Vessel Efficiency Improvements for Reducing CO2 Footprint

+ LNG … A Better Way to Cold Iron

American Association Port Authorities Harbors, Navigation, & Environmental Seminar and Green Port Americas
Charleston, SC
4 - 6 May 2010

John F. Hatley PE
Americas Vice President Ship Power
Wartsila North America, Inc.
john.hatley@wartsila.com
www.wartsila.com
Not just Engines

Products

- Low-speed engines
- Medium-speed engines
- Gas & dual/tri-fuel engines
- Marine generating sets
- Power plant generating sets
- Mechanical drives
- Propulsors
- Seals
- Bearings
- Propulsion packages
- Automation
- Ship design
- Engine auxiliary systems
- Environmental technologies, Marine Industry
- Environmental technologies, Power Industry
- Fuel cell technology

Wartsila Power Range 800 - 80,000 kW
But also ... Matched Propulsion Systems

Wartsila propels Wet End as well
Wartsila SCR in 100+ Vessels

Products

- Low-speed engines
- Medium-speed engines
- Gas & dual/tri-fuel engines
- Marine generating sets
- Power plant generating sets
- Mechanical drives
- Propulsors
- Seals
- Bearings
- Propulsion packages
- Automation
- Ship design
- Engine auxiliary systems
- Environmental technologies
- Marine Industry
- Environmental technologies
- Power Industry
- Fuel cell technology
Agenda

Efficiency Technologies & Energy Savings

Evolving Developments

Ship Design

Propulsion

Machinery

Operations & Maintenance

Why Clean Natural Gas

LNG Improves Cold Ironing
Environment Drives Ship Design

- **Emission reduction**
  - NO$_x$ emissions
  - SO$_x$ emissions
  - SECA areas
  - North American ECA

- **Climate change**
  - Greenhouse gases
  - Focus on CO$_2$ emissions

- **Fuel cost**
  - Scarcity escalates prices
  - Tighter Sulphur requirements

*Good Stewards today for future generations*
US / Canada Emission Control Area “ECA”

US & Canada
- Submitted IMO 27 March 2009
- 200 Nautical Miles off Coastlines
- Exclusive Economic Zone EEZ

MEPC 59
- Committee recommended 17 July 2009

IMO
- Anticipate Adoption March 2010

History “SECA”
- Exclusively Control SOx
- 1st Baltic Sea enforced May 2005
- 2nd North Sea November 2006
Greenhouse Gas

CO₂ emission reduction

Reduce power demand
  Ship and propulsion design
  Operation profile

Improve efficiency
  Propulsion optimisation
  Engine technology
  Waste energy recovery

Use alternative fuels
  Lower carbon content fuels

Fundamental shifts in vessels; why, what, how
Vessel Energy Efficiency

Useful Energy 32.5%

- Energy in fuel: 100%
- Brake power: 46.5%
- Heat and losses: 53.5%
- Transmission losses: 1.2%
- Electric power: 23.6%
- Transmission losses: 14.0%
- Additional resistance from waves, wind and hull fouling: 3.5%
- 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%
- Electric power: 4.2%
- Effective power: 23.6%
- Losses and unused energy: 28.8%

30 000 gt
Estimation for service speed mode

- Additional resistance from waves, wind and hull fouling: 3.5%
- Propulsion losses: 14.0%
- Brake power: 46.5%
- Energy in fuel: 100%
- Transmission losses: 1.2%
- Electric power: 23.6%
- Losses and unused energy: 28.8%
- 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 and unused energy

© Wärtsilä 11 May 2010 Oskar Levander / Ship Power R&D
Typical Annual Costs

- Bunkers: 58%
- Capital costs: 15%
- Manning: 7%
- Canal tolls & misc: 3%
- Port dues: 7%
- Repairs & Maintenance: 3%
- Insurance: 1%
- Sales: 1%
- Stores & lubes: 2%
- Cargo handling costs: 1%
- Admin & Mgmt: 2%
- Fuel Dominates 2/3 Costs

Annual CAPEX + OPEX = 13,000 K € …
Engineered & operational integration of these principles yields optimal overall ship efficiency
Tanker, Bulker Efficiency Improvements

- Air Lubrication
- Delta Tuning
- Optimum Main Dimensions
- Voyager Planning – Weather Routing
- Wind Power
- Hull Cleaning
- Energopack
Container Efficiency Improvements

- Waste Heat Recovery
- Ship Speed Reduction
- Efficiency of Scale
- Lightweight Construction
- Hull Surface – Hull Coating
- Propeller Blade Design
- Bow Thruster Scallops / Grids
Ro-Ro Efficiency Improvements

- Hybrid Auxiliary Power Generation
- Condition Based Maintenance (CBM)
- Solar Power
- Energy Saving
- Operation Awareness
- Reduce Ballast
- Vessel Trim Adjustment
- Efficiency Improvements
Ferry Efficiency Improvements

- ENERGY SAVING LIGHTNING
- COOLING WATER PUMPS, SPEED CONTROL
- ENERGY SAVING LIGHTNING
- INTERCEPTOR TRIM PLANES
- TURNAROUND TIME IN PORT
- PROPULSION CONCEPTS – CRP
- CODED MACHINERY
- FUEL TYPE – LNG
Agenda

Efficiency Technologies & Energy Savings

Evolving Developments

Ship Design

Propulsion

Machinery

Operations & Maintenance

Why Clean Natural Gas

LNG Improves Cold Ironing
Ship types for which the energy efficiency improvement suits best

Retrofit Measures likely for existing vessels

Methods suited for new buildings

Potential upper range of vessel overall annual fuel savings, not a specific power mode

Operational measures

Payback timeframe
Short < 1 year to Long > 15 years
Ducktail Waterline Extension

Ducktail reduces wetted transom and lengthens effective waterline resulting in reduced hull resistance.
Optimum Hull Dimensions

Finding optimum length and hull fullness ratio $C_b$ exponentially impacts ship resistance.

Large Length to Beam $L/B$ ratio means ship has smooth lines, narrow entry and exit, brings benefit of lower wave making resistance.

High block coefficient $C_b$ blunts hull lines and negatively increases resistance.

A vessel with 10-15% extra length may achieve powering reduction near 10%.
Regression analysis shows a 10% larger ship achieves a 4 - 5% higher transport efficiency all other things equal.

Larger ships usually achieve greater transport efficiency.
Computer advances in Hydrodynamic design bring improved interactions between hull and propeller

Negative resistance of propeller water acceleration actions amongst hull, appendages, and propeller are minimized improving performance
Agenda

Efficiency Technologies & Energy Savings

Evolving Developments

Ship Design

- Propulsion

Machinery

Operations & Maintenance

Why Clean Natural Gas

LNG Improves Cold Ironing
Interceptor trim planes

The transom mounted interceptor plate deflects flow downward across stern which creates lift and reduces hull resistance reducing power demand
Streamlining shaft lines and brackets lowers flow disturbances = reduced resistance.
Pulling steerable thrusters combined with center Contra Rotating Propeller or Wing Thrusters improve propulsion efficiency.
Advanced improvements in blade sections reduces cavitation and frictional resistance.
Agenda

Efficiency Technologies & Energy Savings

Evolving Developments

- Ship Design
- Propulsion
- **Machinery**

Operations & Maintenance

Why Clean Natural Gas

LNG Improves Cold Ironing
Waste heat recovery (WHR) recovers thermal exhaust gas energy and converts to electrical energy employing a steam boiler and turbine alternator.
Combined Diesel-Electric and Diesel-Mechanical (CODED) machinery provide broad range of modal efficiency gains; at part load electrical efficiency benefits are achieved while at high power the mechanical drive system loss transmission losses achieve efficiency.
LNG as fuel

LNG as a fuel reduces energy consumption onboard

No HFO heating

Cold LNG (-162 °C) can be utilized in HVAC cooling to reduce compressor power
Agenda

Efficiency Technologies & Energy Savings

Evolving Developments

- Ship Design
- Propulsion
- Machinery
- Operations & Maintenance

Why Clean Natural Gas

LNG Improves Cold Ironing
Hull cleaning

Algae and marine organism hull growth negatively increases ship resistance

Frequent housekeeping with hull cleaning reduces drag influence

Fuel reductions vary by ship type and operational speeds; Tankers 3% ..... OSV 0.6%
Hull surface coatings

Modern paint coatings possess hard smooth surfaces which reduce hull friction and deter fouling.

Fuel savings vary by ship type and operational speeds; Tankers 9% ... Ferry 3%
Ship speed

Speed reduction efficiently cuts energy consumption

Reductions
0.5 kn --> - 7% energy
- 1.0 kn --> - 11% energy
- 2.0 kn --> - 17% energy
- 3.0 kn --> - 23% energy
Reduce ballast

Minimal ballast results in lighter displacement and thus lower resistance

Removing 3000 ton of permanent ballast from a PCTC and achieving similar stability by increased beam 0.25 m reduces propulsion power by 8.5%
Propeller surface finish/polishing

Regular in service polishing off organic growth and fouling reduces surface roughness on propellers.

Efficiency gains up to 10% compared to a fouled propeller.
Updated satellite climatic data allows optimal voyage tracks to follow best weather route
Condition Based Maintenance (CBM)

Satellite communication allows
real time remote monitoring
trend analysis
smart systematic diagnosis
expert personnel observation

Main benefits
lower fuel consumption
lower emissions
longer interval between overhauls
higher reliability
Energy saving lighting

Use efficient lighting wherever possible and optimized lighting use reduces electricity and air conditioning demand

Fuel consumption saving for a vessel: ~1%
A culture of fuel saving and reward or bonus system based on fuel savings encourages internal competition amongst vessels in fleet.
Turnaround time in port

Quicker port turnaround time allows transit speed reduction while maintaining schedules

Turnaround time is reduced by improved maneuvering performance or enhancing cargo flows through innovative ship and terminal design

Reducing ferry port time:

<table>
<thead>
<tr>
<th>Port time</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 h</td>
<td>100%</td>
</tr>
<tr>
<td>-10min</td>
<td>97%</td>
</tr>
<tr>
<td>-20min</td>
<td>93%</td>
</tr>
</tbody>
</table>
Agenda

Efficiency Technologies & Energy Savings

Evolving Developments

Ship Design
Propulsion
Machinery

Operations & Maintenance

Why Clean Natural Gas

LNG Improves Cold Ironing
What is natural gas?

Natural gas … mostly methane (CH₄)

**Methane** has highest hydrogen content energy of any fossil fuel

Carbon to hydrogen ratio 1 / 4 (gasoline: 1 / 2.25)

Natural gas is:
- Non-toxic
- Colourless
- Odourless
- Lighter than air

Natural Gas has least Carbon content = Low CO2 Emissions
Low Natural Gas Emissions

25-30% lower CO$_2$
   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

50% lower PM Particulates
   Particulates vary across operating range

No visible smoke

No sludge deposits extends engine life and time between overhauls achieving maintenance savings
Win Win: Emissions Reduction & OPEX Savings

Sources: www.lngoneworld.com, www.bunkerworld.com, LR Fairplay
Agenda

Efficiency Technologies & Energy Savings

Evolving Developments

Ship Design
Propulsion
Machinery

Operations & Maintenance

Why Clean Natural Gas

LNG Improves Cold Ironing
San Diego approves $7.6 M for giant electrical plugs… so vessels can shut down diesel generators while in port.
Cold ironing at berth substitution of “preferred” shore power over traditional undesirable ship genset fuels misses LNG benefits!
Ship Port Transit Steps

Ship approaches coastline

Ship maneuvers to pier

Cargo load / unloading ops

Ship departs berth

Cold Ironing limits emissions only during dockside cargo efforts while missing majority of vessel activities

Sources:
3. news.xinhuanet.com/.../09/content_11154169.htm
5. flickr.com/photos/77759596@N00/2063547505/

Suboptimal Cold ironing focus at berth … is there a better approach?
LNG Onboard Gensets

LNG auxiliary gen set electrical power for container vessels

Onboard units power vessel’s entire coastwise transit & port stay

Economically feasible

Significant emissions reduction

Available Technology

Port Electricity Production Cost

LNG = Superior solution to coastal and port emissions over dockside Cold Ironing… best duration, costs, stakeholder needs
LNG Storage Possibilities

Topside ISO Containers or permanent below deck LNG fuel tankage
<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>
Trans-Pacific Voyage Route

Los Angeles – Oakland – Dalian – Busan – Nagoya – Yokohama – Los Angeles
Coastal Zone … fuel with very low sulfur to reduce S0x … was 24 miles soon 200 miles ECA
1,300 refrigerated cargo containers consume high electrical power to maintain cold storage.

Large electrical cargo loads demand > 8,000 kW (10,800 HP)
### Operating Profile LNG Consumption

<table>
<thead>
<tr>
<th>Activity</th>
<th>LNG consumption</th>
<th>Run Time per round trip</th>
<th>Consumption per round trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cargo Loading &amp; Unloading</td>
<td>1.5 Ton / hour</td>
<td>138 hours</td>
<td>207.0 tons</td>
</tr>
<tr>
<td>Maneouerining</td>
<td>2.1</td>
<td>6 hours</td>
<td>12.6</td>
</tr>
<tr>
<td>Coastwise slow transit with clean low sulphur diesel*</td>
<td>1.6</td>
<td>10</td>
<td>16.0</td>
</tr>
</tbody>
</table>

236 Tons LNG  =  523  m3

2 Fixed tanks @ 190 m3  ... Bunker twice (1.4 x) each voyage
Topside ISO Containers provide flexibility and capacity
## LNG consumption – West Coast Ports

<table>
<thead>
<tr>
<th>Activity</th>
<th>Ton / hour</th>
<th>hours</th>
<th>tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cargo Loading &amp; Unloading</td>
<td>1.5</td>
<td>58</td>
<td>87.0</td>
</tr>
<tr>
<td>Maneuvering</td>
<td>2.1</td>
<td>2</td>
<td>4.2</td>
</tr>
<tr>
<td>Slow steaming coastwise</td>
<td>1.6</td>
<td>10</td>
<td>16.0</td>
</tr>
</tbody>
</table>

Los Angeles and Oakland Ports

108 tons LNG = 240 m³

**Tankage Need**

8 units 40ft ISO LNG containers @ 31.5 m³ = 240 m³
<table>
<thead>
<tr>
<th>Fuel</th>
<th>USD/ton</th>
<th>EUR/ton</th>
<th>USD/MBtu</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSHFO</td>
<td>440</td>
<td>335</td>
<td>11.4</td>
</tr>
<tr>
<td>MDO</td>
<td>680</td>
<td>515</td>
<td>16.8</td>
</tr>
<tr>
<td>MGO</td>
<td>740</td>
<td>565</td>
<td>18.2</td>
</tr>
<tr>
<td>LNG</td>
<td>510</td>
<td>390</td>
<td>11.0</td>
</tr>
</tbody>
</table>

Source: [www.bunkerworld.com](http://www.bunkerworld.com) (Rotterdam Oct 2008), LNG price estimated

1 EUR = 1.31 USD
Clean fuel is to be used in aux engines in all these time phases.
Annual Aux Gen Set Fuel Cost

LNG Win + Win = Emissions & Cost Reduction

LNG Lowest emissions & Annual Cost Savings 700 K €
Shore Power similar costs but hosts emissions achievement short fall
Investment cost for aux engines includes Engines + Generators … LNG System … Shore Power Connection
Annual CAPEX + OPEX “All In” Costs

LNG Genset Financial Payback 15 Years at 6 %

LNG Genset Emissions Environment Payback immediate

** Shore power rate 0.09 $ / kWh
LNG Emissions Reductions

Diesel DF Diesel with shore power

CO2 NOx SOx

17% 80% 50%

LNG DF Reductions = 1900 Tons CO2 190 Ton NOx 7 Ton SOx
Shore Power Plant … uncertain
Several shore-side linkages bring power to ship from land ... multiple interfaces pose match challenges

Source: http://en.wikipedia.org/wiki/Cold_Ironing
Several different ship electrical systems complicate smooth integration with cold ironing port infrastructure.

Utility frequencies miss ship needs… result employ shore transformers @ 3% inefficiency = costly CO2 increase

What size connection Plug?

Source: http://www.coldironing.us/unitedstates/coldironing.htm

Source:

Variety of ships shore-bus connection types present “plug & play” challenges
### Scorecard: Port Cold Iron Vs. LNG Ship Gensets

<table>
<thead>
<tr>
<th>Cold Ironing Methods</th>
<th>Port Focus Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compatibility</td>
<td></td>
</tr>
<tr>
<td>Electrical Voltage</td>
<td>Public</td>
</tr>
<tr>
<td>Electrical Frequency</td>
<td>Shipowner</td>
</tr>
<tr>
<td>Power Watts Available</td>
<td></td>
</tr>
<tr>
<td>Plugin Style Connects</td>
<td></td>
</tr>
<tr>
<td>Utility</td>
<td></td>
</tr>
<tr>
<td>Emissions of Remote Utility</td>
<td>Public</td>
</tr>
<tr>
<td>Emissions of LNG Gensets</td>
<td>Shipowner</td>
</tr>
<tr>
<td>Port Facility</td>
<td></td>
</tr>
<tr>
<td>Fees for Power</td>
<td>Public</td>
</tr>
<tr>
<td>Time for Port Set up &amp; Disconnect</td>
<td>Shipowner</td>
</tr>
<tr>
<td>Emissions Stewardship</td>
<td></td>
</tr>
<tr>
<td>Ship approaches Coastline</td>
<td>Red</td>
</tr>
<tr>
<td>Ship Maneuvers to Pier</td>
<td>Red</td>
</tr>
<tr>
<td>Dockside Cargo Operations</td>
<td>Green</td>
</tr>
<tr>
<td>Ship Departs Berth</td>
<td>Red</td>
</tr>
<tr>
<td>Ship Sea Bound</td>
<td>Red</td>
</tr>
</tbody>
</table>
Scorecard: Port Cold Iron Vs. LNG Ship Gensets

<table>
<thead>
<tr>
<th>Compatibility</th>
<th>Onboard LNG Gensets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Voltage</td>
<td>Public</td>
</tr>
<tr>
<td>Electrical Frequency</td>
<td>Public</td>
</tr>
<tr>
<td>Power Watts Available</td>
<td>Public</td>
</tr>
<tr>
<td>Plugin Style Connects</td>
<td>Public</td>
</tr>
<tr>
<td>Utility</td>
<td></td>
</tr>
<tr>
<td>Emissions of Remote Utility</td>
<td>Public</td>
</tr>
<tr>
<td>Emissions of LNG Gensets</td>
<td>Public</td>
</tr>
<tr>
<td>Port Facility</td>
<td></td>
</tr>
<tr>
<td>Fees for Power</td>
<td>Public</td>
</tr>
<tr>
<td>Time for Port Set up &amp; Disconnect</td>
<td>Public</td>
</tr>
<tr>
<td>Emissions Stewardship</td>
<td></td>
</tr>
<tr>
<td>Ship approaches Coastline</td>
<td>Public</td>
</tr>
<tr>
<td>Ship Maneuvers to Pier</td>
<td>Public</td>
</tr>
<tr>
<td>Dockside Cargo Operations</td>
<td>Public</td>
</tr>
<tr>
<td>Ship Departs Berth</td>
<td>Public</td>
</tr>
<tr>
<td>Ship Sea Bound</td>
<td>Public</td>
</tr>
</tbody>
</table>
# Scorecard: Port Cold Iron Vs. LNG Ship Gensets

<table>
<thead>
<tr>
<th>Cold Ironing Methods</th>
<th>Onboard LNG Gensets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compatibility</td>
<td></td>
</tr>
<tr>
<td>Electrical Voltage</td>
<td>Public</td>
</tr>
<tr>
<td>Electrical Frequency</td>
<td>Shipowner</td>
</tr>
<tr>
<td>Power Watts Available</td>
<td></td>
</tr>
<tr>
<td>Plugin Style Connects</td>
<td></td>
</tr>
<tr>
<td>Utility</td>
<td></td>
</tr>
<tr>
<td>Emissions of Remote Utility</td>
<td></td>
</tr>
<tr>
<td>Emissions of LNG Gensets</td>
<td></td>
</tr>
<tr>
<td>Port Facility</td>
<td></td>
</tr>
<tr>
<td>Fees for Power</td>
<td></td>
</tr>
<tr>
<td>Time for Port Set up &amp; Disconnect</td>
<td></td>
</tr>
<tr>
<td>Emissions Stewardship</td>
<td></td>
</tr>
<tr>
<td>Ship approaches Coastline</td>
<td></td>
</tr>
<tr>
<td>Ship Maneuvers to Pier</td>
<td></td>
</tr>
<tr>
<td>Dockside Cargo Operations</td>
<td></td>
</tr>
<tr>
<td>Ship Departs Berth</td>
<td></td>
</tr>
<tr>
<td>Ship Sea Bound</td>
<td></td>
</tr>
</tbody>
</table>
### Scorecard: Port Cold Iron Vs. LNG Ship Gensets

#### Cold Ironing Methods

<table>
<thead>
<tr>
<th>Compatibility</th>
<th>Port Focus Power</th>
<th>Onboard LNG Gensets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Voltage</td>
<td>Public</td>
<td>Shipowner</td>
</tr>
<tr>
<td>Electrical Frequency</td>
<td>Public</td>
<td>Shipowner</td>
</tr>
<tr>
<td>Power Watts Available</td>
<td>Public</td>
<td>Shipowner</td>
</tr>
<tr>
<td>Plugin Style Connects</td>
<td>Public</td>
<td>Shipowner</td>
</tr>
</tbody>
</table>

#### Utility

<table>
<thead>
<tr>
<th></th>
<th>Port Focus Power</th>
<th>Onboard LNG Gensets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions of Remote Utility</td>
<td>Public</td>
<td>Shipowner</td>
</tr>
<tr>
<td>Emissions of LNG Gensets</td>
<td>Public</td>
<td>Shipowner</td>
</tr>
</tbody>
</table>

#### Port Facility

<table>
<thead>
<tr>
<th></th>
<th>Port Focus Power</th>
<th>Onboard LNG Gensets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fees for Power</td>
<td>Public</td>
<td>Shipowner</td>
</tr>
<tr>
<td>Time for Port Set up &amp; Disconnect</td>
<td>Public</td>
<td>Shipowner</td>
</tr>
</tbody>
</table>

#### Emissions Stewardship

<table>
<thead>
<tr>
<th></th>
<th>Port Focus Power</th>
<th>Onboard LNG Gensets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship approaches Coastline</td>
<td>Public</td>
<td>Shipowner</td>
</tr>
<tr>
<td>Ship Maneuvers to Pier</td>
<td>Public</td>
<td>Shipowner</td>
</tr>
<tr>
<td>Dockside Cargo Operations</td>
<td>Public</td>
<td>Shipowner</td>
</tr>
<tr>
<td>Ship Departs Berth</td>
<td>Public</td>
<td>Shipowner</td>
</tr>
<tr>
<td>Ship Sea Bound</td>
<td>Public</td>
<td>Shipowner</td>
</tr>
</tbody>
</table>

Onboard LNG Gensets superior win for environmental protection ... optimal stakeholder solution serving both Public & Shipowner
Conclusions

LNG provides OPEX savings and Emissions reduction in port

DF achieves portside goal of lower emissions and uniquely extends reductions to / from horizon

DF independence from port facilities eliminates many concerns and brings timely efficiencies

LNG system + DF gen sets
Investment Payback Less Than 3 years