“The environmental Impact of Plug on the LNG Carrier “

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Abstract

Shut down the main engine in port during the loading and dislodging and use the shore connection Plug (this technique is often referred to as “cold ironing”) would be a logical way to reduce CO₂ emission below the legislative requirements as well as get more environmental benefit such as decreasing fuel consumption.

This paper presents the environmental benefit of the cold ironing through determining the amount of fuel oil consumption and CO₂ emission in three types of LNG carrier.

To enable to estimate the amount of CO₂ emitted from the ship, fuel consumption of ships on the berth by the Auxiliary engine, boilers, fuel used for cargo work must be considered. This report will determine tones of CO₂ emissions based on the CO₂ emission indexing from the LNG ships while running the auxiliary engine on the berth. To underline the importance and relevance of the PLUG in GHG reduction, the amount of co2 emission in port of Fos Tonkin-France is also calculated as a case study. Total expected CO₂ emissions reduction from a standard size of LNG vessel at berth were estimated at 58 and 42 tons for 20 hours running auxiliary engine during unloading and loading respectively.

Keywords: PLUG, Fuel Oil consumption, CO₂ Emission

Introduction

The growing environmental concern over global warming due to green house gases emissions had lead to a global initiative to reduce the emissions. The International Maritime Organization (IMO) is in charge of legislation on limitation/reduction of GHG from ships as CO₂ is the main gas emitted by ships. Presently there is no international mandatory rule approved for cold ironing, However future legislation concerning the limitation/reduction of CO₂ from ships such as “CO₂ emission tax” or “Emission Trading “ will expectedly be based on the measuring amount of CO₂ emissions . [1]

Various research topics in Cold ironing can be identified. To our knowledge, no previous research has analyzed the environmental benefit of the Plug concept in the LNG carriers in terms of CO₂ emissions.

‘Cold ironing’ is the US Navy’s way of describing the practice of connecting a ship to a shore-side power supply in port with the ship’s machinery shut down, causing the hull to become ‘cold’. This term is now commonly used to describe a new generation of different high-voltage shore connections with fast plug-ins and seamless load transfer without blackouts, which allow the full range of in-port activities to continue [2].

There are already existing installations for visiting ships in the ports of Gothenburg (Sweden), Pittsburgh (US), Juneau (US), Lubeck (Germany), Pitea (Sweden), Los Angeles (US) and port of Oakland, USA for its new tugboat wharf.

The U.S. Navy has used cold ironing for decades at naval facilities “Cold Ironing” is a process utilized to reduce exhaust emissions from ships at berth by providing shore-generated electrical power instead of operating the ships' auxiliary diesel generators. Although the U.S. Navy has used cold ironing for decades at naval facilities around the world, its application in a commercial context is relatively new [3].
The feasibility study of SCAQMD in 1987 estimated that total NO\textsubscript{x} emissions from all vessels at berth were 9.0 tons per day. The only pollutant considered in this study was NO\textsubscript{x}. Total expected NO\textsubscript{x} emission reductions from cold ironing were 4.7 tons per day. The SCAQMD estimated the cost effectiveness of reducing 4.7 tons NO\textsubscript{x} per day for non-tanker motor vessels to be $28,115/ton. The report cited advantages of cold ironing, which included reducing emissions of NO\textsubscript{x}, CO\textsubscript{2} and PM; freeing vessel personnel assigned to operate power equipment for other work; providing time for inspection and small repairs; and reducing noise levels on and near the vessel. Disadvantages were also identified.

In 1989 Port of Gothenburg converted a terminal to service ferries with shore side electricity. Port of Long Beach Electrification and Ship Emission Control Study in 1990 under contract to SCE examined the feasibility and cost of providing the shore-to-vessel power and infrastructure required for the Port of Long Beach. This study evaluated thirty vessels and twelve piers in the Port of Long Beach. The study found that the present Edison Company electrical distribution facilities were not adequate to accommodate the added loads imposed by vessels at berth. The existing service system for most terminals was designed only for buildings, transit sheds, silos, cranes and lighting, and could not be utilized to supply vessel electrification requirements. New and separate electrical substations and vessel service connections would be needed. The total capital costs to the vessel operators associated with cold ironing were estimated at $170.2 million, excluding land acquisition costs and interest during the construction, etc. Annual operating and maintenance (O&M) costs would be $14.5 million, including the cost of electricity.

In 1991 The Pohang Iron and Steel Company (POSCO) also established a shore-side electricity system as required by a local air permit [4].

Port of Los Angeles and Port of Long Beach [5] evaluated cold ironing along with other NO\textsubscript{x} control alternatives such as emission fees; retrofit technologies, and vessel speed reductions. The study concluded that shore-to-vessel electrification was feasible for small marine vessels, such as tugboats and workboats.

Port of Gothenburg in Sweden has installed shore-side electricity to two terminals. The port had spare capacity in existing conduits, which meant that cable installation was as cheap as that for a new build terminal. In addition only one of their two converted terminals required a new substation. These factors mean that the Port of Gothenburg incurred low capital and installation costs for the supply of high voltage electricity.

A cost effectiveness analysis of Long beach port in 2004 [6] concludes that cold ironing is generally cost effective with vessels that spend a lot of time at the port, and therefore have high annual power consumption. Use of cold ironing for vessels that currently have high annual power consumption in the Port could cause a significant reduction in the overall annual emissions generated by docked vessels in the Port each year. Finally, the paper concludes that the various technologies that are analyzed, including cold ironing, could have significant regulatory, legal, and logistical hurdles to overcome, particularly if the South Coast Air Quality Management District (SCAQMD) or other local agency wishes to mandate their use.

All of the possible control techniques have significant regulatory, legal, and logistical hurdles to overcome, particularly if the SCAQMD or other agency wishes to mandate their use. These hurdles are at the local, State, Federal, and international levels. Given those constraints, a voluntary program or an incentive program may be the most productive means of reducing emissions from hotelling in the Port of Long Beach [3].

As part of this settlement, the Port of Los Angeles (May 2006) required China Ocean Shipping Co. to use cold-ironing as a condition for allowing the shipper to establish a terminal there in 2002. The cold-ironing was set up in 2004. Currently, 70 percent of the ships that call at the China Shipping terminal use cold ironing [5].

Feasibility study of cold-ironing at California ports "presents an analysis of the feasibility and cost effectiveness of cold-ironing ocean-going vessels while docked at California ports."[7].

Cold-ironing could produce large emission reductions and is cost effective. "According to the report, if all ships used shore power when hotelling in Californian ports, emissions of nitrogen oxides (NO\textsubscript{x}) would be reduced by 22 tonnes per day, and
particulate matter (PM) by 0.4 tonnes per day. In a more likely scenario, according to ARB, if ships making three or more annual visits to the port used cold ironing, then hotel ling emissions would be reduced by 70%: 17 tonnes.

There are several overall conclusions based on this study. First, it is feasible to cold-iron ocean-going vessels visiting California ports, as ships of various types and designs are already connecting to shore power at California ports and other cold-ironing installations are already planned. Cold-ironing could produce large emission reductions and is cost effective at a large number of terminals and for a large percentage of ship visits. The most attractive ship categories are container ships, passenger ships, and reefers.

Cold-ironing container ships and passenger ships is especially crucial for emissions reductions, as these ships account for 56 percent of all ship visits to the State, and container shipments and passenger ship visits are both growing dramatically. On the other hand, there are cases when cold-ironing, while feasible, may not be cost effective, such as for ships with infrequent and irregular visits to California, especially for those vessels with lower power needs and shorter berthing times. This is especially true with the tanker and bulk cargo ship categories. Cold-ironing will require significant infrastructure investment by both the ports and the shipping companies. Finally, the cost-effectiveness values in this report assume that all of the costs and the benefits will be borne by California. As cold-ironing becomes commonplace, other ports—whether U.S. or foreign ports—will reap the benefits of cold-ironing when they install the necessary infrastructure to service the ships retrofitted to cold-iron in California. As this happens, some of the ship-side costs allocated to emission reductions in California should more properly be allocated to these other ports. This would further improve the cost effectiveness of this technology for use in California. [6]

**Fuel cost saving**

Growth in fleet size and fuel consumption (Corbett et al., 2000 and Clarkson Research, 2006) and comparatively, high CO₂ emission during ship idling and maneuvering while entering or leaving port is the major concern to raise the present level to a higher level for this environment friendliest and energy efficient mode.

Cost effectiveness of the plug could be determined by measuring the amount of Reduction in Fuel cost reduction which is a major element of shipping industry especially LNG ships’ profitability. Significant fuel cost differential is expected between alternative technical solutions.

\[
\text{Fuel cost} = \text{Fuel consumption} \times \text{fuel price} \tag{1}
\]

**Fuel consumption**

Amount of fuel consumption depends on the electrical load therefore the maximum electrical load on the switchboard while ship berthing at port will be considered. Fuel consumption of LNG ships on the berth by the following machinery Auxiliary engine, boilers and fuel used for cargo work is calculated as.

\[
Q = P \times b \times T \tag{2}
\]

Where,

- \(Q\) = fuel oil consumption (grammes) (example HFO)
- \(P\) = Electrical load on the switch board
- \(b\) = The SFOC (g/kW.H) of ME and GE
- \(T\) = Continuous operating time

Therefore fuel oil consumption of LNG carriers for (Q-MAX, Q-flex and Steam turbine) is calculated as:
Q-max fuel consumption with the following assumption

Size: 266000m³

Engine quantity per ship: 4 set /ship

Ship use heavy fuel oil while at port

Electrical load on the switch board (Cargo unloading) = 9700 KW

Electrical load on the switch board (Cargo loading) = 7000 KW

Electrical load on the switch board (port /IDLE) = 1900 KW

Average time ship spend at berth in port: 20 hours (15 h. loading /unloading +4h.Idle)

For GE

\[ Q_{(UN\ loading)} = (9700 \times 183 \times 15) = 26600000 \text{ (Grammes)} \]

\[ Q_{(Loading)} = (7000 \times 183 \times 15) = 19200000 \text{ (Grammes)} \]

\[ Q_{(Idle)} = (1900 \times 183 \times 5) = 1730000 \text{ (Grammes)} \]

Therefore, Fuel consumption of Q max in port for 20 hours running Auxiliary engine is equal to:

\[ Q_{(u+l)} = 26 + 1 = 27 \text{ T} \]

\[ Q_{(l+l)} = 19 + 1 = 20 \text{ T} \]

As shown in “Table 1” and figure 1 Fuel consumption of Q-flex and Standard size of LNG carrier are also based on the above calculation determined during loading and unloading.

Table 1: fuel oil consumption of different LNGc

<table>
<thead>
<tr>
<th>Size of the Ship</th>
<th>Q-max 266000m³</th>
<th>Q-flex 217000m³</th>
<th>Standard Size 145000m³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unloading</td>
<td>loading</td>
<td>Unloading</td>
</tr>
<tr>
<td>Fuel Consumption</td>
<td>27 T</td>
<td>20 T</td>
<td>25 T</td>
</tr>
</tbody>
</table>

Figure 1: Average fuel oil consumption of LNGc while at port with the above assumption
As a case study, tones of fuel oil consumption of ships visit LNG terminal at Fos Tonkin of France are calculated based on the above formula.

**Environmental benefits**

Pollution reduction

Shipping is under growing pressure to reduce its emissions to air. Green houses gases from ships mainly are Sulphur oxides (SOX), Nitrogen oxides (NOX), Carbon-di-oxide (CO₂) and refrigeration and fire fighting gases. Shipping industry is a small contributor to the total volume of Carbon-di-oxide emissions compared to road vehicles. It should be recognized that (CO₂) is the largest naturally existing Green House Gas (3/4th of total GHG’s) also is the main GHG emitted by ships [8].

main advantage of the plug is reducing the amount of pollution to the zero level while other alternative technology only enable to reduce some of the GHG to a certain level. For instance use of low sulphur fuel reduces the emissions of SOx up to 70 times better while Emissions of NOx and fine particulates will initially be higher, but only 1 to 2% of the level of CO₂ emissions saved.

The emission rate is depends upon the number of type of engines (i.e medium / slow speed diesel and steam) and installed power of each vessel. Emission rate for CO₂ are dependent upon the sulphur and carbon content of fuel burnt respectively.

To enable to estimate the amount of GHG emitted from the ship Fuel consumption of ships on the berth by the Auxiliary engine, boilers, fuel used for cargo work must be considered. This report will determine tones of CO₂ emissions based on the CO₂ emission indexing from the LNG ships while running the auxiliary engine on the berth as well as the amount of CO₂ emission in port of Fos Tonkin-France. For shipping Companies who wish to calculate GHG indexing for their ships based on their own spreadsheet the 'Interim Guidelines for Voluntary Ship CO₂ Emission Indexing is designed [9].

The amount of CO₂ emitted from a ship is directly related to the fuel consumption of bunker fuel oil calculated in the last section. According to the carbon content of fuel table Tones of CO₂ emissions from an LNG ship (Standard Size) with the same assumption during un/loading and idling will be:

18T x 3206000 g CO₂ / T Fuel = 58T (U)
13T x 3206000 g CO₂ / T Fuel = 42T (L)

In figure 3 the amount of CO₂ emission for Q-max and Standard size of LNG carrier are also calculated based on the above assumption. Furthermore Tones of CO₂ emissions at Fos Tonkln in france are shown in figure 4. These calculations are just underlining the importance and relevance of the PLUG in GHG reduction.
Results and discussions
Minimizing the fuel cost and pollution for economic reason (reduce the daily running cost and emission tax) are the major concern of the ship owners. Fuel cost is the single biggest operational cost component and forms the main item of the voyage costs. Less fuel consumption also means smaller GHG emissions. CO₂—the main GHG emission from the ship—are directly linked with fuel efficiency.
In this paper fuel oil consumption and CO₂ emission of three different types of LNG carrier calculated during loading and unloading. According to the above calculation fuel consumption of a Q-max LNG in port is around 47 tonnes. Consider how much a ship owner could earn by decreasing the fuel oil consumption while at port through applying Plug.

On the other hand there is a significant risk for fuel cost in the market. High inflation rate of fuel price enforce ship owners to reduce the fuel oil consumption in sea and in port through applying different technology. Plug will be able to absorb fuel cost and CO₂ tax pressure.

Conclusion
There is worldwide concern about atmospheric pollution and global warming and the shipping industry is playing its part with a new Protocol to the IMO MARPOL Convention, which entered into force in 2004.
Fuel cost saving and compliance with the international organizations like IMO to reduce the ship emissions are the main advantages of the cold ironing technology.
Plug is also reducing the amount of pollution to the zero level while other alternative technologies only reduce some of the GHG to a certain level.
For GHG abatement model, alternatives like fuel cells, internal engine modifications’ and fuel choices cost may vary depending upon the engine type, builder, and port/dry-dock/shipyard location, since the associated costs varies. Hence, for the future research in this field cost effectiveness is recommended to analyze the cost effectiveness of the each option compare to the plug.

References
[9] Harper, I., Note of Visit to the BP Shipping.,USA, Houston, (October, 2007)