneworld.com), [www.bunkerworld.com](http://www.bunkerworld.com), LR Fairplay
NG in port philosophy

- One engine is of DF-type
- In port vessel is connected to gas pipe network
  or
- Is connected to a shore based LNG storage tank / LNG truck
- At sea, the DF-engine can run on HFO as a gensets among others
- No gas / LNG storage on board needed

→ Simple system
LNG auxiliary power in port for cruise vessels

- LNG auxiliary power for cruise vessels
  - Significant reduction of local emissions
  - Economically feasible
  - Technology is available

Electricity production cost in port

<table>
<thead>
<tr>
<th></th>
<th>Shore power</th>
<th>MGO</th>
<th>MDO</th>
<th>LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>cent/ kWh</td>
<td></td>
<td>14</td>
<td>12</td>
<td>10</td>
</tr>
</tbody>
</table>
Case study – SCHIFFKO CV 7300
## SCHIFFKO CV 7300

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length over all</td>
<td>322.34 m</td>
</tr>
<tr>
<td>Breadth</td>
<td>40.00 m</td>
</tr>
<tr>
<td>Draught</td>
<td>14.00 m</td>
</tr>
<tr>
<td>Deadweight</td>
<td>84 500 ton</td>
</tr>
<tr>
<td>Main engine</td>
<td>Wärtsilä 11RT-flex96C</td>
</tr>
<tr>
<td>Propulsion power</td>
<td>62 920 kW</td>
</tr>
<tr>
<td>Speed (trial)</td>
<td>25.5 kn</td>
</tr>
<tr>
<td>Cargo capacity</td>
<td>7 300 TEU</td>
</tr>
<tr>
<td>Reefer plugs</td>
<td>1 300 FEU</td>
</tr>
</tbody>
</table>
SCHIFFKO CV 7300
Electrical load

<table>
<thead>
<tr>
<th>Mode</th>
<th>Load (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port</td>
<td>8,000</td>
</tr>
<tr>
<td>Manoeuvring</td>
<td>12,000</td>
</tr>
<tr>
<td>Cruise</td>
<td>9,000</td>
</tr>
</tbody>
</table>
Machinery – Diesel (reference)

WÄRTSILÄ 11RT-flex96C 62 920 kW

WÄRTSILÄ 6L32 2 880 kW
WÄRTSILÄ 9L32 4 320 kW

Auxiliary engine loading (% of MCR)

<table>
<thead>
<tr>
<th></th>
<th>Harbour</th>
<th>Manoeuvring</th>
<th>Cruise</th>
</tr>
</thead>
<tbody>
<tr>
<td>6L32</td>
<td>78%</td>
<td>88%</td>
<td>86%</td>
</tr>
<tr>
<td>6L32</td>
<td>-</td>
<td>88%</td>
<td>-</td>
</tr>
<tr>
<td>9L32</td>
<td>78%</td>
<td>88%</td>
<td>86%</td>
</tr>
<tr>
<td>9L32</td>
<td>78%</td>
<td>88%</td>
<td>86%</td>
</tr>
</tbody>
</table>

Bow thruster 2 900 kW

Installed auxiliary power: 14 400 kW
Machinery – DF

**Installed auxiliary power:** 15,040 kW

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WÄRTSILÄ 9L34DF</td>
<td>3,760</td>
</tr>
<tr>
<td>WÄRTSILÄ 9L34DF</td>
<td>3,760</td>
</tr>
<tr>
<td>WÄRTSILÄ 11RT-flex96C</td>
<td>62,920</td>
</tr>
</tbody>
</table>

**Auxiliary engine loading (% of MCR)**

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Harbour</th>
<th>Manoeuvring</th>
<th>Cruise</th>
</tr>
</thead>
<tbody>
<tr>
<td>9L34DF</td>
<td>80%</td>
<td>85%</td>
<td>88%</td>
</tr>
<tr>
<td>9L34DF</td>
<td>80%</td>
<td>85%</td>
<td>88%</td>
</tr>
<tr>
<td>9L34DF</td>
<td>80%</td>
<td>85%</td>
<td>88%</td>
</tr>
<tr>
<td>9L34DF</td>
<td>-</td>
<td>85%</td>
<td>-</td>
</tr>
</tbody>
</table>

Bow thruster:
- 2,900 kW
Installed Auxiliary engine power

- Diesel: 14,000 kW
- DF: 16,000 kW
- Diesel with Shore power: 14,000 kW
Operation route

Los Angeles – Oakland – Dalian – Busan – Nagoya – Yokohama – Los Angeles
Operating in US west coast

24 NM zone:
- clean fuel* is to be used in aux engines

* Sulphur content < 0.5%, after 2010 < 0.1%
### LNG consumption according to op. profile

<table>
<thead>
<tr>
<th>OP MODE</th>
<th>LNG consumption</th>
<th>Running hours per roundtrip</th>
<th>Consumption per roundtrip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading &amp; Unloading</td>
<td>1.5</td>
<td>138</td>
<td>207.0</td>
</tr>
<tr>
<td>Manoeuvring</td>
<td>2.1</td>
<td>6</td>
<td>12.6</td>
</tr>
<tr>
<td>Slow with clean*</td>
<td>1.6</td>
<td>10</td>
<td>16.0</td>
</tr>
</tbody>
</table>

* Only in US West Coast (2 port calls)

\[ 236 \]

\[ 523 \, m^3 \]

2 x 190 m³ fixed tanks → 380 m³ → bunkering 2 (1.4) times per roundtrip
LNG consumption – only in US west coast

<table>
<thead>
<tr>
<th>OP MODE</th>
<th>LNG consumption</th>
<th>Port calls Los Angeles and Oakland</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ton/h</td>
<td>hours</td>
</tr>
<tr>
<td>Loading &amp; Unloading</td>
<td>1.5</td>
<td>58</td>
</tr>
<tr>
<td>Manoeuvring</td>
<td>2.1</td>
<td>2</td>
</tr>
<tr>
<td>Slow with clean</td>
<td>1.6</td>
<td>10</td>
</tr>
</tbody>
</table>

108

240 m³

40ft LNG containers

a’ 31.5 m³ → 8 units
LNG tank arrangement with fixed tanks

- 2 x 190 m³ vertical tanks
- Total capacity: 380 m³
- Cargo capacity: - 20 TEU
LNG tank
LNG tank
Tank arrangement with containers

- 8 x 31.5 m³ 40ft LNG containers
- Total capacity: 250 m³
- Cargo capacity: - 8 FEU
## Fuel prices

<table>
<thead>
<tr>
<th></th>
<th>USD/ton</th>
<th>EUR/ton</th>
<th>USD/MBtu</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFO</td>
<td>350</td>
<td>259</td>
<td>9.1</td>
</tr>
<tr>
<td>MDO</td>
<td>600</td>
<td>444</td>
<td>14.8</td>
</tr>
<tr>
<td>MGO</td>
<td>700</td>
<td>519</td>
<td>17.3</td>
</tr>
<tr>
<td>LNG</td>
<td>336</td>
<td>249</td>
<td>7.2</td>
</tr>
</tbody>
</table>
Operating profile

Operating hours [%]

- Loading & unloading
- Manoeuvring
- Slow
- Slow with clean fuel*
- Service speed

Clean fuel is to be used in aux engines in these modes

* Closer than 24NM from coastline, US west coast only
Annual fuel cost of aux engines in selected modes

- Aux engines are running on MGO (+ LNG) in selected modes

- Diesel: 1,400 k€
- DF: 960 k€
- Diesel with shore power: (no data provided)

Shore power costs not included!
Total annual fuel cost (ME + AE)

- Main engine is running on LSHFO in all cases
- Aux engines are running on MGO (+ LNG) in selected modes
- Aux engines are running on HFO at sea

- 870 k€
- 1 400 k€
Auxiliary engines investment cost*

*Investment cost for aux engines includes:
- Engines + Generators
- LNG system
- Shore power connection
Annual cost in selected modes

Auxiliary engine fuel cost in selected modes + aux engine investment cost*

Shore power 0.09 USD / kWh

DieSEL

DF

Diesel with shore power**

kEUR

- 600 k€

- 300 k€

Repayment time 15 years
Interest rate 6%

*Investment cost for aux engines includes:
- Engines + Generators
- LNG system
- Shore power connection

** Shore power 0.09 USD / kWh
Exhaust emissions – selected modes

Includes Aux and Main engine emissions in selected modes (ME: LSHFO, AE: MGO)

Shore power emissions not included!
Summary

- LNG is a economical solution for generating auxiliary power in port conditions

- DF concept is not dependent on port facilities

- The emissions are significantly lower compared to use of MGO

- The higher investment cost of LNG system + DF engines is paid back in 4 years
Turning the page in ship propulsion

Example: The Next Generation Ferry
Ferry vision

- Design target
  - High efficiency
    - Novel propulsion solutions
    - Large cargo capacity – economy of scale
    - Fast turnaround in port
      - Efficient cargo handling
      - Excellent manoeuvring
  - Environmentally sound
  - New amenities for demanding passengers
<table>
<thead>
<tr>
<th>Main particulars</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross tonnage</td>
<td>65 000 GT</td>
</tr>
<tr>
<td>Length over all</td>
<td>225 m</td>
</tr>
<tr>
<td>Length, bp</td>
<td>210 m</td>
</tr>
<tr>
<td>Breadth</td>
<td>34 m</td>
</tr>
<tr>
<td>Draught, design</td>
<td>7 m</td>
</tr>
<tr>
<td>Deadweight</td>
<td>8 500 tons</td>
</tr>
<tr>
<td>Service speed</td>
<td>23 knots</td>
</tr>
<tr>
<td>Beds</td>
<td>1 800 pcs</td>
</tr>
<tr>
<td>Pax cabins</td>
<td>600 pcs</td>
</tr>
<tr>
<td>Lane meters</td>
<td>3 250 m</td>
</tr>
</tbody>
</table>
Efficient cargo handling

- Large cargo capacity
- Two extra wide cargo decks
  - 10 lanes
  - No lower cargo hold
- No lower hold
- Two level loading from twin level link spans in port
- Drive trough loading
- New bow door arrangement
New amenities for demanding passengers

- Indoor two level street - city atmosphere
- Coffee shops, ice cream stands, news and internet cafes
- Outlet shopping malls
Machinery

Propulsion:
- 3 x pulling thrusters: 3 x 5500 kW
- CPP, centre shaft lines: 15200 kW
- TOTAL: 31700 kW

Engine power:
- 2 x 8L50DF genset: 2 x 7600 kW
- 2 x 6L50DF genset: 2 x 5700 kW
- 2 x 8L50DF mechanical: 2 x 7600 kW
- TOTAL: 41800 kW

Bow thrusters:
- 2 x Bow thrusters: 2 x 2500 kW
- TOTAL: 5000 kW
Combined CRP and Wing Thruster propulsion
- High efficiency
- Excellent manoeuvring
- Possibility to use low power thrusters (reliability)
- Redundancy
Machinery design

- Environmentally sound
  - LNG
- Best efficiency
  - CRP + Wing Thrusters
  - LNG
- Excellent manoeuvring
  - Three steerable thrusters
- Ultimate flexibility
  - CODFEM – Combined Dual Fuel Electric and Mechanical machinery
  - Electric operation at low speeds – good efficiency at part load
  - Mechanical booster – low transmission losses
THE NEXT GENERATION FERRY – AVAILABLE TODAY!
Conclusions

LNG is an attractive fuel for the passenger vessels of the future

- The emissions can be significantly reduced
- The technology needed is available and well proven
- Economically promising
CRUSING ON GAS INTO A CLEANER FUTURE