From the Port Onward...

Opportunities & Synergies for LNG in the port and container handling industry

Value Chain and Maritime LNG Training
Świnoujście, Poland – December 6, 2017

Prof. Lawrence Henesey
Blekinge Institute of Technology,
Karlshamn, Sweden
Who is this guy?

✓ Scientist on the application of techniques from Distributed Artificial Intelligence in Container Ports and Terminals, culminated into 50+ published articles and two books.

✓ Develop solutions for energy and data transmission in ports and container terminals globally. Employing automation and electrification technologies such as AGVs, ASCs, Automated cranes, RTGs and RMGs.

✓ Lecturer at several US and European Universities, member of the board of advisors at the Port Operations Research and Technology Centre at Imperial College London.

✓ Possesses 26 years of industrial work experience while living or employed in several countries such as: Evergreen, Sea Land, Bank of America, Deutsche Post GmbH, Sea Trade Reefer, TTS Port Equipment, Conductix-Wampfler AG and SIMPORT AB.

✓ Dr. Henesey is a member of the following organisations: Port Equipment Manufacturers Association (PEMA), Swedish Artificial Intelligence Society (SAIS), and Association of Computer Machinery (ACM).

✓ PhD in Computer Science from Blekinge Institute of Technology at Karlshamn, Sweden. MSc (Cum-Laude) in Transport and Maritime Management from the University of Antwerp, Belgium and degrees from Old Dominion University, Virginia, USA.
Learning Objectives for today:

- Brief History Lesson
- Opportunities for using LNG for other equipment and vehicles in a port
- Case for Terminal Tractors
- Case for yard cranes (Rubber Tired Gantry Cranes. RTGs)
- Case for other equipment, such as Automated Guided Vehicles and Straddle carriers
- Questions and Answers – don’t be shy – ASK!!
Developing LNG as a business opportunity
Container Terminals & Container Handling
A Very Brief History Lesson
Early days – For centuries, freight was handled manually
A truck driver who eventually built one of the largest trucking companies in America

Malcolm P. McLean

He realized that there had to be a better way
Where would we be today if Malcolm P. McLean had believed the guy who said...

“Cargo can only be moved by hand.”

“But, we’ve always done it this way”
Thankfully he knew better…

In 1956 Malcom changed the shipping world forever!

The ship carried 58 35-feet containers, along with a regular load of 15,000 tons of bulk petroleum from Newark to Houston in April 26, 1956.

Port Newark, 1959
Just 5 Years later, a Global Standard was set that improved production, safety and cut costs while improving the way that we move goods around the world.
1961 – ISO set global standards for container sizes at 10’/20’/30’/40’
As reported on the TV show “Who Made America”

“As McLean’s first container ship left Newark harbor, a man asked Freddy Fields, a top official of the ILA…”

“What do you think of that new ship?”

Fields replied, “I’d like to sink that sonofabitch!”

Longshoreman strikes ensued, but the cost of shipping dropped by 90%.

Modern containerization was born.
As a result of Standardization...

Production went from a rate of 1.3 Tons/Hour to > 30 Tons/Hour

The cost to produce and transport from Gulf of Mexico went from $5.86/Ton to $0.16/Ton.

3,000 in 120 days.
We find ourselves, once again, at the threshold of a new vision in terminal production, safety and cost savings.
Pick up any Trade/Industry magazine and we see that Automation is here to stay.
Since the earliest days of containerization...

There have been a lot of major changes in the way we do business. Standardization will allow us to work effectively and utilize the best that technology has to offer.
Standardize Port / Terminal LNG Bunkering and Distribution Services...?
Market and Customer Trends
Market size for Port Equipment & Container Handling
7 Billion €
Equipment in Container Terminals

1. STS | Ship to Shore Cranes
2. RTG | Rubber Tyred Gantry Crane
3. RMG | Rail Mounted Gantry Crane
4. Intermodal Cranes
5. Horizontal Transport | AGVs, Trucks, Straddle Carriers
Description and Segmentation

☑ Ports and terminals industry projected growth rate of 6% - till 2017

☑ Total global container throughput will be 830 million TEU (Twenty-foot Equivalent Units) by 2017. Growth rate of 40% between 2011-2017.

☑ Conservative growth rate of 5% will double current global container volumes by 2025

☑ Containerisation with strong port development in various regions.

☑ More Large ships ordered, 445 new ships with capacity of 3,27 million TEU

☑ Larger ships means more time at port - leading to more costs.
<table>
<thead>
<tr>
<th>Trends</th>
<th>Container Ports</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing competition of terminals</td>
<td>GTOs</td>
<td>More efficient systems</td>
</tr>
<tr>
<td>Globalization</td>
<td>Carriers/Liners</td>
<td>New investments in modern port facilities</td>
</tr>
<tr>
<td>Bigger Vessels</td>
<td>Port Authorities</td>
<td>Bigger Cranes and faster logistics</td>
</tr>
<tr>
<td>Increase in energy costs</td>
<td></td>
<td>Energy Savings</td>
</tr>
<tr>
<td>Increasing environmental demands</td>
<td></td>
<td>Automation of Container Yards</td>
</tr>
</tbody>
</table>
Factors for developing Ecological Equipment

Environmental
- reducing pollution (air and noise)

Economical
- reducing operating costs (oil prices) and maintenance costs

Technological
- optimizing productivity & performances
If necessity is the **mother** of invention
then
vision is the **father** of innovation!
Where can we apply Ecological Equipment?

- How much energy is consumed?

- Where is the energy consumed?

Reference: GreenCranes Project
Which Machinery or Equipment to Consider?

- Rubber Tyred Gantry Crane (RTG)
- Terminal Tractor
- Reach Stacker
- Empty Forklift
How much ELECTRIC consumption?

NCTV Electrical Consumption 2012 (kWh)
- STS Cranes: 12,522,629 kWh (43%)
- Terminal Lightning: 11,006,280 kWh (37%)
- Offices: 4,801,013 kWh (15%)
- Reefer Containers: 1,815,477 kWh (5%)

Livorno TDT Electrical Consumption 2012 (kWh)
- STS Cranes: 30,145,399 kWh (30.1 GWh)

Total: 30,145,399 kWh

X 3,000 (10,000 kWh / year)
How much DIESEL (FUEL) consumption?

NCTV Yard Machinery. Total Fuel Consumption 2012

- 4,049,138 L (58%)
- 2,245,147 L (32%)
- 611,460 L (9%)
- 80,819 L (1%)

90%

Livorno TDT Yard Machinery. Total Fuel Consumption 2012

- 6,986,564 L

X 4,000 (1,300 L / year)
Terminal Tractors are the most used type of horizontal equipment found in Container Terminals worldwide.

Terminal Tractors represent significant part of the total fuel consumption in a port – often the 2nd most consuming of fuel after yard cranes.
Feasibility Evaluation: Terminal Tractors

**Terminal Tractors**
- 2.4 Million L
- 1.8 Million € GoB

**Alternatives TT**
- Gasoil TIER 4 / Stage IV (2014)
- LNG
- Dual Fuel

**RTGs**
- 4.6 Million L
- 3.4 Million € GoB

**Alternatives RTG**
- RTG Engine Replacement TIER 4 (2014)
- LNG / Dual Fuel
- Electrification
- Conductor Bar
- Cable Reel

**STS + Other**
- 17.8 GWh
- 2.2 Million € kWh

**Supply Alternatives**
- Current Electrical Tariff
- Tariff 6.1 (Electrical Supplier)
- Tariff 6.3 (Electrical Supplier)
The use of specialised trailers differs from world area to world area. In highly developed Europe and North America 85% of the trailers used in terminals are specialised terminal trailers. In South America road trailers still dominate.

- **North America**: 80% terminal trailers, 5% road trailers
- **Europe**: 80% terminal trailers, 5% road trailers
- **North East Asia**: 55% terminal trailers, 5% road trailers
- **South America**: 56% terminal trailers, 40% road trailers
- **Middle East, India, Africa**: 45% terminal trailers, 10% road trailers
- **South East Asia**: 55% terminal trailers, 5% road trailers

Market Shares by Trailer Type
(Size of Chart according to Market Size)
Terminal Tractor Market?

- Terminal Tractor market accounted for 5900 units (2700 delivered to ports and 3200 to other facilities for warehousing and distribution)

Terminal Tractor Market by supplier

- Kalmar: 51%
- Capacity: 24%
- Terberg: 10%
- Mafi: 3%
- CVS: 2%
- MOL: 2%
- Others: 8%
LNG Facts for Terminal Tractors

- LNG in fuel tank is stored at less than 100 PSI but at temperatures of −259 F and lower. It has the ability to **contain more fuel in slightly less space** and much lower pressure than CNG.

- Fuel consumption in liters per hour is about **13.2 – 17 Liters per hour**. (Cummins C Gas + 250 HP/750lb/ft T).

- Based upon a 216 liter usable tank size this would **limit to about 12 –16 Hours** on LNG vs. **about 24 – 30 hours on a standard 190 liter** tank of diesel.

- Clear, odorless, and non-corrosive.

Reference: Kalmar Industries
Fuel Consumption per Liter in comparing Engine Alternatives

<table>
<thead>
<tr>
<th>Engine Types</th>
<th>Liters</th>
</tr>
</thead>
<tbody>
<tr>
<td>6BTA5.9-173</td>
<td>5.68</td>
</tr>
<tr>
<td>BLPG-195 PLUS</td>
<td>14.20</td>
</tr>
<tr>
<td>BGAS-195 PLUS</td>
<td>16.09</td>
</tr>
<tr>
<td>CGAS-250 PLUS</td>
<td>17.60</td>
</tr>
</tbody>
</table>
Energy Comparison

- #2 Diesel: 140,000 BTU / Gal.
- Unl. Gas: 120,000 BTU / Gal.
- LPG: 100,000 BTU / Gal.
- LNG: 80,000 BTU / Gal.
- Methanol: 60,000 BTU / Gal.
## Machinery or Equipment Deliveries 2008-2013

<table>
<thead>
<tr>
<th>Equipment type</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reach Stackers</td>
<td>1408</td>
<td>796</td>
<td>1227</td>
<td>1452</td>
<td>1504</td>
<td>1324</td>
</tr>
<tr>
<td>FLT's Laden</td>
<td>198</td>
<td>110</td>
<td>113</td>
<td>146</td>
<td>178</td>
<td>146</td>
</tr>
<tr>
<td>FLT's empty</td>
<td>613</td>
<td>318</td>
<td>467</td>
<td>549</td>
<td>709</td>
<td>671</td>
</tr>
<tr>
<td>Terminal Tractors 4x2</td>
<td>2843</td>
<td>1778</td>
<td>1343</td>
<td>1727</td>
<td>1625</td>
<td>1596</td>
</tr>
<tr>
<td>Terminal Tractors 4x4</td>
<td>692</td>
<td>404</td>
<td>320</td>
<td>375</td>
<td>414</td>
<td>404</td>
</tr>
</tbody>
</table>

- **Terminal Tractor 4x2**
- **Terminal Tractor 4x4**
- **Reach Stacker**
What is the Pay Back?

LCC = (Initial Cost of Vehicle) – Purchase Incentives + PVFuel – PVResale

Where:
- Purchase Incentives = Value of Grants, Tax Credits, etc. Applied to Vehicle Purchase
- PVFuel = Present Value of Fuel Expenses During Vehicle Service Life
- PVResale = Present Value of Resale Value of Vehicle at End of Service Life
- PV = $F_t / (1 + d)^t$
- $F_t$ = Future Cash Flow in Year $t$
- $d$ = Discount Rate
<table>
<thead>
<tr>
<th>Factor</th>
<th>Diesel</th>
<th>LNG – No Incentives</th>
<th>LNG – LNG Incentives</th>
<th>LNG – SCAQMD (Max. 25 Vehicles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Cost of Vehicle</td>
<td>$80,000</td>
<td>$120,000</td>
<td>$120,000</td>
<td>$120,000</td>
</tr>
<tr>
<td>Purchase Incentives</td>
<td>$0</td>
<td>$0</td>
<td>$32,000</td>
<td>$40,000</td>
</tr>
<tr>
<td>Fuel Cost/Gallon After Tax Credits</td>
<td>$2.60</td>
<td>$0.50</td>
<td>$0.50</td>
<td>$0.50</td>
</tr>
<tr>
<td>Gallons/Operating Hour</td>
<td>1.7</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Annual Operating Hours</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Annual Fuel Costs</td>
<td>$8,840</td>
<td>$3,800</td>
<td>$3,800</td>
<td>$3,800</td>
</tr>
<tr>
<td>Service Life</td>
<td>10 Years</td>
<td>10 Years</td>
<td>10 Years</td>
<td>10 Years</td>
</tr>
<tr>
<td>Discount Rate</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Present Value Fuel</td>
<td>$77,669</td>
<td>$33,387</td>
<td>$33,387</td>
<td>$33,387</td>
</tr>
<tr>
<td>Resale Value</td>
<td>$5,000</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Present Value Resale LCC</td>
<td>$3,832</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>LCC</td>
<td>$153,837</td>
<td>$153,387</td>
<td>$121,387</td>
<td>$113,387</td>
</tr>
</tbody>
</table>
RTG are the main solution for moving containers in terminal yards worldwide.

RTG represent significant part of the total fuel consumption in a port (more than 50%).
Feasibility Evaluation: RTG

Green Cranes

Terminal Tractors
- 2.4 Million L
- 1.8 Million € GoB

RTGs
- 4.6 Million L
- 3.4 Million € GoB

STS + Other
- 17.8 GWh
- 2.2 Million € kWh

Alternatives TT
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- LNG
- Dual Fuel

Alternatives RTG
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Supply Alternatives
- Current Electrical Tariff
- Tariff 6.1 (Electrical Supplier)
- Tariff 6.3 (Electrical Supplier)
Facts + Figures

- Diesel engines are the main source of RTGs
- Container handling increases
- At the same time diesel prices increased rapidly
- In some cases RTGs account for 50% of a container terminals' diesel consumption

Effects

- High fuel consumption & costs
- High dependency on fossil fuels that have unpredictable prices
- High cost in larger size Genset service (~ USD 20k / year)
- Environmental; carbon emissions, air and noise pollution
RTG Electrification technologies

RTG Electrification

Bus Bar

Cable Reel
EcoLogical facts from an eRTG solution – GPA, US

- Diesel RTG CO₂ emission per year 1,000,900 lbs.
- Electric RTG CO₂ emission per year 447,000 lbs.
- CO₂ reduction of ~ 52%
Fully Electric RTGs: eRTG

Principle Function:
Fully Electric RTGs: eRTG

Principle Function:

- Diesel motor
  - V8 – V12
  - 400 – 650 PS

- Generator
  - 300 – 850 KVA
Fully Electric RTGs: eRTG

Principle Function:
Fully Electric RTGs: eRTG

Principle Function:

Efficiencies
- V-Motor:
- Generator:
### Case for e-RTG: E3Economy, Efficiency & Environment

<table>
<thead>
<tr>
<th>RTG Type</th>
<th>Conventional RTG</th>
<th>EcoRTG</th>
<th>EcoRTG w/ supercapacitors</th>
<th>eRTGs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel / Energy consumption (15 moves / hour)</td>
<td>20.9 lit/hour</td>
<td>13.1 lit/hour</td>
<td>6.8 lit/hour</td>
<td>35kWh</td>
</tr>
<tr>
<td>Energy costs: Diesel € 2.31 / kWh: € 0.06</td>
<td>€ 12.79</td>
<td>€ 7.99</td>
<td>€ 4.17</td>
<td>€ 2.33</td>
</tr>
<tr>
<td>Operating hours 3600, cost / year</td>
<td>€ 46,033.92</td>
<td>€ 28,771.20</td>
<td>€ 14,998.32</td>
<td>€ 8,391.60</td>
</tr>
</tbody>
</table>

Additional savings for reducing maintenance costs associated with diesel generators:

- Maintenance costs per operating hours (€1.90 / hour): € 6,840 per yr.
- Tier 4 Diesel replacement @ 25,000 hours (€ 4.45 / hour): € 110,250


Solutions: Electrification to reduce fuel and maintenance for achieving savings of up to 85%
# Financial Benefits:

## Cash flow and ROI statement

<table>
<thead>
<tr>
<th>Benefit Drivers</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved operational time (less down time)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced energy cost due to less running time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced Maintainance cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fewer accidents, resulting in less workers’ compensation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel replacement avoided 150,000 / 7 years other...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total annual benefits</td>
<td>$107,288</td>
<td>$116,468</td>
<td>$116,468</td>
<td></td>
</tr>
<tr>
<td>Implementation filter</td>
<td>90%</td>
<td>95%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Total benefits realized</td>
<td>$96,559</td>
<td>$110,645</td>
<td>$116,468</td>
<td></td>
</tr>
</tbody>
</table>

## Costs

<table>
<thead>
<tr>
<th></th>
<th>Year 0</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>$250,000</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
</tbody>
</table>

## Benefits

<table>
<thead>
<tr>
<th></th>
<th>Year 0</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual benefit flow</td>
<td>-$250,000</td>
<td>$96,559</td>
<td>$110,645</td>
<td>$116,468</td>
</tr>
<tr>
<td>Cumulative benefit flow</td>
<td>-$250,000</td>
<td>-$153,441</td>
<td>-$42,796</td>
<td>$73,672</td>
</tr>
</tbody>
</table>

## Discounted benefit flow

<table>
<thead>
<tr>
<th></th>
<th>Year 0</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discounted costs</td>
<td>$250,000</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Discounted benefits</td>
<td>$0</td>
<td>$96,559</td>
<td>$110,645</td>
<td>$116,468</td>
</tr>
<tr>
<td>Total discounted benefit flow</td>
<td>-$250,000</td>
<td>-$153,441</td>
<td>-$42,796</td>
<td>$73,672</td>
</tr>
</tbody>
</table>

## Initial investment

<table>
<thead>
<tr>
<th></th>
<th>Year 0</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial investment</td>
<td>$250,000</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Implementation costs</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Ongoing support costs</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Training costs</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Other costs</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Total costs</td>
<td>$250,000</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
</tbody>
</table>

## ROI measures

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Cost of capital</td>
<td>6%</td>
</tr>
<tr>
<td>Net present value</td>
<td>$37,355</td>
</tr>
<tr>
<td>Return on investment</td>
<td>39%</td>
</tr>
<tr>
<td>Payback (in years)</td>
<td>2.37</td>
</tr>
</tbody>
</table>
Other equipment to be « LNG-nized »

AGV – Automated Guided Vehicles

Straddle Carriers
Full LNG powered Reach Stackers

Kalmar is to engineer and produce a diesel-LNG powered reachstacker prototype as part of the GREENCRANES project.

“The LNG power is a very interesting future fuel alternative both for port equipment business as well as for the whole shipping industry. Natural gas extractions are increasing and this can clearly be seen as one of the future trends.”
What have we learned on Opportunities & Synergies for LNG in the port and container handling industry?

- Port Container Terminals are huge energy consumers, especially on those energy sources based on fossil fuels.

- From the economic point of view, increase of energy prices means more cost which reduces Port competitiveness.

- In terms of environmental impact, with the current motivation in having LNG bunkering and ships being built with LNG engines, the additional effort to “bunker port equipment is a low barrier to entry (Cherry Picking).”

- Concerning social impact, ports are usually located near populated cities affect nearby population as direct GHG emissions (derived from diesel oil) are locally deployed, not only CO₂, but also other pollutant and toxic gases like N₂O, Sulphur compounds and suspension particles.

- Efforts to reduce fuel consumption and GHG emissions produced by RTGs, yard tractors and reach stackers are strongly recommended. More studies on equipment needed!!
More information found at: WWW.GOLNG.EU
THANK YOU
Total and CMA CGM have signed an agreement covering the supply of around 300,000 tons of liquefied natural gas (LNG) a year for 10 years starting in 2020.
Thank You for your attention!

Asst. Prof. Dr. Lawrence Henesey
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