LNG BUNKERING PROCEDURES IN PORTS AND TERMINALS IN THE SOUTH BALTIC SEA REGION

STUDY ON LNG BUNKERING PROCEDURES FOR CURRENT AND POTENTIAL LNG STAKEHOLDERS

in the frame of the EU project “Maritime Competence, Technology and Knowledge transfer for LNG (Liquefied Natural Gas in the South Baltic Sea Region – MarTech LNG” funded by European Regional (ERDF) Development Fund within the South Baltic Programme 2007-2013

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Acknowledgement

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We express also our thankfulness to the cooperation partners within the MarTech LNG project, who gave our research team opportunity to gather valuable practical insights into LNG bunkering procedures and to share the knowledge between the academic and business sides, in particular to Skangass, Fjordline, AGA AB and Viking Line, etc.

November 2014,

MarTech LNG Project Team

Source: own library.
Introduction

The study on LNG bunkering procedures in ports and LNG terminals across the South Baltic Sea Region aims at facilitating preparation regarding the demanded guidelines for decision support and decision making by the ports of the South Baltic Sea Region (SBSR), who lack LNG bunkering and other relevant infrastructure and related facilities, but are planning to install them in the next future. Indeed, this manual underpins the Clean Fuel Strategy adopted by the European Commission in 2013 that requires the maritime ports of the TEN-T core network to be provided with LNG by 2025.

Furthermore, it shall serve as a consolidated practice-oriented guidance for safe, secure, environmentally compatible and economically sophisticated LNG bunkering procedures. Economic plausibility is evident from several port practices, where responsible port authorities offer special financial incentives to ships with better environmental performance – port dues and charges for shippers using LNG are lower, e.g. in Stockholm, Goteborg and Hamburg.

This study encompasses consolidated results of the comprehensive LNG fuel bunkering study in port infrastructure and LNG small-scale terminals of the South Baltic Sea Region. As a result, it is devoted to LNG practitioners – policy actors, business people and all potentially affected stakeholders from LNG use and / or application or LNG market. It is recommended for those who are looking for a manual on LNG fuel bunkering scenarios and procedures in brief, on the one hand. On the other hand, this manual includes LNG bunkering scenarios and procedures, which have been successfully tested across the Baltic and North Sea, are in line with the proposed and recommended practices and methodology on international level, e.g. DNV GL and draw up on international standardisation regarding LNG bunkering.

This LNG bunkering study including key theoretical considerations and critical evaluation of the empirical observations was conducted in the frame of the “MarTech LNG” project activity – LNG Knowledge and Partnership Platform Building.

The LNG bunkering study is based on practical observations of two bunkering procedures done by LNG project research group: Truck-to-Ship (TTS) and Ship-to-Ship (STS). Site-based observations of both LNG bunkering procedures were implemented during the LNG bunkering operations in Stavanger in Norway (September 2013) and at the Ports of Stockholm (Loudden) in Sweden (May 2014).

The comprehensive LNG bunkering study and this consolidated manual reflect critical examination and assessment of both bunkering scenarios (TTS and STS) carried out by the interdisciplinary project research group representing project partners from Lithuania, Poland and Germany. This manual summarises key pillars regarding LNG bunkering procedures:

- LNG bunkering framework conditions (pre-bunkering procedures): legislative basis, bunkering approval by authorities, involvement of affected stakeholders, permits and licences;
- LNG bunkering procedures (Truck-to-Ship and Ship-to-Ship) and its comparison in terms of safety, security, ecology and economy and
- Evaluation of two bunkering procedures and recommendations for SBSR potential LNG users and stakeholders.
I. LNG import terminals in South and East Baltic Sea regions

East Baltic Sea ports are handling about 150 – 160 million tons per year oil and oil production. 12 big oil and oil production terminals located on the East coast of the Baltic Sea.

Fig. 1. Oil and oil production terminals on East Baltic ports
Fig. 2. LNG terminals on the East Baltic Sea coast (in Ventspils port operate ammoniac terminal)
Fig. 3. Planning LNG infrastructure for ship fuelling in Baltic and North Seas (DNV vision)

- Import terminal
- Small scale LNG production/LNG storage accessible for ships
- Export terminal

Pre-conditions use LNG fuel on ships and other transport modes could be considered as follows:

- New SO\textsubscript{x} regulations for the Baltic Sea, North Sea and England channel;
- Ships fuel prices;
- Environmental impact by the traditional ships and other transport modes fuel;
- Limit of the traditional fuel.

LNG terminals develop in many places of the world and the Baltic Sea has just started to develop LNG terminals as well.

2 LNG potential users and demand

LNG fuel flow forecast based on potential LNF fuel users and new requirements, coming in nearest future.

Potential LNG fuel users could be considering as follows:

- Ships (mainly Ro-Ro vessels on first stage);
- Cities small boiler stations;
- Cities public transport (busses);
- Road transport;
- Railway transport.

As basis for the potential users calculation could be taken:

- Number of the ships in Baltic Sea (every day) – 2200 – 2600;
- Ships, which has length up to 100 m – about 35 \%, that means about 770 – 910 (did not oriented to LNG);
- Number of the Ro-Ro vessels visit East Baltic ports – about 30 – 40 (from Kaliningrad up to Tallinn) (object to LNG fuel);
- Weekly request of the LNG fuel for the Ro-Ro vessels in East Baltic ports: 10000 – 15000 m\textsuperscript{3}.
As example planning (potential possible) LNG fuel for the Ro-Ro ships quantities in Klaipeda port in coming years:

- 8 – 10 Ro-Ro ships constantly work on Ro-Ro lines link Klaipeda port with other ports;
- Ro-Ro ship in average should use per day up to 60 – 80 m$^3$ LNG;
- Planning LNG fuel per week for the Ro-Ro ships (weekly bunkering) 3000 – 4000 m$^3$ LNG.
Fig. 7. RO-Pax ferry "Viking Grace" use LNG fuel (operate on line Stockholm – Turku)

- LNGpac Tanks
- 2 @ 200m³ each

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>214.0 m</td>
</tr>
<tr>
<td>Breadth</td>
<td>31.8 m</td>
</tr>
<tr>
<td>Speed</td>
<td>22 knots</td>
</tr>
<tr>
<td>Passengers</td>
<td>2800</td>
</tr>
<tr>
<td>Cabins</td>
<td>880</td>
</tr>
<tr>
<td>In service</td>
<td>2013</td>
</tr>
<tr>
<td>Shipyard</td>
<td>STX Finland Oy</td>
</tr>
<tr>
<td>Ship Owner</td>
<td>Viking Line</td>
</tr>
</tbody>
</table>

Fig. 8. LNG tank used on ships
Fig. 9: Ro-Ro ship’s LNG bunker station

Fig. 10: Tug works on LNG fuel
Fig. 11. Natural gas engines with diesel-equivalent performance on trucks

Fig. 12. Over 800 trucks on the road already (USA)
LNG fuelling systems and LNG users develop very fast and it is very important to provide necessary actions for the LNG fuelling network preparation.

3 LNG bunkering systems and possibilities in Baltic Sea Countries

LNG fuel and fuelling systems could be used in a different manner depending on the technical, technological, organizational, and legal conditions. As an example, LNG-fuelled ships could use Ship-to-Ship, Truck-to-Ship, Pipeline-to-Ship, or a container with LNG fuel systems.
For the fuelling transport means or tank containers request facilities in ports or in other LNG fuelling stations:

- LNG supply ships (delivery LNG from LNG terminals to LNG supply stations and directly to the ships);
- LNG supply stations (could be in many ports);
- Road transport units delivery LNG from LNG supply stations to users;
- Inland waterways LNG supply barges.
Fig. 15. Possible LNG fuelling ship bunkering system

Fig. 16. Ro-Ro ship bunkering by LNG supply vessel (principle) (Swedish Marine Technology Forum)
Fig. 17. Real LNG fuel supply vessel M/V SEAGAS (Sweden)

Fig. 18. LNG fuel supply Ro-Ro ship by road transport (DNV)
Fig. 19. Ro-Pax ship LNG fuelling

Fig. 20. LNG fuel transportation in LNG tank containers possibilities
LNG fuel supply ship in port should fulfil main conditions, which could be considered as follows:

- LNG fuel quantity on LNG supply vessel should be at least for the 2 Ro-Ro vessels;
- LNG supply vessel must have possibility fulfil at least 2 times per week on LNG terminal;
- LNG supply vessel could provide LNG supply operations near Ro-Ro quay walls or in port waters;
- LNG supply vessel should be able supply LNG shore storage facilities.

On basis mentioned requirements to the LNG supply vessel in the ports, port should be LNG supply ships main parameters:

- Length up to 40 – 50 m;
- Width up to 10 – 12 m;
- Draft up to 3,5 – 5,0 m;
- Capacity (LNG) not less as 800 – 1200 m³;
- Speed up to 10 knots.

Fig. 21. LNG inland waterway barge

In Baltic Sea are under construction and should start operate in end of 2014 two LNG import terminals (Klaipeda and Swinoujscie), which could be as main points for the LNG fuel supply network creation. For the LNG fuel delivery to other ports there could be used supply vessels.

LNG fuel supply as example in East Baltic ports main conditions could be considered as follows:

- LNG fuel quantity on LNG supply vessel should be at least for the 1 – 2 ports (at least for 3 - 6 Ro-Ro vessels in one port);
• LNG supply vessel must have possibility fulfil at least 1 time per week on LNG terminal;
• LNG supply vessel could provide LNG supply operations near quay walls or in port waters;
• LNG supply vessel should be able supply LNG shore facilities.

For the calculations LNG fuel supply ship’s parameters were taken sailing distances and time between ports. As example is presented East Baltic ports conditions, where distances and sailing time between Klaipeda port and other ports are:

- Klaipeda – Baltisk – 110 n.m. – 8 h;
- Klaipeda – Liepaja – 55 n.m. – 5 h;
- Klaipeda – Ventspils – 120 n.m. – 12 h;
- Klaipeda – Riga – 236 n.m. – 18 h;
- Klaipeda – Paldisky – 285 n.m. – 22 h;
- Klaipeda – Tallinn – 320 n.m. – 24 h.

In mentioned situation (sailing distances, sailing time and loading operation time) LNG supply vessel round trip could be considered as follows:

- To Liepaja – 1,5 days;
- To Baltisk – 1,8 days;
- To Ventspils – 2 days;
- To Riga – 2,5 days;
- To Paldisky – 2,8 days;
- To Tallinn – 3 days.

On basis mentioned conditions optimal LNG supply ships for the East Baltic sea main parameters could be considered as follows:

- Length up to 110 - 125 m;
- Width up to 14 – 18 m;
- Draft up to 5,5 – 6,5 m;
- Capacity (LNG) up to 7000 – 10000 m³;
- Speed up to 14 – 16 kn.
LNG fuel supply network in Baltic Sea is very important for the clean shipping conditions implementation and this work for the creation such network should starts as soon as possible.

4 Legal basis for LNG bunkering in different Baltic Sea Countries

To address safety during bunkering, potential hazards associated with LNG bunkering, hazard distances, and risks associated with each bunkering concept must be analysed. In addition, relative risks and safety zone guidance should be evaluated for three different bunkering concepts: Truck-to-Ship (TTS), Shore-to-Ship (STS) and Ship-to-Ship (STS). Individual risk should be estimated and compared for the three different bunkering concepts.

Guidelines for systems and installations for supply of LNG as fuel to ships” drafted by the International Association of Oil and Gas Producers (OGP) and the International Organisation for Standardisation (ISO) (cf. OGP Draft 118683) serve as important legal basis. However, this proposed documentation is not an international standard and represents at the moment a draft provisional application and guidance on information and experience existing in terms of LNG fuelling and bunkering onshore.

Bearing in mind the overview of the LNG-related regulatory framework, it can be stated that there is a critical gap identified within the international standardisation regarding LNG use and application. Although there exist a reasonable number of international standards in terms of waterborne LNG supply, waterborne LNG transport and supply facilities (cf. Appendix 15.1 of the Study on Standards and Rules for bunkering of
gas-fuelled ships\(^1\)), most of the internationally binding standards and rules directly referring to LNG bunkering operations remain internationally not regulated or are subject to further development.

### Table 1: Regulatory framework relating to LNG bunkering

<table>
<thead>
<tr>
<th>Regulation domain</th>
<th>Relevant existing bunkering regulation</th>
<th>Regulation status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onshore regulations</td>
<td>- LNG bunker station&lt;br&gt;- Risk analysis procedure for LNG bunker stations</td>
<td>NO</td>
</tr>
<tr>
<td>Bunkering regulations</td>
<td>- LNG bunkering definition&lt;br&gt;- LNG bunkering procedures (STS, TTS, PTS)&lt;br&gt;- LNG bunker port operations&lt;br&gt;- LNG bunkering safety distance&lt;br&gt;- LNG bunkering risk assessment&lt;br&gt;- LNG environmental requirements</td>
<td>NO</td>
</tr>
<tr>
<td>Overview: 18 bunkering regulations</td>
<td>1 of 18 bunkering regulations is internationally regulated: “LNG fuel transfer systems ISO 28460”</td>
<td></td>
</tr>
</tbody>
</table>

In general, development and implementation of a regulatory approval process for LNG bunkering operations and associated facilities is recommended. The process should include a Quantitative Risk Assessment (QRA) that utilizes probabilistic risk acceptance criteria to assess the acceptability of the risk posed. Specific recommendations to promote safe LNG bunkering operations include the following:

- Completion of a port risk assessment at each port where LNG bunkering will likely take place.
- Development of a methodology for and completion of a quantitative port-wide navigational risk assessment that determines how changes in traffic character and frequency/density affect the safety and security of the public, workers, critical infrastructure, and commercial operations.
- Development of effective security and safety zone enforcement procedures to promote a safe environment for the port population.

5 LNG bunkering analysis on basis AGA experience

5.1 Study visit and discussions.

The study visit on bunkering procedures took place on 9 May 2014 in the premises of AGA Gas AB as well as the port of Stockholm (Loudden), where the LNG bunkering ship “Seagas” is located. The study visit was focused on documenting different types of LNG bunkering procedures and recording state-of-the-art LNG bunkering experiences.

The documentation will facilitate the preparation of the guidelines for decision support and decision making by the ports of the South Baltic Sea Region (SBSR), who lack LNG bunkering and other relevant infrastructure and related facilities and plan them to install in the next future (Lithuania & Poland, \(^1\) European Maritime Safety Agency: Publications and documents, 2014.)
particularly). Further, the study visit will contribute to the preparation of the training material related to LNG bunkering and knowledge absorption by the relevant knowledge and business stakeholders.

Main task of the study visit was exchange of experiences on LNG bunkering by the Swedish stakeholders. After the introduction the host representative Michael Lindström gave the presentation on AGA. Subsequent to this presentation, Michael Lindström gave the presentation of LNG bunkering experiences and cooperation in terms of LNG bunkering and infrastructure development with related shippers, shipbuilders and other stakeholders. The linking-up discussion and question round took place after the presentation. Afterwards, a film of AGA experiences in LNG bunkering was showed to the MarTech LNG team, in particular, track to ship bunkering at Loudden port and ship to ship bunkering at the port of Viking Grace, where the LNG is bunkered from the AGA LNG bunkering vessel Seagas directly to the Viking Grace ferry. As a result, project team was able to document the LNG ship to ship bunkering procedures taking place at the Ports of Stockholm.

More specifically, the project team was able to discuss such issues related to the bunkering procedure as approval of the bunkering procedures and launch at the Ports of Stockholm, bunkering vessel design, building and operation issues. With regard to the approval and regulations related to LNG bunkering procedures, AGA representative confirmed that legislation relating to the bunkering procedure must be ensured before the effective LNG bunkering operations can take place. Currently, there are no special regulations in Sweden regarding LNG bunkering. Initially, the request for LNG bunkering was submitted in 2010 by AGA.

The approval to start LNG bunkering procedures was delivered in 2012. As a result, legislative / regulative processing of necessary bunkering documentation and legislation is likely to be time-consuming and took in case of Sweden approximately two years (December 2010 – March 2012). However, since there is no specific LNG bunkering related legislation in Sweden, the Swedish Transport agency (main responsible authority) was asked for the permission to perform bunkering. Aga Gas AB had licenses to transport LNG, but not to transport LNG at sea and to undertake bunkering procedures. Further important institutions to be involved were fire brigade, police department, Swedish coast guard, Ports of Stockholm, City of Stockholm and County, administrative board, etc. Moreover, important is to note that LNG bunkering legislation / regulations are needed for both onshore and offshore. In case of Sweden, first they were applied onshore and extended to offshore operations.

In the frame of the so-called permit process to convince the responsible authorities a series of risk & safety assessments were carried out and risk plans produced. This was needed principally due to the fact that there was a lack of regulation and support documents covering handling of LNG in maritime environment.

Thus, respective risk analyses were used to have better understanding of potential risks related to LNG operations. There can be distinguished 3 parts or risk assessment:

- General part – vessel movements and operational instructions at Stockholm harbour;
- Risk analysis relate to bunkering operation and dissemination of calculations (safety zones, bunkering procedure, vessel design, Cryo installation design). In this second stage, there are two critical zones: moving LNG from AGA to “Seagas” (tracks) and from “Seegas” to “Viking Grace”. There apply 25 m safety zones;
- Risk analysis where collision and sea keeping are studied, vessel design, operational instruction, pressure, etc. Compliance with ATEX directives is important in this context. Furthermore, dispersion is not possible because the ferry is 50 m high in the back (building a wall), and the cargo and passengers are going through the front of the Viking Grace ferry.
Important aspects to ensure safety are technologies used, e.g., Mantek couplings, Ship-to-Ship (STS) transfer 3 interface. The principal issue of risk is related to two hoses connected and potential release of LNG. Dry Gas Couplings (DGC) couplings of Mantek are very critical for the tracks to minimise (close to zero) spill and ensure no emissions to the environment at all.

In terms of “Seagas” bunkering vessel design, the team discussed the technology used for the LNG and the entire vessel building and preparation process for the LNG. It is emphasized that the bunkering vessel was not a new ship, but was bought from and started to be reequipped for bunkering procedures in Sweden (2 concepts). The bunkering vessel “Seagas” enjoys a unique concept, i.e., the bunkering vessel is relatively small and optimized to be used for bunkering of Viking Grace. Due to the Viking Grace design, the bunkering of the ferry is usually taking place at the back of the ferry, whereas the passengers and cars operations are taking place in the front of the ship. Due to such design, the Swedish authorities were convinced of security and safety of simultaneous processes of bunkering and passengers & cars operations.

The original first concept of the ferry with a tank of (200 cm³) was not accepted according to existing regulations because of the tank. In contrast to the first concept, the concept 2 included rebuild of the vessel with design fully complying with IGC code and the wheelhouse in the back of the vessel.

Accordingly, DNV certified the tanker fully complying with the necessary requirements. In terms of the AGA Cryo tank, the pressure is generated by head boiler on the ship without any use of pumps usually used for bunkering. Respectively, the heat boiler enables transfer of LNG from the vessel “Seagas” to the “Viking Grace” ferry’s 4-5 decks. The pressure generated is up to 10 bar at “Seagas” vessel, whereas the pressure of “Viking Grace” is usually up to 3,5 bars. Both the “Seagas” and “Viking Grace” are using a specific connection system, i.e., before coming to the port, the “Seaga’s” system can connect half an hour in advance before the ferry mooring to the Viking Grace system to map the LNG level.

“Seagas” bunkering vessel is diesel operated ferry, which is fuelled by 3 trucks. Each truck takes about one hour, i.e., for the vessel 2,5-3 hours are needed to bunker it with LNG. Seagas bunkering vessel is located and fuelled at harbour Loudden. The ship is 53 long and has the capacity of 190 cm³. AGA Gas AB uses a flexible system in a sense that “Viking Grace” ferry can be bunkered from the track and ship-to-ship (offshore). The hoses used are 10 meters long. The AGA Gas AB solution is capable to bunker the “Seagas” vessel onshore, i.e., from tracks and trailers, or if needed, via fixed pipes, an “Viking Grace” ferry is bunker from ship-to-ship (“Seagas” – “Viking Grace”).

With regard to LNG bunkering procedure, the fuelling procedure from ship-to-ship takes in total 60 minutes, what makes the AGA Gas AB solution a very flexible and competitive one. It enables ship-to-ship, truck-to-ship and even shore-to-ship bunkering, which can be used optionally. Due to short laying times of “Viking Grace” at the port it is hard to bunker it directly by “Seagas” from the terminal Nynäshamn, which is located about 90 km from the port where “Viking Grace” is moored.

More specifically, the total fuelling procedure is divided into three main parts:

- Pre-fuelling measures;
- Bunkering and Post-fuelling actions. According, within the pre-fuelling processes, which take approx. 5 minutes, the “Segas” vessel is moored to “Viking Grace” ferry, the tank system is checked and the fuelling hose is connected.
- LNG bunkering (opening LNG valve and monitoring) takes place 45 minutes.
- After the LNG transfer, stripping of LNG lines, purging with the nitrogen and hose and couplings handling is undertaken.
Since the hoses are heavy, they are handled by the cranes installed on the “Seagas” bunkering vessel. Afterwards, “Seagas” is un-mooring and departing. This last phase takes approx. 10 minutes.

In total, there were undertaken 360 bunkering operations. Viking Grace usually consumes about 295 kg/GT and annually up to 17,000 tonnes of LNG. “Viking Grace” is fuelled 6 times per week. The bunkering procedure takes place when the ferry is laying at the Port of Stockholm. By now, “Seagas” bunkering vessel is utilised up to 25-30%. It was noted that there is more opportunity to use the vessel by other customers. In the future, there will be needed a bunkering vessel with higher capacity. In terms of limitations for LNG bunkering at the Ports of Stockholm, due to good geographical conditions there were experienced no unfavorable environmental conditions, i.e. the weather is usually calm. Additionally, there were no recorded experiences of operation under ice conditions, which may have impact of the efficiency of LNG bunkering. However, there is a limit related to mooring, since additional 4 mooring equipment is needed. Other ship transport at the port is not disrupted and the ships can pass by the “Seagas” LNG bunkering vessel the Seagas LNG bunkering vessel.

5.2 Visit of LNG bunkering ship “Seagas” at the Loudden harbour

After the extensive discussions of LNG bunkering procedures, the MarTech LNG project team and the Representative of AGA Gas AB undertook a study visit to the Loudden harbour where the “Seagas” LNG bunkering ship is moored. Accordingly, the project partners had an opportunity to directly visit the vessel (interior and exterior) and to discuss with the responsible LNG bunkering officers the practical LNG bunkering procedure. It is worth to note that the monitoring system is extensive and the LNG bunkering operation monitoring is secured in the sense that the second monitoring computer for back-up purposes is used in case of emergency. Furthermore, the officers responsible for LNG bunkering have to fill LNG checklists and fill in reports after each bunkering procedure from the track to “Seagas” and from the “Seagas” to “Viking Grace”. Project partners became acquainted with the vessel’s technology, pipe system and connection to the onshore pipes.

Afterwards, the project partners followed the truck-to-ship bunkering preparation, i.e. connecting LNG tracks to the “Seagas” LNG bunkering vessel.

5.3 LNG bunkering training

With regard to extensive bunkering procedures and profound risk and safety issues, an important part in the efficient LNG bunkering procedure plays LNG bunkering training, which is done by AGA Gas AB trainers. Usually the training consists of three parts:

- Category a – basic training for safety crew (harbour personnel, mooring staff, port managers and personnel) and takes approx. 2 hours;
- Category b – supplementary training for deck officers, in particular, equipment with the time frame of approx. few days;
- Category c – supplementary training for engineer officers.

There is a joint training program for “Seagas” and “Viking Grace” bunkering procedures. Usually, category a training refers to as a short training, whereas b & c category trainings are long version trainings, e.g. STCW gas course. Finally, the category c training is an in-depth theoretical course for engineers done by Linde
5.4 Observations and recommendations

- No special legal regulation regarding LNG bunkering in Sweden.
- Vessel bunkering with passengers on board.
- Trip to Stockholm was very useful because delegation was able discuss with practical person who is involved in LNG bunkering planning, preparation and execution.
- First year exploitation of the LNG supply vessel shown that LNG bunkering by ship to ship system is useful and could be implemented in other ports.
- Many institutions were involved in approval and long time for the approval legal documents for the LNG bunkering in Sweden shown that in other ports it is necessary start in advance preparation works.
- LNG supply vessel utilization in Stockholm port about 30 % shows that it is necessary in planning more optimal solutions to increase LNG supply vessels utilization, that means involve more LNG potential users, which are interesting in LNG fuelling as well (cities public transport, power stations, etc.)
- In MT-LNG project executed ideas regarding utilization of the LNG supply vessels in ports shown is relevant.
- Ro-Ro vessels are main LNG fuel object in East Baltic ports (on first stage)
- For the LNG supply in port should be facilities for the LNG operations
- In general should be in port small (600 - 1000 m$^3$) supply vessel
- At least 1 LNG supply vessel (7000 – 10000 m$^3$) should be in East Baltic (in case port LNG supply vessels or other possibilities will be able in main Ro-Ro ports)

6 Safety Management Systems for LNG fuelling systems in Baltic Sea Ports

Shore based permanent facilities, as well as being covered by Occupational Safety and Health Administration. These have the same general structure as OSHA but require additional offsite consequence assessment for worst-case dispersion, fire, and explosion events. This is not used for setting buffer zones, but used for public communications and by local emergency responders for planning their emergency response. It is well recognized that LNG is a major hazard liquid similar in properties to LPG although cryogenic and thus a greater hazard than current bunkering fuels.

In this context, process safety is different and it is an extension to address respect for the equipment and the hazards of LNG fuel.

Safety Management Systems (SMS) are required on vessels according to the International Safety Management (ISM) code and for shore-based facilities as per the OSHA standard.

There are 12 main elements in PSM and some key aspects of PSM (Process Safety Management) that are related to LNG operations, not previously addressed:
• Operating Procedures
• Safe Work Practices
• Training and Competence
• Mechanical Integrity
• Hazardous Identification
• Safety Documentation
• Management of Change (MOC)
• Incident Investigation
• Emergency Planning and Response
• Pre-Start-up Safety Review (initial commissioning)
• Compliance Audits
• Contractors

Mechanical integrity is a key part in PSM programs and is required to maintain safe on-going operations, e.g., auditing, routine inspections, maintenance programs, and material suitability.

According to the recent experience, bunkering operations should be developed and conducted by a recognized SMS. Therefore, the LNG bunkering operations training needs to go beyond the typical technical training and safety to address management systems and safety culture (Ref. 8).

7 Harmonised LNG fuelling and bunkering scenarios at Baltic Sea Ports

Based on the overview of LNG bunkering procedures and recommended practices, this manual underpins two from four possible LNG bunkering scenarios.

It is worth mentioning that the following depicted bunkering scenarios do not encompass the pre-bunkering measures necessary to be ensured before the bunkering process itself, such as local pre-conditions (regulative base, licencing, fire protection, police involvement, coast guard, etc.), since such measures are subject to change and / or modification based on the given bunkering location / site and other framework conditions. As a result, two bunkering scenarios reflect harmonised processes and measures, which are common for each Truck-to-Ship and Ship-to-Ship bunkering process.
7.1 Truck-to-Ship LNG bunkering scenario

1. Preparations – fire equipment, bunkering scheme and personal protection equipment checked and ready for use.
2. Checklists – both ship and truck have to fulfil proper pre-bunkering checklists.
3. Documentation exchange – bunkering scheme and details should be agreed, signed and delivered.
4. Safety zones – safety zones should be established.
5. Communication test – communication link have to be established and checked.
6. Grounding and hose connection – a grounding cable from ship to quay must be connected and followed by bunker hose connection.
7. Visual check – all equipment should be checked before bunkering operation.
8. Checklist and documentation – pre-transfer checklist and documentation containing bunkering scheme and details have to be fulfilled by receiving ship and transferred to bunker truck.
9. Inerting and purging – inerting is performed in order to remove moist and O₂ in bunkering line, if necessary piping is purged by LNG.
10. Pump start sequence – during this stage possible leaks, hose and equipment behaviour and system functions should be monitored.
11. Bunkering operation – system pressure, tank volume and equipment behaviour should be monitored.
12. Pump stop sequence – stop sequence is started after signal from ship or shore / truck is received, or when the agreed amount of LNG is transferred.
13. Pump must be stopped immediately in emerging or deviation cases.
14. Stripping and purging – the liquid that remains in the bunker hoses after the pumps have stopped must be drained before disconnection.
15. Disconnection of hoses and grounding.
16. Handling over the documents.
17. Checklist and documentation – after LNG bunkering checklist and other documentation on both ship and truck have to be carried out.
7.2 Ship-to-Ship LNG bunkering scenario

1. Preparations – safety zones, fire equipment, personal protection equipment and emergency shutdown systems have to be prepared, checked and ready for use.
2. Checklists – both ships have to fulfil proper pre-bunkering checklists.
3. Communication – communication link have to be established, emergency signal and contingency plan have to be agreed.
4. Manoeuvring and mooring operation – after permission is granted manoeuvring and mooring operations can be carried out.
5. Hoses connection – dedicated hose handling equipment or typical hose crane can be used.
6. Checklist and documentation – pre-transfer checklist and documentation containing bunkering scheme and details have to be fulfilled by receiving ship and transferred to bunker ship.
7. Open manual bunker valves – remotely controlled valves have to be closed.
8. Ready signal from both ships.
9. Pump start sequence – during this stage possible leaks, hose and equipment behaviour and system functions should be monitored.
10. Bunkering operation – system pressure, tank volume and equipment behaviour should be monitored and the checklist filled in during the LNG bunkering process.
11. Pump stop sequence.
12. Pump must be stopped immediately in emerging or deviation cases.
13. Purging of bunker hoses – the liquid that remains in the bunker hoses after the pumps have stopped must be drained before disconnection.
14. Close manual and remote controlled valves – the valves, at both manifolds, are to be closed when the hoses are purged. First, the remote controlled valves are to be closed, and then the manual valves.
15. Disconnection of hoses.
16. Inerting of bunker lines – the receiving ship has to inert the bunker lines before departure, which means that the inverting sequence is to start as soon as the hoses are disconnected from the manifold and run until lines are gas free.
17. Bunkering documentation exchanged.
18. Unmooring and manoeuvring.
19. Checklist and documentation – after LNG bunkering checklist and other documentation on both ships have to be carried out.

Fig. 25: Ship-to-Ship LNG bunkering scenario

### 7.3 Conclusions and recommendations for the South Baltic Sea Ports

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Ship-to-Ship bunkering (STS)</th>
<th>Truck-to-Ship bunkering (TSS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pros</td>
<td>Pros</td>
</tr>
<tr>
<td>Security and safety</td>
<td>• Logistical flexibility and simultaneous operations possible (possible loading and unloading and embarking / disembarking operations during bunkering procedure); • Less potential exposure.</td>
<td>• Higher weather and sea conditions influence; • Safety zone established on both ships.</td>
</tr>
<tr>
<td>Environmental</td>
<td>• Possibility of bunkering at sea (less potential exposure to port infrastructural sites or critical / protected areas).</td>
<td>• Higher exposure potential to both ships (bunkering vessel and LNG powered ship).</td>
</tr>
<tr>
<td>Economic</td>
<td>• Higher possible volumes per one bunkering operation;</td>
<td>• Higher cost of bunkering vessel design, building and operations</td>
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<td>Dimension</td>
<td>Ship-to-Ship bunkering (STS)</td>
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</tr>
<tr>
<td>-----------</td>
<td>------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td><strong>Pros</strong></td>
<td>Higher storage capacity;</td>
<td>More time consuming;</td>
</tr>
<tr>
<td></td>
<td>Less standard port operations disruption;</td>
<td>Not designated for large ship operators / consumers;</td>
</tr>
<tr>
<td></td>
<td>Time saving solution (higher transfer rate);</td>
<td>Impact on cargo handling and passenger embarking / disembarking;</td>
</tr>
<tr>
<td></td>
<td>Favourable for LNG powered ships with short port turnaround time.</td>
<td>Requires a good road infrastructure and connection to the port infrastructure.</td>
</tr>
<tr>
<td><strong>Cons</strong></td>
<td>(requires more intensive risk analysis due to potential ships collision in port and under sea and weather conditions);</td>
<td>No additional operational costs;</td>
</tr>
<tr>
<td></td>
<td>Requires at least some onshore port infrastructure for bunkering vessel berthing and loading,</td>
<td>No additional requirements for a special designated port area for LNG loading;</td>
</tr>
<tr>
<td></td>
<td>and operational costs;</td>
<td>No additional infrastructure / facilities needed for LNG bunkering procedure;</td>
</tr>
<tr>
<td></td>
<td>Less potential operational breakdown (trucks can be easier replaced when compared to a bunkering vessel).</td>
<td>Less potential operational breakdown;</td>
</tr>
</tbody>
</table>

Based on the observations gathered, following recommendations can be made for the South Baltic Sea ports:

- LNG bunkering is feasible in terms of security, safety, environment and economics and can be implemented in different mode (e.g. Ship-to-Ship or Truck-to-Ship).
- According to the latest LNG-related regulation documentation, LNG bunkering practices and procedures are not standardised on international level.

There are existing a critical number of case studies and active port practices, which enable establishing LNG bunkering infrastructure in the South Baltic Sea ports.
Truck-to-Ship LNG bunkering scenario

18. Preparations – fire equipment, bunkering scheme and personal protection equipment checked and ready for use.
19. Checklists – both ship and truck have to fulfill proper pre-bunkering checklists.
20. Documentation exchange – bunkering scheme and details should be agreed, signed and delivered.
21. Safety zones – safety zones should be established.
22. Communication test – communication link have to be established and checked.
23. Grounding and hose connection – a grounding cable from ship to quay must be connected and followed by bunker hose connection.
24. Visual check – all equipment should be checked before bunkering operation.
25. Checklist and documentation – pre-transfer checklist and documentation containing bunkering scheme and details have to be fulfilled by receiving ship and transferred to bunker truck.
26. Inerting and purging – inerting is performed in order to remove moist and O₂ in bunkering line, if necessary piping is purged by LNG.
27. Pump start sequence – during this stage possible leaks, hose and equipment behaviour and system functions should be monitored.
28. Bunkering operation – system pressure, tank volume and equipment behaviour should be monitored.
29. Pump stop sequence – stop sequence is started after signal from ship or shore / truck is received, or when the agreed amount of LNG is transferred.
30. Pump must be stopped immediately in emerging or deviation cases.
31. Stripping and purging – the liquid that remains in the bunker hoses after the pumps have stopped must be drained before disconnection.
32. Disconnection of hoses and grounding.
33. Handling over the documents.
34. Checklist and documentation – after LNG bunkering checklist and other documentation on both ship and truck have to be carried out.
Ship-to-Ship LNG bunkering scenario

20. Preparations – safety zones, fire equipment, personal protection equipment and emergency shutdown systems have to be prepared, checked and ready for use.
21. Checklists – both ships have to fulfil proper pre-bunkering checklists.
22. Communication – communication link have to be established, emergency signal and contingency plan have to be agreed.
23. Manoeuvring and mooring operation – after permission is granted manoeuvring and mooring operations can be carried out.
24. Hoses connection – dedicated hose handling equipment or typical hose crane can be used.
25. Checklist and documentation – pre-transfer checklist and documentation containing bunkering scheme and details have to be fulfilled by receiving ship and transferred to bunker ship.
26. Open manual bunker valves – remotely controlled valves have to be closed.
27. Ready signal from both ships.
28. Pump start sequence – during this stage possible leaks, hose and equipment behaviour and system functions should be monitored.
29. Bunkering operation – system pressure, tank volume and equipment behaviour should be monitored and the checklist filled in during the LNG bunkering process.
30. Pump stop sequence.
31. Pump must be stopped immediately in emerging or deviation cases.
32. Purging of bunker hoses – the liquid that remains in the bunker hoses after the pumps have stopped must be drained before disconnection.
33. Close manual and remote controlled valves – the valves, at both manifolds, are to be closed when the hoses are purged. First, the remote controlled valves are to be closed, and then the manual valves.
34. Disconnection of hoses.
35. Inerting of bunker lines – the receiving ship has to inert the bunker lines before departure, which means that the inerting sequence is to start as soon as the hoses are disconnected from the manifold and run until lines are gas free.
36. Bunkering documentation exchanged.
37. Unmooring and manoeuvring.
38. Checklist and documentation – after LNG bunkering checklist and other documentation on both ships have to be carried out.

Fig. 28: Ship-to-Ship LNG bunkering scenario

<table>
<thead>
<tr>
<th>Pre-fuelling actions</th>
<th>Bunkering actions</th>
<th>Post-fuelling actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparations</td>
<td>Open manual bunker valves</td>
<td>Purging of bunker hoses</td>
</tr>
<tr>
<td>Checklist</td>
<td>Ready signal from both ships</td>
<td>Close valves</td>
</tr>
<tr>
<td>Communication</td>
<td>Pump start sequence</td>
<td>Disconnection of hoses</td>
</tr>
<tr>
<td>Mooring operation</td>
<td>Bunkering operation</td>
<td>Inerting of bunker lines</td>
</tr>
<tr>
<td>Hoses connection</td>
<td>Pump stop sequence</td>
<td>Bunker documentation</td>
</tr>
<tr>
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<td></td>
<td>exchange</td>
</tr>
<tr>
<td>documentation</td>
<td></td>
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</tr>
<tr>
<td></td>
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</tr>
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Source: own draft.

Insights for the South Baltic Sea Ports

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<td>-----------------------------</td>
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<tr>
<td>Pros</td>
<td>capacity;</td>
<td>costs;</td>
</tr>
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<td>Less standard port operations disruption;</td>
<td>No additional requirements for a special designated port area for LNG loading;</td>
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- According to the latest LNG-related regulation documentation, LNG bunkering practices and procedures are not standardised on international level.
- There are existing a critical number of case studies and active port practices, which enable establishing LNG bunkering infrastructure in the South Baltic Sea ports.
Conclusions and recommendations

The purpose of safeguards is to reduce risk through mitigation, control, and prevention. DNV GL’s “Development and Operation of Liquefied Natural Gas Bunkering Facilities” has recommended safeguard criteria for best practice of LNG bunkering (Ref. 6).

The following safeguards should be considered standard operational safeguards for standard best practice, which is promoted by the “Guidelines for Systems and Installations for Supply of LNG Fuel to Ships” (Ref. 7). Deviation from these safeguards would require validation through a site-specific safety assessment that operations can be carried out within appropriate levels of risk. For bunkering of LNG the preventive measures to reduce risk are:

- Suitable specification and regular inspection of loading hose. A major contributor to the likelihood of loss of containment is integrity failure of the loading hose. An emphasis on visual inspection of loading hoses before every bunkering operation will help reduce the chance of hose failure.
- Purging of bunkering hose with inert gas. Purging of bunkering hose is part of industry best practice for large transfers of LNG.
- Continuous monitoring during LNG transfer. This will ensure the quickest possible detection and isolation time in the event of a leak.
- Excess flow valves installed on bunkering manifold. Installation of excess flow valves that trigger automatic shutdown at high flows greater than 150% of normal flow will add further assuredness that isolation will occur quickly.
- Effective training and competence programs for operators including truck driver operators. Employing the appropriate training scheme will reduce the incidence of human error and ensure that previously mentioned safeguards are maintained.
- Competence gained through training should be implemented regularly during the operator’s normal duties. Besides the initial training, continued maintenance of competence by means of refresher training is a key issue.
- Maintain effective safety zones during LNG operations. Developing an effective safety zone enforcement procedure is recommended since the risk of vessel striking is a significant risk driver.
- Compatibility of equipment and operations.
- Assess the effectiveness of mitigation strategies (such as training, gas detection, firefighting capability, and emergency response) against potential incidents arising from co-locating bunkering activities with other uses of LNG.
- Applying emergency deluge systems around the bunkering storage tank.
- Effective security zone enforcement. Developing an effective security zone enforcement procedure is recommended since the risk of vessel striking is a significant risk driver.
- Effective safety zone enforcement. Developing an effective security zone enforcement procedure is recommended to promote a safe environment for port population.
- High-level barrier assessment. Approval of proposed LNG bunkering facilities in a given port presupposes that the existing risk at the port is acceptable and would not pose unacceptable risks onto the bunkering operations.
- Asset owners should manage the critical barriers identified in the risk assessment for their LNG facility.
• Risk assessments provide insight and guidance to protecting operations against hazards inherent with operations. More information available specific to a site or facility empowers the assessment to identify hazards and make recommendations specific to said site or facility.

• Gather additional data. Related to the recommendation to conduct risk assessments for non-standard LNG bunkering operations, additional data and assessments are needed to establish maximum thresholds concerning marine traffic density.

• The assessments to be conducted should clearly establish a threshold to marine traffic exposure for LNG bunkering.
References

Baltic Sea charts.


Google maps.


Klaipeda port website: www.portofklaipeda.com;


Swinoujscie port information: www.szczecinport.com