LNG Masterplan Rhine-Main-Danube

Liquefied Natural Gas Fuel and Cargo for Inland Navigation
LNG Masterplan for Rhine-Main-Danube

Masterplan for introduction of LNG as fuel and as cargo for inland navigation

2012-EU-18067-S
Liquefied Natural Gas (LNG)

Liquefied natural gas (LNG) is natural gas (predominantly methane, CH₄) produced by cooling down natural gas to minus 162 °C, thus converting it to liquid form for ease of storage and transport.

Physical properties

<table>
<thead>
<tr>
<th>Structure</th>
<th>More than 90% methane (CH₄) with the rest mostly ethane, propane, butane, nitrogen. LNG shall not to be mistaken for LPG – Liquefied Petroleum Gas (mainly propane and butane).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>-162 °C (-260 °F)</td>
</tr>
<tr>
<td>Volume</td>
<td>1/600 of the volume of natural gas in gaseous form and 3.5 times more compact than compressed natural gas (CNG)</td>
</tr>
<tr>
<td>Density</td>
<td>Between 430 kg/m³ and 470 kg/m³ (compared to water it is less than half as dense, which means that LNG will float on water if spilled)</td>
</tr>
<tr>
<td>Conversion</td>
<td>1 ton LNG = 2.2 m³ LNG; 1 ton LNG = 15.2 MWh (GHV); 1 MWh = 3.4121 MMBTu</td>
</tr>
<tr>
<td>Attributes</td>
<td>Odourless, colourless, non-toxic, non-corrosive</td>
</tr>
<tr>
<td></td>
<td>Flamability range</td>
</tr>
<tr>
<td></td>
<td>5-15% of fuel-air mixture</td>
</tr>
<tr>
<td></td>
<td>Behaviour if spilled</td>
</tr>
<tr>
<td></td>
<td>Evaporates, forming visible “clouds”. Portions of cloud could be flammable or explosive under certain conditions.</td>
</tr>
<tr>
<td></td>
<td>A fuel-air mixture of about 10% methane in air (about the middle of the 5–15% flammability limit) and atmospheric pressure might be ignited if it does encounter an ignition source (a flame or spark or a source of heat of 1000 °F (540 °C) or greater). Otherwise the vapor will generally dissipate into the atmosphere, and no fire will take place.</td>
</tr>
</tbody>
</table>

Energy

- 21 megajoules per litre (diesel 36.0)

Environmental drivers

LNG contributes to significant reduction of sulphur oxides emissions (SOₓ), nitrogen oxides emissions (NOₓ), Particulate Matters (PM) and carbon dioxide emissions (CO₂) from engine exhaust emissions in comparison to traditional fuels.

In comparison to diesel:
- CO₂ reduced up to 25% (for near zero methane slip)
- PM reduced nearly to 100%
- NOₓ reduced up to 90%
- SO₂ emissions up to 95%

In comparison to LPG:
- Greenhouse gas emissions reduced by 15%
- PM reduced by up to 10%
- NOₓ reduced by up to 50%

Economic drivers

- Price gap LNG – diesel reduces fuelling costs for barge operators. Price gap is expected to widen due to massive increase of LNG liquefaction in next few years and due to spot market developments.
- Cost reduction in fuelling results in higher profitability, lower transport costs and higher demand of inland water transport services.
- Switch to LNG triggers modernisation of fleet and facilitates additional measures increasing energy efficiency.
- LNG becomes a commodity (cargo) which needs transportation on European rivers.
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Clean power for transport

The European Commission’s 2011 Transport White Paper on a Roadmap to a Single European Transport Area calls for breaking the oil dependence of transport and sets a target of 60% greenhouse gas emissions reduction from transport until 2050. Low-CO₂ alternatives to oil are indispensable for this gradual decarbonisation of transport.

Liquefied Natural Gas (LNG), including bio-methane (LBM), can play an important role in Europe’s transition to a low-carbon economy. The European Commission works to create favourable framework conditions to allow this to happen, with several initiatives which are being deployed to facilitate the introduction of LNG as fuel for transportation.

The adoption of the Directive on the deployment of alternative fuels infrastructure (Directive 2014/94/EU), which is part of the “Clean Power for Transport Package”, represents an important step towards a wide-scale use of LNG. It requires member states to ensure an appropriate number of LNG-refuelling points in maritime and inland ports by the end of 2025 and 2030 respectively to enable LNG inland or seagoing vessels to circulate throughout TEN-T Core Network.

The EU co-funded LNG Masterplan for Rhine/Meuse-Main-Danube represents a stepping stone towards the full exploitation of LNG as fuel and as cargo and supports the Commission’s efforts to promote a sustainable inland navigation. The project has led to a number of success stories, including the deployment of three LNG-fuelled inland vessels, the first LNG terminal and fuelling station in the Danube region and many contributions to the development of the required legislative framework. The Masterplan Strategy, another outcome of the project, sets out further measures necessary for the successful deployment of LNG and represents valuable guidance for future policy actions on both national and EU level.

The EU funding programme Connecting Europe Facility (CEF), a key supporter of priority transport infrastructure and innovation projects, will continue to provide funding to projects that bring clear benefits beyond national borders. The latest 2015 CEF Transport Call makes available EUR 7.56 billion to improve European transport infrastructure, promote innovation and new technologies, develop intelligent transport systems and mitigate the safety and environmental impact of the sector.

Henrik Hololei
Director-General for Mobility and Transport, European Commission
Central Commission for the Navigation of the Rhine
Liquefied Natural Gas (LNG) constitutes an environmentally friendly alternative fuel capable of playing a vital role in supporting innovation, sustainable development and the competitiveness of inland waterway transport.

The full exploitation of this very attractive source of energy requires the development of a harmonised regulatory framework for LNG as fuel and cargo in inland navigation, as well as critical mass of investment in shipping solutions and terminal infrastructure. The platform for the cooperation of authorities and industry stakeholders, created by the LNG Masterplan, has indeed widely facilitated the implementation of a harmonised framework in Europe, notably on the Rhine, as well as delivered a significant number of pilot deployments of vessels and terminals.

Simultaneously and as stated in its Vision 2018, the Central Commission for the Navigation of the Rhine (CCNR) supports the introduction of LNG as an alternative fuel for inland navigation. In order to determine whether LNG could be used safely, the CCNR has over the last 4 years temporarily authorised its use by 16 vessels. The experience gained with these pilot vessels, as well as the valued expertise collected in the LNG Masterplan platform, have provided a significant input to the development and adoption of a dedicated CCNR regulatory framework governing the use of Liquefied Natural Gas (LNG) as a fuel in the Rhine navigation. The entire body of regulations, finally completed at the end of 2015, covers the construction and operation of the vessels as well as the training of their crew members. It ensures high safety standards and, at the same time, the necessary legal certainty for investors, in particular with stable technical requirements for vessels and a harmonised bunker checklist.

With this booklet, the LNG Masterplan has produced a comprehensive publication on LNG and highlighted the milestones achieved regarding the expansion of knowledge and experience of the potential, capacities and benefits of LNG in the inland navigation sector. It is an indispensable source of information for all those involved and interested in the story of the successful use of LNG in inland navigation.

Hans van der Werf, General Secretary
Central Commission for the Navigation of the Rhine (CCNR)
Liquefied Natural Gas (LNG) has much to offer for the European inland shipping sector: a clean and efficient fuel and high potentials as valuable cargo. Therefore, Pro Danube Management GmbH (Austria) and Port of Rotterdam Authority (Netherlands) initiated the LNG Masterplan project for the Rhine/Meuse-Main-Danube axis with the purpose to shape a favourable regulatory framework along with the pilot deployments of LNG in inland vessels and port infrastructure.

With high ambitions and clearly defined objectives, the project brought together 33 EU-funded partners from 12 EU member states and one associated partner from Switzerland. Their intensive work over the last 36 months resulted in more than sixty main deliverables: concepts and pilot deployments of LNG-fuelled vessels and onshore infrastructure, important contributions to a concise regulatory framework for LNG as fuel and cargo, dedicated training curricula and lessons material, numerous studies and guidelines to ensure safe operations of LNG on vessels and in ports as well as a comprehensive strategy for the further deployment of LNG. The majority of the deliverables is publicly available on the website of the project: www.lngmasterplan.eu.

Beyond that, this booklet shall provide an easy-to-read introduction into the consortium’s voluminous achievements enabling interested stakeholders to learn from the experiences of the LNG pioneers for their own projects. The collaborative work approach and the high number of key actors from private and public sector ensure validity and wide acceptance of the elaborated guidelines and recommendations.

LNG certainly is not the solution to all problems in inland shipping and it will still take considerable efforts to overcome all barriers for LNG on its way to become the dominant green fuel for inland shipping. But, the LNG Masterplan certainly created an indispensable knowledge base which will facilitate many new successful initiatives and projects.

We therefore would like to thank all our partners and supporters for the excellent cooperation and the remarkable achievements despite the difficult framework conditions of the fledging small-scale LNG market.

Manfred Seitz, Pro Danube Management GmbH
Nico van Dooren, Port of Rotterdam Authority
LNG Masterplan for Rhine/Meuse-Main-Danube

The LNG Masterplan for Rhine/Meuse-Main-Danube (2013–2015), jointly coordinated by Pro Danube Management GmbH (Austria) and Port of Rotterdam Authority (Netherlands), unites 33 partners from 12 countries and one associated partner from Switzerland to facilitate the introduction of LNG as fuel and as cargo for European inland shipping. Due to its high innovative character and its relevance for major objectives of the European transport policy, the project is co-financed by the European Union from the Trans-European Network for Transport Programme 2007–2013.

The LNG Masterplan project addresses barriers typical for pre-mature markets such as incomplete regulatory framework, technical innovation needs, lack of standardisation and harmonisation, high prices for equipment and low awareness among decision-makers and general public. The LNG Masterplan writes its success stories by delivering several highly innovative technical designs, deploying pilot infrastructure and putting forward important guidelines and best practices for safe LNG operations. It will still take considerable efforts to overcome all barriers for LNG to become the dominant green fuel for inland shipping. But, the LNG Masterplan represents an important step to the use of LNG as vessel fuel and also paves the way for LNG to be transported on the most important European waterway axis, the Rhine/Meuse-Main-Danube corridor.

The project provides an impressive number of deliverables, such as market analyses of European and regional developments, safety studies and feasibility reports, training materials in the form of curricula, lessons material and interactive pilot classes, and contributes to the elaboration of technical provisions necessary for creating a consistent regulatory framework for safe operations of LNG. It also develops a comprehensive strategy with actions and measures for the implementation of LNG in line with the European transport, energy and environmental policy objectives.
LNG Masterplan for Rhine-Main-Danube

Masterplan for the introduction of LNG as fuel and cargo for inland navigation

Framework & Market Analysis
- Status quo analysis & trends
- LNG supply analysis
- LNG demand analysis
- Impact analysis: safety, ecology & socio-economic aspects

Technologies & Operational Concepts
- Engine technologies & concepts
- LNG tank & equipment technologies
- LNG bunkering
- Technical evidence & safety and risk assessment

Terminal & Vessel Solutions
- Terminal concepts & cost assessment
- Vessel concepts (newly built)
- Vessel concepts (retrofit) & other vehicles & machinery
- Financing models for terminal infrastructure & vessel investment

Regulatory Framework & Masterplan
- Provisions for harmonised European regulations
- Education & training requirements
- Assessment of concepts, trials & pilot deployments
- Masterplan (strategy & recommendations)

Pilot Deployment
- LNG terminals
- LNG tankers (LNG as cargo)
- LNG-propelled vessel (LNG as fuel)
- LNG vehicles & machinery
Global LNG market has moved from tightness to glut
Market studies – Rhine region
Market studies – Danube region
LNG technologies: Engines & tank solutions
LNG end-users: Greening the port equipment
LNG end-users: LNG for road transport
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Global LNG market has moved from tightness to glut

Lower LNG prices and hub-related pricing of LNG could make the fuel more attractive for use in industry, trucking and marine transport if oil prices rebound, according to IPA Advisory Ltd, a firm that specialises in small-scale uses of LNG.

The global LNG market has been transformed over the last year. As oil prices have collapsed from $110/bbl to less than $50/bbl, LNG spot prices have dropped by more than a half to around $6.50–7.50/MMBtu. Moreover, LNG prices around the world have converged, and arbitrage economics are increasingly defining regional prices. European LNG and trading hub prices are now more closely aligned.

Moving forward, a swathe of new liquefaction capacity additions will result in a surplus of LNG out to 2020 that will have profound implications for the structure of the market. Around 65 million tons per annum (mtpa) of LNG capacity will be added in Asia-Pacific by around 2018. Australia will become the world’s biggest exporter of LNG, taking over pole position from Qatar.

Even more significantly, around 70–75 mtpa of new capacity will be built in the US, much of which will be available to European buyers. US LNG exports will have a profound impact on the global LNG business. These cargoes are free destination, and are tied to the price of the Henry Hub (HH) index, which is currently at around $2/MMBtu. Using a typical price formula for US LNG exports, US LNG would land in Europe at around $6–6.50/MMBtu based on current HH prices.

A significant tranche of the US LNG has been contracted by Asian buyers and portfolio players and will be sold into the spot market. By the end of

About IPA Advisory Ltd.
IPA Advisory is a leading independent advisory practice company, providing services in Markets & Transactions, Regulation & Policy and Public Private Partnerships (PPP) across the Energy, Water and Infrastructure sectors. IPA offers advisory services along the full oil and gas value chain and upstream development to downstream markets. Furthermore it provides techno-economic appraisals of projects, global and regional market and pricing analysis as well as commercial and transactional technical and market due diligence.

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In the decade, it seems likely that around half of LNG traded will be on a spot or short-term basis, compared to around 30% currently. The overall size of the market will have risen by nearly 50% from around 310 mtpa currently to 450 mtpa by 2020.

How long the current LNG glut lasts will depend on decisions to be taken in the next one or two years. Many countries around the world are looking at ways to monetise enormous new finds of natural gas. East Africa, Russia, Canada, and eastern Mediterranean countries all have plans to build LNG export plants, and more than 40 projects have sought approval to export LNG from the US beyond the five already under construction. However, such projects are delaying any Final Investment Decision (FID) given low prices and future market uncertainty.

The LNG surplus has significance for the pricing mechanisms used when it is sold. Around 70% of LNG traded around the world is currently indexed to the price of oil. In the past, when oil prices have risen, so too has the price of LNG. With the new LNG from the US determining marginal prices, it is likely that LNG will move more closely in line with natural gas prices on trading hubs. This could result in a divergence of oil and LNG prices that could make the use of gas in transport more attractive.

The oil market is currently swamped by surplus supply, which has narrowed the price gap between oil and LNG. If oil were to rebound, oil-indexed LNG would rise but US hub-linked LNG would potentially be able to undercut the price of oil-indexed LNG. For this reason, US LNG could act as a cap to gas prices in Europe. This should be reassuring to companies taking the difficult decision to switch from diesel to LNG as a bunkering fuel, or as a fuel for industry and long-distance trucking.

“We may see oil and LNG prices diverge, and this could result in more widespread use of LNG as a fuel in marine transport, industry and long-distance trucking, particularly given its importance for European energy security.”

Peter Stewart, Energy Specialist
What are the sourcing options and how do the small-scale LNG supply chains develop? What are the main drivers for supply chains’ development and what are the location factors for the distribution points for suppliers and end-users? How will the demand in the Rhine regions develop till 2020 and 2035? These are some of the questions answered by the Rhine market studies.

**LNG supply study** Primary supply in the Rhine region is from import terminals (Zeebrugge, Rotterdam-GATE and Dunkirk); though bio-methane (LBM) and gas grid peak shavers will contribute as well. Means to deliver relatively small LNG quantities are in place and continue to expand by investments into break bulk facilities. Development of the supply chain however requires further investments in utilities and equipment for storage, (un-)loading of LNG and investments for transport. As part of the study an inventory of all facilities (in operation and planned) for import, storage, transport and distribution of LNG has been made.

The study furthermore focuses on the optimisation of the LNG supply structure, from the current structure to future supply chain configurations. It discusses the stakeholders involved in developing the supply chain and the drivers such as (i) market demand per end-user type, (ii) regulations, (iii) availability of technical equipment.

Last but not least, the study elaborates supply scenarios for the Rhine corridor, in particular the Rhine Ports group – Rotterdam, Antwerp, Mannheim, Strasbourg and Basel. It gives an overview of the most likely supply options for the ports and high-level analysis of the potential investments, whereas the supply chain developments and the preferred supply options closely relate to the individual port market potential as identified in the LNG demand study.

**LNG demand study** The study assesses the future demand for LNG by 2020 and 2035 along the Rhine Corridor as an alternative fuel for power generation, industry and transport and the necessary infrastructure development required to support this nascent market. The output from the model calculations presents the LNG use per user group and the market potential for the ports in the Rhine Port Group.

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**Quick facts**
- LNG sourcing is not an issue for both Lower and Upper Rhine – several sourcing options are available.
- Basic LNG supply chains are in place in the Lower Rhine region.
- Bunkering and storage infrastructure in the Upper Rhine region needs to be developed.
- Demand in the Lower Rhine will be dominated by the maritime demand (volumes).
- Demand in the Upper Rhine Corridor is not only inland water transport but also industry and trucks.

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Market studies – Danube region

What are the sourcing options and how will small-scale LNG supply chains in the Danube region develop? What will be supply costs and what potential volumes for specific markets? These are some of the questions answered by the Danube market studies.

**LNG supply analysis** The deployment of the LNG terminal Ruse/Bulgaria as part of the LNG Masterplan project (page 60) brings the first permanent LNG supply to the Danube region. Due to the lack of nearby LNG import terminals, more complex supply chains are needed resulting in higher costs and consequently smaller market potentials. Various sourcing options were analysed, including routes from North-Western Europe, the Black Sea/Eastern Mediterranean and from the Caspian region. Bio-LNG and liquefaction of stranded conventional gas fields will contribute in the future to a balanced and secure supply. Basically, LNG can be transported by (i) trucks, which is already done but costly and environmentally critical for long distances, (ii) inland vessels but regulatory framework needs to be finalised and sufficient base load of LNG demand generated, or by (iii) rail, which is economically and ecologically more advantageous than road transport, however, adequate terminal infrastructure is missing yet.

**LNG demand analysis** Market potentials of LNG as a fuel (for inland vessels and road vehicles) and as an alternative energy source for industries were investigated in several regional/national studies. Potential LNG customers were identified and interviewed regarding their requirements. The results show that LNG demand is heavily dependent on the price gap to conventional fuels and on the reliability of LNG supply.

The studies also disclosed big differences in structure and volume of LNG demand: The natural gas transmission network is not well-developed in Bulgaria, thus industry shows a high interest in LNG. The opposite is valid for the upper Danube countries. In the transport fuel market interest for LNG is generally good but missing infrastructure and high supply chain costs are crucial obstacles for the current start-up phase. A stronger engagement of the public authorities comparable to north-west Europe is needed to create favourable framework conditions and to tap the potentials.

**Quick facts**

Analysis of options for supplying the Danube region and the assessment of market potentials in various Danube countries and regions are the main focus of Danube market studies.

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- Romania (Galati): hidro@apdmgalati.ro
- Romania (Constanta): ion.stanciu@tts-group.ro
I. STUDIES

LNG technologies: Engine solutions

**State-of-the-art LNG propulsion systems** LNG-driven systems for power generation and propulsion on inland vessels need to reach economic viability and fulfil state-of-the-art emission regulations. The LNG-driven engines for use aboard ships are described along with different concepts of engines and propulsion systems. Advantages and disadvantages of those concepts are discussed. In addition, the required redundancy for propulsion systems running on LNG is shown up on the vessels in operation. Special requirements for engines of inland vessels, such as matching of load distribution and propeller curve, are identified. Further, methane slip and its origins are explained as well as actions for future investigation and development to decrease the emission of the greenhouse gas methane. A market analysis of available engines running on gas or dual fuel is presented, including also publicly available information about upcoming engine developments.

Beside the most common version of engines consuming Natural Gas (NG), the so-called dual-fuel engines and other alternative concepts are described. This includes also electric propulsion systems, which allow an easy replacement of the energy source in case of a regulation change or availability of new technologies. In addition, fuel cells are presented with basic information about this energy generation concept. Benefits of fuel cell systems are, that they can also operate on methane instead of hydrogen, they are working with very little noise emission and they have no revolving parts (reduced risk of vibration).

**Recommendations for future development** In the next years, the main challenge for implementing LNG regarding gas engine technology is the reduction of methane slip, because the unburned methane may negate the greenhouse emission benefit from using LNG. Further, engine development needs to take place because the amount of engines which are suitable for inland shipping is relatively low. In order to increase the motivation for engine developments, publicly funded research programs are useful as well as efforts to increase the total market. An increase of the market may be obtained by agreed regulations for different regions and engine users, which share similar power and engine load requirements. Beforehand, a detailed analysis of recommended power for realistic operation profiles will help creating customised engine solutions.

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**Quick facts**

This study of the Masterplan discusses different engine types available for inland navigation. Load distribution, redundancy, exhaust and GHG emissions are considered. For use as auxiliary machinery, alternative engines, e.g. micro turbines and fuel cells, are discussed, too.

Thomas Myland, thomas.myland@uni-due.de
Different systems are available to store LNG on-board ships, including vacuum-isolated pressure tanks and membrane containment systems. However, the selection of a tank type is strongly related to its application. Most important aspects are storage efficiency, boil-off gas (BOG) handling and safety.

For LNG fuel tanks in Inland Waterway Transport (IWT), only vacuum-insulated-double walled pressure tanks are currently in use. This tank system provides the lowest heat transfer among the available IMO type C tanks, implying the lowest boil-off rate (BOR) and thus the lowest pressure increase when no LNG is extracted. Two different methods for LNG extraction are used: either a pressure build-up system or a submerged pump. The use of expensive BOG handling systems may be omitted when engines can burn the BOG. However, less BOG results in less pressure increase in the tank and thus a longer holding time.

The membrane containment system is another technology used for transporting LNG as cargo in the maritime sector. A concept developed for inland LNG/gasoil bunker vessels (page 41) employs it for the first time in inland navigation. The membrane tank system consists of two insulation layers and two gas barriers. They are designed for low pressure. Re-liquefaction units are used to treat the BOG in that case. In general, a BOG treatment system or the use of BOG as fuel is recommended to increase the economic viability of LNG cargo transport. The membrane tank concept received derogation from the ADN Safety Committee in August 2015.

**Fuel tanks and related equipment** This study analyses and describes existing fuel tank technologies for inland navigation. The thermodynamic background for tank operation is described and a diagram of different states in LNG fuel tanks is provided.

**Recommendations for future developments** Double-walled, vacuum-insulated fuel tanks are state-of-the-art and available. But using type C tanks for LNG cargo on IWT is not very suitable. Thus, new tank solutions with improved insulation as well as economically viable solutions for BOG handling with the appropriate size for IWT, need to be developed.

**Quick facts**
The study provides an overview of different LNG tank systems, describes the thermodynamic background and the behaviour of LNG in a closed system. An improved understanding why tank technology is of importance for the implementation of LNG as fuel is provided to the reader.

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Thomas Myland, thomas.myland@uni-due.de
LNG end-users: Greening the port equipment

Port of Antwerp (through subcontractors Haskoning DHV Belgium and Thomas More) analysed the technical, economic and ecological aspects of drivetrain mechanisms for port equipment in the port of Antwerp. An inventory of port equipment deployed in the port area, both for the handling of goods at the terminals as well as for the transport of goods between different terminals, was generated. The total fleet amounts to 1,699 vehicles, emitting annually 881 tons of NOx, 767 tons of CO, 42 tons of PM and 0.4 tons of SOx. The fleet is dominated by straddle carriers (33%), forklifts (24%) and mobile cranes (17%).

Although more than half of the fleet is equipped with stage IIIa engines, there is room for environmental improvement (23% equipped with stage I and II engines). Several cases were taken forward in a high-level cost benefit analysis: upgrade of forklifts and straddle carriers to stage IV diesel engines, conversion of hybrid diesel straddle carriers to CNG, LNG and full electric, as well as the provision of onshore power supply for mobile cranes. A first analysis indicates that the total cost of ownership (TCO) of an LNG-driven straddle carrier is comparable with a diesel hybrid straddle carrier. The TCO is 27% lower if a gas turbine LNG-driven version is considered. This is mainly due to the doubled lifetime of the gas turbine compared to the diesel hybrid engine. It should be noted that in both cases the LNG refuel infrastructure costs are not taken into account. As such, further analysis is needed.

The result of the analysis should allow the Antwerp Port Authority to make underpinned strategic choices in facilitating technologies with highest environmental cost efficiency.
In its findings the LNG Masterplan project concludes that in order to create a viable business case the LNG inland terminals shall function as satellites for hinterland ensuring that LNG reaches its end-users like the public or heavy duty transport sector or industry stakeholders.

In this regard, Danube LNG assessed possible hinterland applications of LNG, among others public bus transportation. Various technical solutions were reviewed and a manual was elaborated describing step-by-step procedures to exchange existing diesel engines for LNG propulsion by public transport companies or organisations using a greater fleet of diesel vehicles. The options to install a temporary liquefying unit and a dispenser terminal to overcome current low availability of LNG were investigated.

**Trials with LNG buses** To promote and create awareness for LNG, Danube LNG organised trials with LNG-fuelled busses of the Polish bus manufacturer Solbus. The buses were integrated and tested in the daily operation of various Slovakian bus operators in four Slovakian cities in order to let them experience the benefits of LNG-fuelled buses and to collect necessary data to analyse environmental and economic impact.

**Outcomes of trials** Even compared to CNG, LNG technology is a significant step forward regarding the operational efficiency and safety. Costs of operating LNG-fuelled buses are up to 15% less per kilometre than those using CNG with emission reductions up to 75%. The trials showed that use of LNG may contribute significantly to the emission savings. With a total of 5,108 km toured in Slovakia, emission savings comprise 43.58 kg of NOₓ, 1.47 kg of PM and 0.04 kg of SO₂. The advantages of buses running on LNG compared with the CNG buses are among others (i) smaller operating costs, (ii) greater range, (iii) shorter refuelling, (iv) lower weight of a bus, (v) higher safety due to the lower pressure, (vi) fuel does not freeze in winter as it is already frozen. Moreover, the LNG mobile fuel station used for trials proved to be an ideal start-up for transport companies, considering economic and logistics aspects due to (i) lower procurement and maintenance costs, (ii) no need for special permissions and construction works and (iii) its mobility.

**Quick facts**
The trials with public buses showed that use of LNG in transport contributes much to emission savings. Having travelled 5,108 km in Slovakia, 43.58 kg of NOₓ, 1.47 kg of PM and 0.04 kg of SO₂ were saved.

**Study carried out by:** Danube LNG
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www.danubelng.eu
Before starting to organise local safety regulations and procedures for LNG bunkering and (un-)loading, it is necessary to have an overview of the current regulatory framework and information where to find further input for safety procedures.

**Frameworks: LNG bunkering and (un-)loading** What are the options of LNG bunkering and (un-)loading and what future configurations will prevail, what will be technical challenges, what aspects do we have to cover in our safety procedures? Will we keep using the truck to ship LNG bunkering or will there be onshore LNG bunker facilities or pontoons? Maybe we will have LNG bunker vessels on rivers, and will they be allowed to do LNG bunkering alongside sailing ships? The respective studies answer these questions and give guidance in the maze of existing regulations, guideline procedures and example port byelaws.

**Operational safety during LNG bunkering** Despite its extraordinary characteristics, you can consider LNG as an ordinary dangerous good used in a safe way for cleaner propulsion of ships. The risks comparing to a traditional bunkering are different. The main focus during a conventional bunkering is on environmental risks, how to avoid an oil spill. The main focus during an LNG bunkering is on safety aspects. The study provides an overview on general framework, specifying LNG bunker procedures, checklists and requirements for the safe bunkering of inland ships. It zooms in on safety zones, requirements and gives examples from ports where LNG bunkering is already a common activity.
Nautical conditions and impact on LNG bunkering

Every part of the river is different. Every LNG bunker location has its own local nautical situation. Every bunker configuration has its own nautical impact and challenges. A location with an increased nautical risk of a collision is not the best to do a transfer of LNG. A port basin is mostly a preferred location to avoid risks. A LNG bunkering requires a safe passing distance to other ships. Can you moor alongside a ship that is performing LNG bunkering? These nautical aspects are all covered in the study.

Risk comparison of different LNG bunker scenarios

Every bunker configuration is different and has an own risk profile. This risk profile is needed for spatial planning of LNG bunker infrastructure. A truck-to-ship bunkering, mostly only 30 m³ through a 1.5 inch line, needs a smaller safety zone than LNG bunkering from a bunker facility with a large LNG storage, larger quantity and a larger bunker line diameter. How likely a loss of containment event can occur, and the resulting effect of a loss of containment differs with each LNG bunker scenario. Hazard identification, failure case definition and risk calculation lead to a calculated “Individual Risk” and “Societal Risk”. And this leads to safety distances to residential areas and other vulnerable objects. External safety distances determine where LNG is feasible. What are the parameters that have an impact on the result of the calculations? Will a safety zone decrease due to safety measures that reduce the effect of an incident? The results of this study help to decide what bunker configuration is possible in a specific local situation and which safety measures can reduce the risk level.

Quick facts

Safety and incident response studies, carried out by a group of Rhine Ports (Rotterdam, Antwerp, Mannheim, Strasbourg and Switzerland), give insight into safety regulations and procedures in the small-scale inland waterways LNG world. Studies give guidance on how to organise local safety regulations and procedures for LNG bunkering and (un-)loading.

Cees Boon, JC.Boon@portofrotterdam.com

“We are confident that these reports will be the key reference for the years to come in developing LNG as a fuel. As a port with a leading position in the field of LNG as fuel we fully recognise the need to have a harmonised approach to ensure efficient and practical LNG bunker operations.”

Cees Boon, Program Manager at the Port of Rotterdam
In a seaport inland vessels are interacting with seagoing vessels. It will happen that a seagoing vessel with LNG propulsion will be bunkered with LNG from an inland ship. Different modalities that have to comply with different regulations. A lot of international regulations already apply. What should a seaport regulate and organise to make a safe handling and bunkering of LNG possible? What bunker configuration can you expect to occur in a seaport and what are the challenges? In a seaport, the bunkering likely will take place out of LNG bunker ships. LNG gas tankers have to go alongside containerships, LNG bunkering will be carried out during loading and unloading of containers. Processes you have to control with accreditation.

The Case Study Rotterdam gives guidance for what a seaport has to regulate and organise, and also provides examples how the Port of Rotterdam deals with this.

Of course, all efforts in safety are performed to prevent incidents. The safety standards are high, the awareness, education and training of the people involved in a LNG chain is on a high level as well. Still, a dangerous occurrence can happen and the emergency response organisations should be prepared for incidents with LNG. For this reason in the LNG Masterplans’ Incident Response study, guidance for emergency response is given to emergency response organisations, as well as guidance for the fire brigade personal who have to respond in a case of an incident with LNG.

The report gives an overview of incident scenarios and guidance for incident response. The report zooms in on preparedness as well as training and education.
Regulatory, legal and contractual impact on LNG Supply Chain

Schönherr, a leading international law firm, has compiled a comprehensive overview over the legal framework of the LNG industry in the Danube countries (AT, BG, HR, HU, MD, RO, RS, SK, UA).

**Exploitation of hydrocarbons** Hydrocarbon is a scarce and valuable natural resource. Virtually all Danube-bordering CEE states provide for an ex lege state ownership of hydrocarbons. National legislations foresee complex mechanisms to transfer exclusive state rights to private entities, including tendering procedures, private law contracts, concessions or permits. The study provides a handy overview on how to get through the legislative jungle to obtain mining rights.

**Licensing of LNG infrastructure** Developing LNG infrastructure is a key element for a sustainable internal LNG market. Due to significant possible impact on the environment, LNG infrastructure projects are subject to complex licensing procedures. Currently neither on national nor on EU level comprehensive licensing procedures for LNG facilities are in place. Project developers have to face a scattered landscape of applicable licensing regimes, ranging from strategic environmental assessments over environmental impact assessments to Seveso or IPPC procedures. The study provides an overview over applicable licensing regimes in CEE for LNG infrastructure.

**Inland shipping** Shippers of LNG on inland waterways are the modern pioneers of the European energy market. However, with their pioneering steps, they have to be prepared to face a series of legal hurdles. The study addresses relevant issues of inland waterway transport, including recognition of boatmaster certificates abroad, prerequisites to execute cabotage, safety and technical standards for LNG transport, overview on mandatory crew trainings foreseen in national legislation, etc.

**Storing gas and injecting it to the grid** Non-discriminatory treatment of all market participants is the cornerstone of the European gas market model. For LNG-market players it is of utmost importance to receive access to regasification and liquefaction plants. However, a lack of regulations was identified, which may result in burdensome negotiations with facility operators. The study provides an overview over third-party access regimes to gas infrastructure.

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**Quick facts**

Project developers of all stages of the LNG supply chain may have to face a stoney legal road until their concepts turn into reality. The study assists project partners in identifying legal difficulties of their concepts and provides guidelines how to diminish them.

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Erste Group Bank – one of the leading banking groups in the Danube Region – investigated from a commercial perspective key factors on which lenders will focus when evaluating financing opportunities of LNG structures and drafted a set of guidelines and recommendations for such projects.

Transport infrastructure investments determine to a significant extent the performance of a region’s economy. Inland and maritime transportation play a key role in the further development of the region and represent a major competitive advantage for several countries in the region.

**Financing needs of LNG infrastructure investments** The significance of LNG terminals could be substantial for the energy security of Central and Eastern Europe and a step forward for a trans-European energy network. It would diversify both sources and routes of energy supply. It is therefore reasonable to expect that a significant portion of the initial LNG infrastructure investments will benefit from the support of the European Commission as well as international financial institutions (IFI).

The LNG value chain (liquefaction, shipping and regasification) is highly capital-intensive. While the liquefaction portion of the chain typically constitutes roughly 70–75% of total midstream investment, significant investments are necessary along the entire value chain.

**Project finance structures** Project finance is a form of long-term financing typically utilised for large infrastructure projects. It is different to other forms of finance because it is modeled off the projected cash flows of a project and not the balance sheets of the project sponsors – for this reason it is also referred to as off-balance sheet financing.

Since 2000, project finance has been a critical element in the development of new LNG capacity all over the world. However, despite the numerous benefits of project finance in the LNG industry, several factors are inhibiting a project’s ability to secure project finance loans. Specifically, these challenges include: 1) the introduction of new liquidity ratios mandated by Basel III, 2) challenging regulatory environments, especially with regard to the locations for some of the proposed LNG infrastructure projects and 3) the introduction and utilisation of new technologies in the industry.

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**Quick facts**
The LNG value chain (liquefaction, shipping and regasification) is highly capital-intensive. While it is reasonable to expect that a significant portion of the initial LNG infrastructure investments will benefit from the support of the European Commission as well as international financial institutions, private money and private finance structures will play a key role in the development of the industry, as soon as initial risks related to the regulatory environment and used technologies are properly mitigated.

Vlad Vasile-Voiculescu, Vlad.Vasile-Voiculescu@erstegroup.com
Converting inland vessels to LNG as fuel can provide economic and environmental benefits in many cases. Nevertheless, the conversion requires significant investment and must be based on solid economic considerations. To support the decision process, the LNG Masterplan delivered a first decision support tool. This tool is based on a Total Cost of Ownership (TCO) model. It addresses private funding (business case) as well as public funding (economic and social effects) and compares TCO of a LNG dual-fuel refit with conventional gasoil (LSMGO) operation.

The tool targets the main parties involved in the decision-making process:
- Ship owners – assessing individual business cases for LNG refit
- Public parties – evaluating the socio-economic impact of certain vessel emissions with regard to public funding
- Investors – investigating scenarios for bankable business cases

Based on inputs being derived from existing pilot deployments, the model refers to a standard business case and estimates emission values for LNG dual-fuel drive (new engine or add-on to existing engine). The currently limited amount of input data narrows the results to initial estimates based on ship characteristics and operational profile. Furthermore, the standard values are subject to market, legal and technical developments and circumstances. Despite these weaknesses in the fledging phase, the total cost of ownership approach and the hereupon based detailed analysis of costs, savings and benefits reduce complexity of the decision-making process and deliver valuable indicative information.

The TCO model uses a first limited set of standard data which shall be further elaborated by:
- adding more ship profiles to reflect the diversity of the inland waterway fleet
- extending the model with other “greening the fleet” innovation solutions to provide a decision tool encompassing up to date green technologies
- including costs of related LNG infrastructure (where applicable)
- update standard input values on a regular basis to ensure that the tool follows the state of technology.

The TCO Model is currently managed by the Dutch LNG Knowledge and Expertise Centre (KEC): www.eicb.nl.

Quick facts
The TCO Model foresees two calculation modes: The Quick Scan providing rough indications of the benefits of LNG addressing ship owners. The Full Scan is a more elaborate calculation of different investment costs, operational costs and revenues and also calculates reduction in emissions and social benefits resulting from these reductions.

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Trainees at LNG Masterplan Pilot Class

LNG Bunkering of the first LNG propelled vessel Argonan
By worldwide growth in the use of LNG, the demand for skilled labour force with specific knowledge of LNG increases. Therefore, the LNG Masterplan set the objective to elaborate the “standards” for education and training of personnel handling LNG in the inland navigation sector.

**Curricula and lessons material** The best practices developed in the maritime sector, standardisation initiatives, draft regulatory frameworks such as those of CCNR or IMO (IGF Code), interviews with experts from industry and shipping sector as well as online questionnaires were basis for model curricula, lessons material and E-learning modules developed in the LNG Masterplan project. The curricula and lessons material distinguish between operational and management level and focus on transportation, transfer, bunkering and use of LNG as fuel. Intellectual Property Rights apply to elaborated lessons material and educational institutions themselves provide more information on them and invite to participate in their trainings.

**Pilot classes** In the Netherlands, in Austria, Bulgaria and Romania the pilot classes were executed, covering different areas of competencies such as crew members, terminal, bunkering and management personnel, competent authorities, or students focusing on logistics. More than 200 “students” took part in these classes and, with their feedback, contributed to improvements of curricula and lessons material in an iterative way.

**E-learning modules** have been designed to provide basic knowledge of LNG covering the topics: LNG Introduction, Risks of LNG, Markets, Layout of a Terminal and Environmental Information of LNG. The access to E-learning modules is offered prior to the training to get familiarised with the topic.

**Simulations/simulators and a tanker training facility** Practical knowledge and theoretical knowledge both are important phases of learning. The first practical experience with LNG is gathered through the simulations of everyday situations on LNG-fuelled vessels, from normal vessel operation through bunkering to emergency situations. The simulators and training facilities were extended or developed, when necessary, in the project providing a practical way to obtain competencies.

**Quick facts**
Model curricula, training material, E-learning modules, simulators and practical training equipment (e.g. tanker training facility) are project outcomes available for several staff categories along the LNG supply chain; all contributing to a harmonised approach towards training of necessary personnel.

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Romania: office@ceronav.ro
LNG bunker station: Port of Antwerp
Gemeentelijk Havenbedrijf Antwerpen (Port of Antwerp)

“We believe that reliable bunkering infrastructure in our port will help convince ship owners to switch to LNG as a clean and competitive fuel.”
Greet Bernaers, Director Infrastructure

Quick facts
Start of operations: by January 2019 (currently permits in place, ready to build)
Capacity: 400 m³ of LNG
Facilities: storage of LNG and CNG, bunkering inland ships with LNG, fueling road transport with LNG and CNG
Investment & operation: by concessionaire

About the project owner
Port of Antwerp manages and develops the port area and distinguishes itself by providing environmental services to shipping. The port community also confirms its commitment to Corporate Social Responsibility.

Pieter Vandermeeren, pieter.vandermeeren@portofantwerp.com
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The Port of Antwerp engaged itself in 2011 to play a proactive and pioneering role in the development of LNG as a fuel for shipping. The first truck-to-ship bunkering of an inland vessel in Antwerp was successfully carried out in 2012 – followed by many others in the coming years – and in September 2015 the first seagoing ship was bunkered with LNG.

LNG bunkering in Antwerp Meanwhile, an important milestone was reached in early 2014, when LNG bunkering procedures and checklists for bunkering of LNG via truck-to-ship, terminal-to-ship and ship-to-ship were included in the police regulations of the Port of Antwerp, making the bunkering of LNG an integral part of the daily port operations. Port of Antwerp has also taken an active role in harmonisation and knowledge sharing through international cooperation, including its leading role in the LNG working group of WPCI and its close cooperation with the Rhine Ports of the LNG Masterplan.

Currently trucks are loaded at the import terminals of Zeebrugge or Rotterdam for truck-to-ship bunkering operations in Antwerp. This is a cost-effective solution for inland shipping in the current immature market, but a storage facility of LNG should be installed in the Port of Antwerp in order to really get the market going. Indeed, ship owners are more likely to switch to LNG as a fuel when the continuous and permanent availability of LNG in the port is guaranteed.

LNG bunker station A technical concept of an LNG bunkering station was developed in the framework of the LNG Masterplan project, which consists of a tank for the storage of 400 m³ LNG, a boil-off gas management system and all necessary equipment for bunkering inland ships with LNG as well as fuelling road transport with LNG and CNG. Based on this concept, a building permit and environmental permit were obtained by the port authority, thus paving the way for the effective realisation of the project.

The Port of Antwerp will shortly grant the terrain to a concessionaire who will invest in the construction and operation of the installation that should be ready by January 2019.
LNG infrastructure: Port of Mannheim
Staatliche Rhein-Neckar-Hafengesellschaft Mannheim mbH

“Port of Mannheim, located at the rivers Rhine and Neckar near Frankfurt, Stuttgart, France and Switzerland, is an ideal location to develop a LNG logistic hub.”

Michael Dietrich, Head of Technical Department

Port of Mannheim conducted a feasibility study for a LNG terminal and a bunker station in the southern part of Mannheim. A quick scan during a port visit by a vessel helped to identify the best available location within the port area. The quality risk assessment confirmed the feasibility of a LNG infrastructure on this specific plot, which is located directly at the Rhine. After determining the location, a cost estimate of investment and operational costs was performed.

Due to its favourable location at the rivers Rhine and Neckar, Port of Mannheim is logistically very well located. Being one hour away from France, the metropolitan areas of Frankfurt/Main and of Stuttgart/Neckar and two hours away from Switzerland, Port of Mannheim is an ideal location to build a LNG infrastructure.

LNG infrastructure location The favourite available land was found in the southern part of Mannheim, directly at the Rhine. The site has a size of ca. 1 hectare, with rail and road access. This location in the port area was selected by considering space availability, ship accessibility, distance to residential areas and protected environmental areas.

Facilities and investment costs The proposed LNG infrastructure foresees a combination of a LNG terminal to function as a hub to distribute LNG into the hinterland and a fuelling station for ships and trucks. The design foresees a jetty, an embankment crossover, a piping bridge with staircases, a walkway with LNG pipes, two 250 m³ double-walled LNG tanks and a (un-)loading/bunkering area for trucks. The estimated investment costs for this design amount to approximately 6–7 million EUR, with yearly operational costs of up to 250,000 EUR.

With the main results of the feasibility study such as location, quality risk assessment and cost estimates, this design of possible LNG infrastructure is supposed to help investors judge the potential of Port of Mannheim to be a part of a wide-scale LNG supply chain.

Quick facts
Capacity: 500 m³ LNG
Facilities: LNG storage, truck fuelling, vessel bunkering
Estimated investment: 6–7 MEUR
Operational cost/year: 250,000 EUR

About the project owner
Staatliche Rhein-Neckar-Hafengesellschaft Mannheim, with its four port areas (14 basins and 3 river docks) and a total area of 1,131 hectares, is Germany’s largest inland port in terms of area and a driving force in logistics and integrated transport.

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II. TERMINAL & VESSEL SOLUTIONS

LNG infrastructure: Port of Switzerland

Port of Switzerland

“In a comprehensive feasibility study, Port of Switzerland investigated the options for the location of its LNG infrastructure, in particular an LNG storage facility – a terminal for distribution of LNG to hinterland end-users and a bunker station for fuelling vessels and trucks. The introduction of LNG for inland navigation and other transport modes will boost the innovative capability of the Basel business location, thus making a vital contribution to competitiveness.

Port of Switzerland is opening up new segments of business
Import and distribution of LNG offers good opportunities and reduces dependence on individual energy sources. Port of Switzerland sees LNG as a new business segment with significant potential. According to a risk assessment study, the import and distribution of LNG to Switzerland on the Rhine can be carried out in compliance with Swiss laws.

The construction of a LNG bunker facility within the Port of Switzerland is fundamentally possible. This was proved in a relevant case study carried out within the framework of the LNG Masterplan project. A risk assessment in accordance with Swiss laws was conducted in exemplary manner on the basis of the preliminary design assumptions. The underlying assumptions are based on a storage volume of 1,000 m³, delivered by 25 shiploads per year. The executed study can be used as a reference in a future a specific application process. At the present time however, none of the identified suitable locations within the Port of Switzerland’s sphere of responsibility are available as they are currently occupied by other uses. The construction of the LNG infrastructure in the port area therefore will require cooperation with current port tenants. Port of Switzerland is pleased to act as project facilitator and point of contact for all interested parties.

About the project owner
Seven million tons of goods and more than 100,000 containers a year are transshipped in the 3 port areas of Port of Switzerland, namely Basel-Klein-üningen, Birsefelden and Muttenz Auhafen. This is equivalent to 12% of all Swiss imports.

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© Port of Switzerland
LNG terminal: Komarno

Danube LNG, EEIG

Danube LNG investigated the most suitable location for a LNG terminal in the port of Komarno or in its adjoining areas in Slovakia. As a result of the feasibility study, the preliminary risk assessment and the assessment of permitting procedures, it was concluded that a floating terminal might be a more flexible and feasible solution compared to an onshore terminal. The floating terminal offers the same functions as a land terminal – receiving, storing and bunkering of LNG – but represents a different technical concept. The innovative solution of a floating LNG terminal easily can be applied to other inland ports with similar framework conditions.

Facilities The Danube river floating LNG terminal (FLNG) is designed to be a non-propelled facility which ensures unloading and storage of LNG, while also serving as a multi-purpose service station for vessels providing diesel fuel, potable water and holding also ship waste reception facilities. The designed FLNG is able to satisfy the requirements for rapid and safe unloading of LNG from tankers and barges, as well as storage of up to 4,200 m³ of LNG, in 12 tanks of 350 m³ each. The FLNG is supposed to supply the LNG for the road transport sector as well as for industrial LNG end users identified during the market studies.

Technical solution In terms of the durability and requirements for maintenance, an iron-concrete composite is recommended as hull. Based on the rules of the classification society Slovak Lloyd, the terminal has an anchoring device on the fore and on the stern. The FLNG will be equipped with a mooring and harness device for specific fixation of the pontoon to pillars and for mooring LNG tankers during (un-)loading and for other vessels during bunkering.

Location assessment Placement of the FLNG terminal is a subject to a hydrological conditions assessment. The study assessed the impact on water flow and sedimentation at the proposed location. A hazard and operability (HAZOP) study as well as a CBA are part of the results.

Quick facts

- **Size**: 126 m x 24 m (L x W), Draught: 2 m
- **Capacity**: 12 x 350 m³ of LNG (total 4,200 m³)
- **Facilities**: LNG storage, vessel bunkering, facilities for other vessel services

About the project owner

Danube LNG was established as EEIG by commercial companies with the objective to prepare a concept and a mature project for a comprehensive logistical system delivering LNG to Central Europe via inland waterways.

© Danube LNG

“The highly innovative solution of the floating LNG terminal provides a flexible and convenient solution for inland ports and is not limited to bunkering of LNG”

Robert Kadnar, CEO

Visualisation of the floating LNG terminal

© Danube LNG

www.danubelng.com
APDM has concluded a pre-feasibility study and a preliminary technical concept for a LNG terminal in the maritime Danube area in Romania. The study analysed three potential locations for the LNG terminal, namely the ports of Galati, Tulcea and Braila. It furthermore provides a quantification of the size for the identified location based on the demand and supply analysis. It assesses the necessary technical facilities and determines the size and number of LNG tanks and related equipment. The study also includes an initial calculation of the investment costs as well as an assessment of environmental and socio-economic impact.

**Location**
Initial analysis showed that the most suitable location is the eastern part of the Port of Galati situated on the riverbank inside the Industrial Park Galati of 20,000 m². It has a convenient road access and is located in the vicinity of the Oil Terminal Galati (dangerous goods zone) and of other currently operating industrial areas (e.g. Damen Shipyard).

**Functions**
A proposed LNG terminal with an initial storage capacity of 4,000 m³ (design capacity up to 8,000 m³) may offer a wide range of distribution: LNG bunkering for inland and maritime vessels, supplying LNG to road transport as well as to industries.

**Technical solution**
The study investigated several storage concepts such as spherical tanks, flat bottom tanks (FBT) and semi-pressurised tanks (SPT). Selection criteria included elements such as total capacity of the planned terminal, prospects for LNG demand development, characteristics of the available land (surface and ground bearing capacity), limitation of safety and security issues in the location area. Considering benefits, the focus was set on two options: SPT and FBT as within the site it is possible to locate the LNG terminal with a total capacity of 8,000 m³ (SPT) or up to 10,000 m³ (FBT). Due to the high uncertainty about the demand level, the implementation of SPT option in two phases is recommended, envisaging at first a LNG terminal with a capacity of 4,000 m³.

"The LNG terminal in Galati is an important opportunity for local and regional economy, a factor for trade intensification and an incentive of further growth of the IWT sector."

Silviu Meterna, Head of Development Department

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**Quick facts**
- **Capacity:** 4,000 m³ at the first stage in semi-pressurised (SPT) tanks with an option to increase up to 8,000 m³
- **Facilities:** LNG storage, truck fuelling, vessel bunkering
- **Estimated investment:** 17 MEUR

**About the project owner**
APDM Galati is in charge of administration and development of maritime ports on the Lower Danube and their integration into intermodal links (inland waterways, maritime, road and rail transport) to and from Romania.

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In close cooperation with Constanta Port Authority TTS Group has commissioned a pre-feasibility study and a preliminary design for a small-scale LNG terminal in the port of Constanta. In addition, the small scale LNG terminal was put into relation with a potential future LNG regasification terminal. The study analysed possible locations and scenarios for LNG supply, assessed investment needed, provided preliminary cost benefit analysis and elaborated on financing scenarios. The work also included a general technical design.

The LNG small-scale terminal shall facilitate the initial LNG development in the area. It shall supply maritime and inland vessels as well as road vehicles with LNG and shall enable its further distribution into the hinterland. The considerations were made for a terminal of an initial capacity of 5,000 m³ with a future expansion up to a maximum of 10,000 m³. The layout includes a storage facility, (un-)loading facilities for maritime vessels, fuelling of inland vessels and trucks. The chosen location will allow vessels with a draught up to 7 m. For its gradual expansion bullet-type horizontal storage vacuum-isolated tanks of 2,500 m³ each are recommended.

The LNG regasification terminal will cater for import and storage of LNG in bulk volumes. An initial storage capacity of 130,000 m³, expandable to 260,000 m³, was considered for the location study. A full containment storage tank solution designed for a throughput of 5.75 million m³/year (over 100,000 m³/week) of LNG and a production of 3.5 BCM of natural gas was explored. This terminal shall be reachable by vessels with draught up to 19 m. Becoming operational after 2025, it shall supply LNG to the LNG small-scale terminal by a dedicated bunker vessel.

The deployment of the small-scale terminal shall be facilitated with the help of appropriate European funding schemes based on a public-private partnership model.

“A small-scale LNG terminal in the Port of Constanta will not only fulfil the European Directive on alternative fuel infrastructure but also provide huge opportunities for all kinds of transport operators and industrial fuel users looking for environmentally friendly and cost-effective fuel solutions.”

Serban Cucu, Senior Advisor

Quick facts

LNG small scale terminal: 5,000 m³ (up to 10,000 m³) with LNG storage, (un-)loading of (smaller) seagoing vessels, fuelling of inland vessels and trucks.

LNG regasification terminal (onshore): 130,000 m³ (up to 260,000 m³) with regasification facility connected to the gas grid, (un-)loading of seagoing & inland carriers, bunker vessel supplying small-scale terminal and vessels.

About the project owner

TTS Group acts as multimodal logistics provider and port operator in Eastern and Central Europe. It also owns NAVROM SA which operates the biggest inland vessel fleet on the lower Danube.

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LNG/Gasoil bunker vessel
Argos Bunkering B.V.

Argos Bunkering has developed a concept for the first LNG/Gasoil bunker vessel. The Argos-GL is a type G tanker designed for carriage of LNG (two tanks of 935 m³ each) and gasoil (four tanks of 380 m³ each). It is designed for bunkering both seagoing and inland vessels, of either regular gasoil or LNG. It can as well be used for delivering LNG to bunker stations. The envisioned working area covers mainly the ports of Amsterdam, Rotterdam and Antwerp.

**Propulsion** Three LNG-electric generators are planned for the ship’s propulsion and power generation, with a diesel generator as a backup power in a separate engine room in the aft ship. For LNG propulsion a separate LNG fuel type C tank of 40 m³ (gross) is considered. The LNG propulsion system and LNG cargo system are totally independent by design. This implies that tank monitoring system, safety equipment, pressure management, piping for LNG fuel and LNG cargo parts are totally independent.

**Membrane tank technology** Despite the fact that the transportation of LNG with inland vessels is allowed only in pressurised cylindrical tanks, Argos-GL decided for the membrane tank technology and finally received derogation from the ADN Safety Committee.

Argos-GL uses the Mark III Flex membrane system developed by GTT for its LNG containment system, which is the most frequently used LNG cargo containment system for seagoing vessels integrated into the ship structure. The main difference to the carriage in a regular pressure tank is the re-liquefaction of the LNG onboard the vessel. The LNG boil-off is extracted from the cargo tank, made liquid again and pumped back into the tank. Due to this, the tank is almost pressureless. From a safety point of view, the membrane tanks have further advantages, such as (i) no risk of BLEVE (Boiling Liquid Expanding Vapour Explosion), (ii) no jet fire or (iii) limited amount of spill and reduced dispersion range in case of a hypothetical catastrophic containment failure, as the leaking flowrate would be purely generated by gravity instead of pressure.

“To use a membrane tank system, the LNG cargo volume is increased by 55% in relation to use type C tanks in the same space of the hull.”

Piet van den Ouden

**Quick facts**
- **Size:** 110 m x 13.5 m (L x W)
- **Propulsion:** 3 x gas generators and 1 diesel generator (backup)
- **Tanks (cargo):** 4 x 380 m³ of gasoil (total 1,520 m³), 2 x 935 m³ of LNG (total 1,870 m³) – GTT Mark III Flex membrane system
- **Bunker capacity (LNG):** 40 m³ (gross) – type C tank located below deck

**About the project owner**
After the merger of Varo Energy with Argos to the large Varo Energy Group, becoming a new major downstream player in North West Europe, the current project management investigates the possibilities to bring this unique project into reality.

Piet van den Ouden, piet.van.den.ouden@argosenergies.com
It is not only the LNG installation that will reduce emissions dramatically. The four-propulsion line concept with larger propeller surface and a novel design of retractable flanking wings will realise another plus of 16% to total ship’s efficiency that will save fuel as well as reduce emissions.”

Peter Vrolijk, Project Manager

Kooiman Marine has developed a concept for an inland push boat with a LNG dual-fuel propulsion system. The push boat is designed to navigate the river Rhine with up to six Europe type II barges. The concept received derogations for the use of LNG as fuel for the propulsion installation.

**Propulsion** The newly designed push boat foresees four main Wärtsilä 6L20 dual-fuel engines plus a DF auxiliary engine arrangement. The main engines have a double-walled gas fuel piping system to ensure hazardous free operation in the engine room. The four-propulsion line concept with shaft generators combined with batteries to store a surplus of power whilst sailing upstream enables a downstream trip on only two engines using the stored power for ship’s systems.

**Tanks** LNG is kept in a 165 m³ double-shelled stainless steel vacuum-insulated type C tank of novel vertical design located in the centre of the boat, between engine room and accommodation. The valve box is also made of stainless steel with access and ventilation to open deck to prevent any leakage of NG and LNG to harm personnel or ship construction. The Tank’s thermal insulation is sufficient to keep the gas in liquid state for extended periods, even without any gas consumption. The LNG boil-off will be consumed by the main engines whilst sailing and by the DF generator only whilst in harbour and lay-down conditions.

**Bunkering** The bunkering station on the push boat is designed for receiving LNG from shore, truck or bunker barge. Its capacity allows the vessel to sail a minimum of one week 24/7 or approximately 2,000 km, that is 1,000 km with fully loaded barges upstream and 1,000 km with empty barges downstream.
LNG inland tanker

LNG E-Motion B.V.

LNG E-Motion has developed a concept for the first dual fuel LNG inland carrier, LNG Prime, being able to transport 2,250 m³ LNG (in three LNG fuel tanks, 750 m³ each). This proposed carrier is supposed to contribute to a high-quality LNG infrastructure by delivering LNG for bunker stations in sea and inland ports as well as to LNG storage infrastructure in Rotterdam, Antwerp, Zeebrugge, Hamburg, Switzerland and the northern seaports of the Netherlands.

Propulsion and manoeuvring of the vessel will be done by two Veth Z-drive of 450 kW each and two bow thrusters of 150 kW each. Beside the LNG-propelled generators, the LNG Prime is outfitted with one diesel generator of 500 kW that could propel the barge in emergency situations. The auxiliary power on-board of the ship is represented by three gas generators, of 635 kW and 320 kW, as well as a special Capstone generator of 60 kW for the boil-off after 90 days.

Tanks The vessel has three highly insulated cargo tanks and one LNG fuel tank in the front of the ship. The special high vacuum-insulated cargo tanks could hold the LNG in condition without using the boil-off for at least 90 days. The maximum cargo capacity is designed to supply 1,000 tons of LNG.

Technology & innovation To protect the cargo tank against collision, the front of the ship was designed to absorb the energy so the tanks cannot be pinched.

Permits Due to still missing legislation during the project life time, the LNG inland carrier would need to undergo a special derogation procedure at the Rhine Commission (CCNR) for the use of LNG as fuel for the propulsion installation. Thanks to the update of the ADN 2015 the transportation of LNG in type C – pressurised vacuum-insulated cargo tanks – intended to be used in the LNG inland carrier is allowed.

It is expected that LNG E-Motion will deploy the vessel concept in the near future with the company Deen Shipping, which is operating the first European LNG-fuelled inland vessel Argonon.

“A ship like the LNG Prime is needed to develop the last link in the chain to the marine customer for bunkering LNG in the ARA-area. This specially designed inland ship is preferred to seagoing LNG bunker vessels because of its flexibility and efficient operations needed in the ARA-area.”

Ad van Berchum, Project Manager
As part of the concepts to supply the Danube region with waterborne LNG supply chains, Danube LNG elaborated a conceptual design for a river-sea LNG tanker, two river barges for transportation of LNG and a multi-purpose floating pier for reloading and bunkering of LNG. In addition, retrofitting possibilities of two pushers of the Slovak shipping company were investigated.

Due to the lack of closeby LNG import terminals, more complex supply chains are needed to supply the Danube region resulting into higher logistics costs. Danube LNG analysed sourcing options with focus on the Black Sea, Eastern Mediterranean and the Caspian region using the Volga-Don channel to access the LNG sources from Azerbaijan, Turkmenistan and Iran directly from Caspian ports.

**River-sea LNG tanker** Being the main part of the supply chain, the river-sea tanker is able to sail on sea and on inland waterways. The omission of reloading in sea ports saves time and transport costs.

A dual-fuel engine is proposed for propulsion using the boil-off as well as traditional diesel fuel as backup. The double-hull construction meets the requirements of the seagoing vessel designed to face the waves up to 5.6 m and is
able to sail 50 naval miles offshore. With its minimal draught of 1.6 m (after reloading part of the cargo into specialised barges) it can operate also under low water conditions on the Danube. This ensures a year-round supply of LNG. The dimensions of the river-sea LNG tanker – 16.6 m width and 130 m length – are set according to the limits of the Volga-Don canal locks. LNG is stored in 10 vacuum-insulated cryogenic LNG tanks, each with a capacity of 348.5 m³ (3,485 m³ in total). The analysis shows that the vessel can theoretically make a round-trip from Caspian Sea ports to Linz (Austria) and back in 28 days.

**Specialised LNG river tanker barge** Two Danube barges are designed as support vessels used to decrease the draught of the tanker by reloading up to 50% of the cargo from the tanker to barges, thus allowing a continuous navigation also in very shallow waters (e.g. below 1.65 m). The barges can also be used for inter-port LNG transport.

**Floating pier for reloading and bunkering of LNG** The last part of the study is dedicated to a multi-purpose LNG reloading pier with LNG and diesel fuel bunkering facilities, as well as fresh water and ship waste reception facility with one 348.5 m³ LNG tank and one 200 m³ diesel fuel.

**Retrofitting of pushers** Based on a fleet analysis covering economical and technical aspects, two types of pushers of the fleet of the Slovak shipping operator were selected for the elaboration of a conceptual design for retrofitting. Dual-fuel propulsion with vacuum-insulated LNG tanks with a capacity of 2 x 49 m³ for the type TR 1000 and of 4 x 6.75 m³ for the type TR Muflon 1100 is considered as a viable option.

“Our river-sea tanker represents a revolutionary idea which could change the whole European river transport. We hope that in future this concept will be transformed into a fleet of ships, navigating the European waterways.”

Robert Kadnar, CEO
LNG-fuelled inland push boat
Compania de Navigatie Fluviala Romana Navrom S.A. (Navrom)

“LNG is a promising option for Navrom. Cost reduction means a lot for our business as fuel costs represent around 35% of our spending. Therefore we put our hope in this alternative fuel for our pushers operating on the Danube.”
Constantin Hartan, General Director

Navrom has conducted a feasibility study for retrofitting of three existing vessels (the self-propelled barge Jaristea and two river pushers - Sadu and Mercur) to run on LNG and diesel. For each vessel, several retrofit solutions have been analysed. For the vessel types Jaristea and Mercur, the feasibility study proved that the retrofit is technically possible, but several factors speak against it, among them high investment costs, large design modifications in superstructure and several operational limitations (less cargo capacity, increased air draft, etc.). For the 1985-built river pusher Sadu, the retrofitting is technically almost impossible, mainly because of the lack of space for the LNG installation and economically not recommended due to the large cost of the LNG pack.

New LNG-fuelled inland pusher As the analysed retrofit solutions proved unsuitable, Navrom developed an initial concept design for a new dual-fuel pusher. The new pusher is fully adapted to meet specific navigation conditions on the Danube. The investment costs are estimated at about 8 MEUR, of which about 50% represent the additional cost for the dual fuel option, in comparison to classic fuels such as diesel.

Technical concept The pusher’s hull is divided in five areas consisting of (i) steering, anchoring and aft deck equipment, (ii) engine room, (iii) LNG pack, fuel oil tanks and ballast tanks, (iv) accommodation, fresh water and ballast tanks and (v) fore equipment, fuel oil tanks and ballast tanks. The pusher is foreseen with a large wheelhouse with a 360 degree visibility. In the aft part, a raised roof is provided in order to create space for the engine arrangements. The concept foresees dual-fuel Wärtsilä 6L20DF engines. The fuel tanks are integrated into the structure. The cryogenic LNG tank is an independent type C vacuum-insulated tank, with a volume of 160 m³ LNG (100% volume). This LNG tank provides the pusher a sailing time of 200 hours, to which 270 hours can be added in diesel fuel mode.
II. TERMINAL & VESSEL SOLUTIONS

LNG-fuelled gas supply vessel
Bernhard Schulte (Cyprus) Ltd.

Bernhard Schulte has developed a detailed technical design for a next generation seagoing LNG carrier with gas electric propulsion, called the “Gas Supply Vessel”. This new type of ship will be used to supply LNG to other ships, marine craft and to deliver gas to small onshore facilities and large off-pipe consumers. Among other application options, the concept can be deployed to supply LNG to the planned terminals in the Black Sea, to be further distributed to the hinterland by dedicated inland waterway tankers sailing on the Danube.

Propulsion
The ship features Azipod propulsion for increased manoeuvrability. The vessel’s design takes an innovative approach to manage the boil-off gas generated from the cargo tanks, using compressed natural gas (CNG) technology to supply the gas to the Wärtsilä dual-fuel medium-speed engines more efficiently.

Technical specification
The ship’s specification has been enhanced to allow simultaneous operations. The vessel is designed with an unusual hull form featuring a low wash bow which is very similar to the passenger river cruise vessels being used in Europe, enabling them to work in harbours and inland waterways at a reasonable speed without causing a lot of wake. The cargo-holding capacity ranges from a very small 3,500 m³ up to 7,500 m³ (net), which is the most intensely discussed capacity at the moment. The design could stretch to 13,000 m³ or 15,000 m³ if needed. Naval architects, BMT TITRON, were careful to build a high level of sophistication into the design, while also ensuring the vessel was fully capable of deep sea operation. Safe delivery of liquefied natural gas demands significant design competence but when the vessel is being used to fuel other ships then the skills involved raise the bar a few notches.

Training and safety aspects
Crew training to ensure safe operation of the vessel is a vitally important aspect of the project. It will be the job of Bernhard Schulte to ensure the recruitment and training of the right personnel to perform the refuelling tasks, manage the vessels and ensure the vessels are operated to the highest possible safety standards.

Quick facts
- **Size**: 109.93 x 18 m (L x W), Draught: 5.3 m
- **Propulsion**: 3 x Wärtsilä DF Generators 1,065 kW each (use of boil-off gas generated from the cargo tanks, stored as CNG, to supply the gas engines)
- **Tank (cargo)**: range from 3,500 m³ to 13,000 m³
- **Tank type**: Type C tanks (pressurised or atmospheric pressure delivery)
- **Other**: Zero methane emissions during LNG transfer including nitrogen purge

About the project owner
Bernhard Schulte is an integrated maritime solutions leader, with a strong heritage spanning more than 130 years in the shipping industry, and trusted as a partner by responsible and demanding customers worldwide.

© Bernhard Schulte, BMT TITRON

“Wind gave way to coal and coal in its turn gave way to oil. The move from oil to natural gas is simply the next progression in the evolution of maritime transportation.”

Angus Campbell, Managing Director

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Pilot Deployments

Small-scale LNG terminal in Ruse (Bulmarket) ...........................................50
LNG-fuelled retrofitted container vessel – *Eiger* (DCL Barge) ......................52
LNG-fuelled type G tanker – *Sirocco* (Chemgas Barging) .................54
LNG-fuelled type C tanker – *EcoLiner* (Damen Shipyards Hardinxveld) ......56
Bulmarket DM has built the first small-scale LNG terminal on the Danube with a total volume of 1,000 m³ being used for the storage of liquefied natural gas (LNG), the bunkering of inland vessels and fuelling of trucks as well as the further distribution of liquefied natural gas in the region. The terminal is located on the river Danube in the port area in Ruse (Bulgaria), on the grounds of the former heavy machinery building factory, on an area of 1,000 m².

**Facilities** The small-scale LNG terminal is equipped with four vacuum-isolated cryogenic tanks for storage of LNG with a volume of 250 m³ each placed parallel to the shore, while respecting a 4-metre safety distance between each other. Each tank (LNG reservoirs) has a diameter of 4 m and a height of 30 m. The terminal offers the facilities for the (un-)loading of inland LNG carriers, the bunkering of inland vessels and the fuelling of trucks using liquefied natural gas. The fuelling station is connected with the facility for loading LNG trucks in order to distribute LNG into the hinterland to various LNG customers. The LNG storage facility is connected with the existing terminal for hazardous cargo with its own pontoon. The tankers supplying LNG will berth at this existing terminal pontoon. The same pontoon will be used for the bunkering of inland vessels running on LNG. (Un-)loading operations will be done through special flexible hoses at the pontoon and fixed pipelines connecting the pontoon with the storage facility. Both flexible hose and pipelines have special insulation to transport cryogenic gas – LNG. The terminal is connected to the public infrastructure, such as water, electricity and road network through existing connections.

**LNG-fuelled trucks** The LNG road fuelling market is not developed in south-eastern European countries. Bulmarket with the help of the project
procured three IVECO trucks running on LNG. They will be the first LNG trucks using the truck-fuelling station located in the LNG terminal area. These trucks will be further used for the distribution of LNG to customers identified by Bulmarket in their market analysis. This showed a large baseload market both in Bulgaria as well as in neighbouring countries with about 70 potential customers being on the company’s shortlist.

**Permits** In December 2013 the planned LNG terminal with its facilities received positive statements from authorities responsible for NATURA 2000 and Water Management after complex negotiations with the relevant authorities in Ruse and Sofia. Due to the changes in the national legislation in 2015, the final civil construction permit was slightly postponed and was received at the end of September 2015.

“**This first LNG storage in the lower Danube contributes not only to the uptake of new green fuel in south-east Europe but as well to the diversification of the energy supplies for industries. With its bunkering facilities it supports the fulfilment of the EU Directive on the deployment of alternative fuels infrastructure.**”

Dimitar Baev, Deputy Manager

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**About the project owner**

BULMARKET DM Ltd. is a 100% private Bulgarian company established in 1996. The company deals among others with the distribution of LPG as well as CNG, gasoil, petrol, and other fuels.

Dimitar Baev, dimitar.baev@bulmarket.bg

www.bulmarket.bg

**Quick facts**

**Facilities:** LNG storage, vessel (un-)loading facility, truck-loading station, truck-fuelling station, inland vessels bunkering station

**Capacity:** 4 vertical tanks of 250 m³, each with a total volume 1,000 m³ of LNG
LNG-fuelled retrofitted container vessel – *Eiger*

DCL Barge B.V.

**DCL Barge has refitted the tug-barge Eiger-Nordwand to accommodate a liquefied natural gas (LNG) drive system.** It is the first inland waterway container vessel worldwide refitted for LNG. The operational area is mainly from Rotterdam to Basel and Antwerp and back, with stops in Strasbourg and in Weil am Rhein. The vessel sails approximately 63,000 km/year and is always loaded with containers during sailing. The vessel is built and equipped to sail 24 hours continuously.

DCL Barge commissioned the turn-key project to Koekood and Wärtsilä, who completed the refit from diesel to LNG within three months. With the Wärtsilä dual-fuel drive system, the vessel gets 95 to 99% of its power from LNG, which significantly reduces emissions (20% less CO₂, 85% less nitrogen and 99% less fine particulates) as well as fuel costs. DCL Barge expects to earn back its investment within seven years.

**Propulsion** Two dual-fuel Wärtsilä 6L20DF main engines are installed for the ship’s propulsion, each developing 900 kW at 1,200 rotations per minute. The vessel also accommodates one auxiliary grid bow thruster of 350 hp operational only during
harbour manoeuvres and emergency stop situations. In case of emergency, power supply is assured by means of 2 separate generator sets (one in front of the bow thruster/generator room and one in the engine room).

**LNG fuel tank** For LNG propulsion a separate cryogenic LNG tank of 60 m³ (gross) is installed. It is a vacuum-insulated double-walled pressurised tank IMO type C. The LNG tank is placed below deck in front of the engine room in a tank compartment of the size of six 20-foot containers. In order to guarantee optimal safety, the tank compartment is mechanically ventilated and the sides and top of the compartment are open.

**Experience** After commissioning in June 2014, Danser together with its partners worked towards the optimal adjustment of the system. The latest measurements are proving that all the objectives with respect to emissions have been achieved. The current crew of Eiger-Nordwand comes from Danser’s existing shipping department and has agreed to sail on this “new” technically advanced ship. Intrinsic motivation of the sailing crew and a good LNG training contributed to the successful transition to LNG as fuel.

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**About the project owner**
DCL Barge, a member of the Danser Group, is an independent logistic service provider. With an annual volume of more than 1 million TEU it is one of the leading container and break bulk operators in Europe.

Ben Maelissa, ben.maelissa@danser.nl
www.danser.nl

**Quick facts**
- **Size:** 105 x 11.45 m (L x W), Draught (max): 3.55 m
- **Propulsion:** 2 dual-fuel Wärtsilä 6L20DF, 900 kW each at 1,200 rpm
- **Bunker capacity (LNG):** 60 m³ (gross)
- **LNG tank:** Vacuum-insulated double-wall pressurised tank IMO type C
Chemgas Barging has built an inland waterway conventional gas tanker (type G). This vessel, named Sirocco, is the first inland vessel with the LNG fuel tank below the deck within a cargo area, in a compartment protected by double hull and bottom. The vessel is equipped with a dual-fuel engine, running on LNG and diesel, in order to switch to diesel in case of problems with the LNG system or a lack of LNG bunker facilities. It is operational in the Amsterdam-Rotterdam-Antwerp region and on the Rhine. With a total cargo capacity of 2,620 m³, it is dedicated to transport common gases such as LPG, ammonia, vinyl chloride, isoprene, or propylene oxide.

**Dual-fuel propulsion** The Sirocco is equipped with a single 8L20DF Wärtsilä main engine capable of running on LNG as well as on marine gasoil. It has LNG-powered genset units from Sandfirden Technics as auxiliaries with straight marine gasoil backup auxiliary engine. In case of a failure in the gas supply, the main engine switches automatically and without interruption from gas to diesel. The engine room is designed and executed as a gas-safe machinery space. All gas piping, valves, reducers and connections use a double wall principle or are located within a gastight casing equipped with a gas detection system and provided with ventilation leading to a safe location on open deck.

The dual-fuel engine concept enables Sirocco to optimise LNG consumption to 99%. With LNG as a fuel, NOₓ particles and CO₂ emissions are substantially reduced showing the values similar to those from the test bed of Wärtsilä.

**LNG Fuel Tank** Sirocco is the first newly built inland tanker in which the LNG fuel tank is located below decks inside the cargo area. The LNG fuel tank is a cylindrical vacuum-insulated independent pressure
tank with a design pressure of 10 bars and a total volume of about 88 m³ of LNG. The advantages of such a tank are proven technology concerning crashworthiness, no sensitive connections below deck and access for inspection. All connections to the tank are located above deck at the dome. The tank space has a double bottom and double hull construction. In the event of a collision the shell absorbs more energy than a standard hull construction.

**Experience** Since November 2014, LNG fuelling has become a routine operation either in Moerdijk or Antwerp and the low working pressure of the LNG fuel tank on board of *Sirocco* makes a swift transfer possible. The cryogenic behaviour and insulation of the fuel tank is outstanding. During normal operation the noise level in the living quarters during gas mode is about 3 dB less than in diesel mode. Compared to a conventional diesel propulsion vessel *Sirocco* shows that the exhaust of soot particles is about zero. The deck and accommodation surfaces remain spot clean which is a remarkable difference. The special training and familiarisation program for the crew was a must due to new technologies on board and all involved parties are ready and happy to sail on *Sirocco*.

“Besides cost savings LNG propulsion brings silence and less exhaust emissions. As the LNG supply chain and logistics develop, the dual-fuel redundancy will become less important over the years.”

Arie van der Ven, Manager Maintenance & Projects

**Quick facts**

- **Size:** 110 x 11.40 m (L x W), Draught (max): 3.15 m
- **Propulsion:** Single 8L20DF Wärtsilä main engine capable of running on LNG and on marine gasoil
- **Bunker capacity (LNG):** 88 m³ (gross)
- **LNG tank:** Single wall independent vacuum-insulated pressure tank with design pressure of 10 bar
III. PILOT DEPLOYMENTS

LNG-fuelled type C tanker – EcoLiner

Damen Shipyards Hardinxveld has built the 100% gas-fuelled inland waterways type C tanker EcoLiner. EcoLiner is the first purely LNG-powered inland tanker to combine LNG-fuelling with electrical shaft-driven propulsion and steering gear instead of electrically driven rudder propellers. The vessel is built to sail on European waterways, in the ARA (Amsterdam-Rotterdam-Antwerp) region as well as on the river Rhine up to Basel.

Innovation The EcoLiner is the first vessel to feature the “ACES” (Air Chamber Energy Saving) air-lubricated hull. Air lubrication system (air chambers) fitted to the bottom of the hull reduces the wetted surface of the vessel which shall, according to executed calculations and tests with model and full-scale vessels, result on average to a 15% reduction in required power. Retractable Van der Velden FLEX® tunnels are installed to ensure sufficient water supply to propellers when sailing unloaded and to prevent increase of resistance when loaded. This innovation reduces the resistance by 15% on average. Thanks to all innovations contributing to the high efficiency, the two 26 m³ LNG tanks installed on the aft ship allow the EcoLiner to sail the distance from Rotterdam to Basel and back without refuelling.

Propulsion The EcoLiner is equipped with four generator sets which power both the propulsion trains and all other onboard systems via a comprehensive power management system. It uses four lean burn Scania SGI-16M gas engines of 285 kWe each. For redundancy and international regulation requirements two independent engine rooms are installed. The engine-generator sets and main switchboards are located in both engine rooms and can run independently from each other.

About the project owner
Damen Shipyards Hardinxveld is a member of the DAMEN Group. It is specialised in custom-built, small and medium-sized vessels and in general repairs and maintenance of all kind of waterways vessels.

✉️ Peter Baars, p.baars@damen.com
www.damenshipyardshardinxveld.nl

Scania SGI-16M gas engine

EcoLiner – visualisation

EcoLiner – first trip from the Romanian shipyard
LNG storage LNG is stored in two double-walled cryogenic tanks, each with a capacity of approximately 26 m³. The inner and outer tank are made of stainless steel. The inner space between the two tanks is under vacuum and they are connected in a way that heating through conduction is minimised. The holding time of LNG in the tanks is over 6 weeks.

No part of the LNG system enters the cargo area of the vessel. The aft ship is where the whole cryogenic LNG installation, double-walled LNG piping and generator power engines are installed in a gas-safe machinery area. The tanks are rigidly mounted outside on the aft deck, together with all the ancillaries required to convert the LNG into natural gas with ambient temperature and low pressure. The wheelhouse is also located on the aft ship. Midship (cargo area) and foreship are entirely similar to any conventional tanker. This configuration can be tailored according to customer-specific requirements for transporting any commodity.

“As a complete package this innovative development makes sure that the EcoLiner becomes an efficient 100% gas-propelled inland vessel. Fuel, power supply, power management, propulsion, hull shape and air lubrication – together they make the EcoLiner.”

Rob Schuurmans, Project Manager

Quick facts
- **Size**: 110 x 11.4 m (L x W), Draught (max): 3.4 m
- **Propulsion**: 4x Scania SGI-16M gas engines (285 kWe each, lean burn technology)
- **Bunker capacity (LNG)**: 2 x 26 m³
- **LNG tank**: Double-walled vacuum-insulated cryogenic tank
- **Specifics**: ACES (Air Chamber Energy Saving) air lubrication system; Van der Velden FLEX® tunnel to reduce the resistance in shallow waters
Masterplan
Strategy for wide-scale LNG deployment
The European Commission, in its Transport 2050 Strategy (COM [2011] 114 final), calls for breaking the oil dependence of transport and sets a target of 60% greenhouse gas emissions reduction from transport by 2050. Low-CO₂ alternatives to oil are indispensable for a gradual decarbonisation of transport towards the EU target of a 60% reduction of CO₂ emissions from transport by 2050. With its “Clean Power for Transport Package” and the Directive on the Deployment of Alternative Fuels Infrastructure, the European Commission aims to facilitate the development of a single market for alternative fuels for transport in Europe.

LNG for inland waterway transport

LNG is considered the most prospective option for inland water transport (TEN-T Regulation [EU] No 1315/2013, article 3, point w). A transition to LNG strongly supports innovation in the IWT sector which will result into additional gains in sustainability and efficiency of inland water transport, thus strengthening its attractiveness and competitiveness. From an overall perspective, the use of LNG results in:

• Reduction of operational costs for inland waterway transport due to fuel cost savings which reduce the total cost of ownership.

• Reduction of air pollutant emissions (CO₂ by up to 25%, NOₓ by up to 90% and PM reduced nearly to 100% comparing to diesel engines). Blending of liquefied BioGas (LBG) with conventional LNG adds a further CO₂ emissions reduction while at the same time the use of LBG contributes to the increase of the share of non-fossil (renewable) fuels.

• Creation of a new potential market for inland shipping transporting the LNG (or LBG) between main hubs and distribution points to refill LNG depots in the hinterland.

LNG Masterplan – strategy for deployment

Three aspects are critical for the successful uptake of LNG in the inland water transport sector defining the so called LNG Masterplan scenario and setting up the basis for the further elaboration of the strategy with the action plan:

• LNG market development outside Europe – lowering of costs for LNG equipment is essential for the success of the LNG market uptake. The European market, still quite small, does not create enough demand to offset R&D costs and other fixed costs,
e.g. for manufacturing engines and tanks. The access to other markets (USA, China) creates bigger demand, thus justifying the R&D costs. Vice-versa, the availability of more suppliers accessing the European market would knock down prices for LNG-related equipment.

- Price gap between LNG and diesel fuel – the attractiveness of the LNG business case depends, to a large extent, on the future fuel price development.
- Emission standards – a major impact is to be expected from more strict emission standards. In case of strict emission standards for all vessels and engines (existing and new) which can be met without additional investment into exhaust treatment, the roll-out potential for LNG is increasing.

As part of their activities in the LNG Masterplan project, the partners and invited stakeholders identified several barriers (weaknesses and threats) in the deployment of LNG in inland water transport. These were summarised and addressed in a comprehensive strategy listing actions and measures (pages 62–63) needed for the LNG uptake. The actions cover various aspects of LNG deployment such as (i) Governance and Legislation, (ii) Markets & Finances, (iii) Vessels & Equipment, (iv) LNG Infrastructure, (v) Jobs & Skills, and (vi) Awareness for LNG among general public and the decision makers.

The actions together with measures were validated by experts in three European expert roundtables and one dedicated strategy roundtable for ports. The strategy, as one of the main results of the project, will be widely disseminated at local, national and European levels. Necessary steps towards its implementation are being discussed with the decision and policy makers on the European and national levels.

Quick facts
A comprehensive strategy sets actions and measures needed for the wide-scale deployment of LNG in inland water transport in line with the European transport, energy and environmental policy objectives and addresses (i) Governance and Legislation, (ii) Markets & Finances, (iii) Vessels & Equipment, (iv) LNG infrastructure, (v) Jobs & Skills, and (vi) Awareness.

Manfred Seitz, seitz@prodanube.eu
**Masterplan: Actions and Measures**

### Governance & Legislation (1)

1. **Provide air emission limits in line with technological development on global perspective**
   - Develop long-term roadmap for air emissions of gas engines in cooperation with engine producers and vessel operators
   - Stimulate Research & Innovation in engine technologies with Horizon 2020 and CEF-Innovation
   - Provide comparable evidence on environmental performance of IWT and other modes based on real-life operations monitoring
   - Ensure enforcement of air emission regulation for levelled playing field

2. **Implement adjusted regulatory framework for the use of LNG as fuel for inland vessels**
   - Set into force amendments to the regulatory framework for the use of LNG as fuel for inland vessels (Revision of CCNR RVIR and of Directive 2006/87/EC)

3. **Provide standards/guidelines for mobile LNG fuel tanks on board of inland vessels**
   - Elaborate standards & guidelines for mobile LNG fuel tanks on board of inland vessels incl. their transfer & connection to LNG-fuelled inland vessels

4. **Provide amendments to ADN regulations**
   - Provide amendments to ADN regulations to include the use of LNG as fuel
   - Provide amendments to ADN regulations to include transportation of LNG in non-pressurised tanks
   - Provide interim solutions to facilitate smooth derogation procedure at ADN Safety Committee

5. **Harmonise port regulations on European level**
   - Provide guidelines on European level for LNG-related port operations in inland ports
   - Align port regulations for LNG bunkering with relevant (police) regulations

6. **Provide guidelines for more harmonised spatial planning of LNG bunker operations in inland/maritime ports**
   - Develop harmonised guidelines for land use planning for all bunker scenarios
   - Include external safety conditions and nautical conditions in spatial planning process for LNG bunker locations
   - Include LNG bunker suitability map in Port Bye Laws

### Governance & Legislation (2)

7. **Clarify and harmonise risk assessment**
   - Specify requirements for risk assessment of each bunker configuration and harmonise on the European level
   - Define emergency response scenarios for each bunker configuration according to risk assessment

8. **Support the industry to set rules and standards for LNG bunker stations and vessels**
   - Provide a European best practice guideline for permission of onshore/floating LNG bunker facilities
   - Provide European regulation for construction and operation of LNG bunker pontoon
   - Provide European regulation for construction and operation of LNG bunker vessel
   - Develop cross-national guidelines for permission/accreditation of LNG bunker vessel operators

9. **Ensure safe and efficient LNG bunkering and (un-)loading**
   - Elaborate harmonised bunkering standards and checklists for all bunker scenarios (STS, TTS, TPS)
   - Disseminate safety aspects of SIMOPS (passenger & cargo (un-)loading) concerning LNG bunkering to terminal operators and ensure adequate training of terminal personnel
   - Review European best practice guideline and specification of technical safety requirements for LNG (un-)loading
   - Develop technical standard for bunker coupling and ESD (emergency shutdown systems) connections
   - Develop technical standard for LNG transfer equipment connections

10. **Improve emergency response knowledge of local authorities**
    - Develop guidelines how to include emergency response procedures in the incident management systems of emergency response organisations

### Markets & Financing

1. **Provide user-oriented information on LNG market development and price**
   - Consolidate existing market intelligence into information services dedicated for IWT sector
   - Ensure user-friendly and transparent LNG price models

2. **Ensure fair and sustainable competition in LNG market**
   - Facilitate sufficient open access LNG infrastructure (import and break bulk terminals)
   - Ensure attractive taxation of LNG for road vehicles to support economies of scale

3. **Create economies of scale in LNG supply**
   - Set up LNG hubs in hinterland inland ports supplied by barge/rail through synergies with other LNG users (fuel & energy)
   - Reduce LNG supply chain costs by operational and technical innovations
   - Apply multi-client strategy for (hinterland) fuelling points by initiating and implementing projects along LNG value chain and across transport modes and energy customers

4. **Provide public support for vessel operators**
   - Optimise EU programmes to facilitate pilot as well as wide-scale deployment of LNG fuelled vessels
   - Support critical mass of newly built and retrofitted vessels as pilot projects in CEF Transport
   - Include LNG fleet investment into relevant Structural Fund programmes and other relevant EU programmes providing financial support to member states
   - Include LNG fleet investment as funding objective into National State Aid Schemes for Fleet Modernisation and other national financial support schemes
   - Provide financial incentives for LNG-fuelled vessels
   - Support barging sector in getting access/making use of existing and new financial instruments and support schemes

5. **Provide public support for LNG infrastructure build-up and extension**
   - Support critical mass of LNG onshore/floating infrastructure as pilot projects in CEF Transport
   - Provide funding for combined energy and transport fuel LNG projects in related EU programmes
   - Contribute to LNG base demand by investing in public vehicles/LNG-based energy demand
### Jobs & Skills

1. **Provide regulatory framework together with competencies required in handling of LNG in IWT for various personnel**
   - Provide inventory of required competencies together with education & training requirements as part of the EU-wide regulatory framework for (a) use of LNG as fuel on inland vessels, (b) transport of LNG as cargo on inland waterways, (c) LNG bunkering in IWT, (d) LNG terminal operations

2. **Facilitate EU-wide acceptance of education & training related to handling of LNG in IWT**
   - Create EU Knowledge Transfer Network that maintains and provides information on developments within the LNG supply chain with respect to education and training
   - Provide public funding for EU Knowledge Transfer Network
   - Further elaborate wide accepted curricula for various personnel along the LNG supply chain applicable for IWT sector
   - Promote curricula EU-wide among specialised education and training institutes
   - Facilitate further elaboration of education & training material through EU-funded projects involving main IWT education & training institutes

3. **Improve availability of and access to education & training**
   - Integrate LNG handling courses into traditional educational programmes
   - Offer further trainings for experienced personnel
   - Ensure sufficient LNG experts for education & training (“train the trainer”)

4. **Improve quality of LNG-related education through dedicated learning tools**
   - Provide public financial support for dedicated learning tools

5. **Ensure recognition & certification of E&T institutes**
   - Identify & decide on responsibilities and processes for the recognition and certification of E&T institutes

6. **Ensure capacity of emergency response**
   - Prepare emergency forces for emergency response to LNG incidents with ensuring appropriate training at well-equipped training facilities based on harmonised curricula

### Vessels & Equipment

1. **Minimise methane slip of engine and along LNG supply chain**
   - Reduce methane slip of engines through further R&I
   - Set achievable long-term objectives for the maximum methane slip to guide engine research
   - Develop and implement operational guidelines to avoid/minimise methane slip along entire IWT LNG supply chain

2. **Facilitate production & use of advanced gas engines**
   - Identify IWT specific operating conditions
   - Support development of new engine solutions
   - Develop attractive retrofitting solutions through engine replacement and recycling programmes for old engines
   - Create synergies with other markets (e.g. land-based gen-sets, truck engines) to motivate R&I investments
   - Initiate & implement lead technology project(s) for engine innovation (and support through public funding)

3. **Manage boil-off on inland vessels**
   - Support R&I for handling the boil-off

4. **Reduce bunkering time to comparable values with traditional fuels**
   - Investigate technical, operational and organisational solutions for quicker tank-fuelling addressing use of mobile bunker tanks and bunkering during navigation or (un-)loading

5. **Facilitate retrofitting of vessels**
   - Further develop technical solutions for retrofitting
   - Adapt TCO model for special needs of retrofitting

6. **Reduce unit costs of LNG equipment**
   - Stimulate R&I for cost-effective solutions as result of standardisation, modularisation and mass production
   - Initiate cooperation and harmonisation with other IWT countries and markets making use of synergy effects
   - Set up LNG technology platform for IWT for targeted innovation to reduce TOC and to improve environmental performance
   - Set up EU-funded lead project to achieve cost savings of main LNG components

7. **Initiate continuous research on required safety levels for LNG equipment & operations**
   - Investigate options for establishment/adoption of regulation that allow reduction of costs with keeping the same safety levels/standards than other fuels, cargoes or procedures
   - Carry out technical trials, HAZID studies, stress-tests of equipment

### Infrastructure

1. **Facilitate sufficient LNG-fuelling infrastructure**
   - Ensure timely implementation of Directive 2014/94/EC and its enforcement
   - Provide adequate locations for fuelling infrastructure and facilitate LNG investment in maritime and inland ports
   - Ensure efficient and fast admission/permitting processes for LNG infrastructure deployment
   - Create a (harmonised) regulatory framework for efficient environmental permitting procedures that also leaves room for innovation

2. **Provide infrastructure for intermodal LNG logistics**
   - Extend LNG infrastructure at import terminals to facilities for vessels/rail & truck loading
   - Provide public funding for terminal investment to enable/enlarge break bulk facilities

### Awareness

1. **Increase awareness on socio-economic and environmental benefits of LNG**
   - Define and execute public information campaign on socio-economic and environmental benefits of LNG

2. **Inform on safety requirements and standards for LNG infrastructure and operations**
   - Create and regularly update knowledge basis and disseminate to relevant stakeholders
   - Foster exchange of real-life experiences

3. **Ensure implementation of Action Plan of LNG Masterplan**
   - Create organisational structure to coordinate implementation of LNG Masterplan and implement measures

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**IV. MASTERPLAN**

LNG Masterplan for Rhine-Main-Danube
Project deliverables
Project deliverables

This overview provides a summary of project deliverables, most of them being public and published on www.lngmasterplan.eu.

Framework & Market Analysis
- Status quo and trend analysis
- LNG supply chain analysis and assessment of supply options for the Danube and Rhine corridor
- LNG demand analysis for the Danube and Rhine corridor
- Impact analysis of LNG as fuel and cargo for inland navigation: safety, ecology and socio-economic aspects

Technologies & Operational Concepts
Technologies
- Report on engine types and configuration options available and under development
- Report on fuel quality requirements and optimised energy management
- Report on impact of engine technologies on future targets for emission reduction
- Recommendations and implementation guidelines for the use of LNG in road transport
- Report on current fuel tank systems and related equipment technologies including outlook on promising developments as well as recommendations for further RTD and technical trials
- Report on current onshore and onboard based LNG storage tanks solutions and related equipment technologies

Operational concepts and safety studies
- LNG bunkering and LNG (un-)loading: regulatory framework, scenarios and procedures, standardised installations for (un-)loading
- Safety studies: operational safety and nautical conditions, risk comparison of different LNG bunker scenarios, comparison of risk assessment tools
- LNG emergency and incident response study and guidelines
- Case study Port of Rotterdam
- Case study Port of Switzerland

Terminal & Vessel Solutions
Terminal solutions
- Technical concept for LNG bunker station in the Port of Antwerp
- Technical concept for LNG terminal in Ruse, Bulgaria
- Case study for LNG infrastructure in the Port of Mannheim
- Case study for LNG infrastructure in the Port of Switzerland
- Pre-feasibility study and preliminary design for LNG terminal in the Port of Constanta
- Pre-feasibility study for LNG terminal in Galati, Romania
- Case study and preliminary design for LNG terminal in Komarna, Slovakia

Vessel solutions
- Database and analysis on technical vessel concepts and solutions for newly built and retrofitted vessels
- Technical concept for LNG-fuelled type C tanker EcoLiner (Damen)
- Technical concept for LNG/Gasoil bunker vessel (Argos Bunkering)
- Technical concept for LNG-fuelled inland push boat (Kooiman Marine)
- Technical concept for LNG-fuelled inland tankers (LNG E-Motion)
- Technical concept for Danube river-sea LNG tanker (Danube LNG)
- Technical concept for river barge (type EUROPA II) to transport LNG (Danube LNG)
- Technical concept for river multi-purpose floating pier for reloading LNG, LNG bunkering and disposal of waste (Danube LNG)
- Technical concept for LNG-fuelled Gas Supply Vessel (Beghert Schulte)
- Technical concept for LNG-fuelled retrofitted container vessel Eiger (Damen Barge)
- Technical concept and economic evaluation for retrofitting of actual fleet of pushers of SPaP a.s. (Danube LNG)

Other vehicles & installations
- Economic, technical and environmental impact of use of alternative fuels, including LNG, and driving technologies for cargo handling equipment in the Port of Antwerp

Financing models for terminal infrastructure & vessel investments
- Analysis of legal, regulatory and contractual impact on LNG supply chain including legal assistance
- Guidelines and recommendations for structuring finance of LNG terminal projects
- Generic financial models for LNG-related infrastructure investments
- Total Costs of Ownership (TCO) – decision support tool for the transition towards LNG-fuelled inland vessels
- Booklet “Financing LNG-related Infrastructure Investments”
- Booklet “Legal and Regulatory Road Map”

Regulatory Framework & Masterplan
Provisions for harmonised European regulations
- Guidelines and recommendations on LNG bunkering regulations
- Guidelines and recommendations on port regulations
- Guidelines and recommendations on police regulations

Training & Education Requirements
- Curricula & lessons material for inland vessels crew for use of LNG as a fuel
- Curricula & lessons material for inland vessels crew for use of LNG as a cargo
- Curricula & lessons material for bunkering personnel and staff
- Curricula & lessons material for terminal personnel and staff
- Curricula & lessons material for inspectors from competent authorities and for company personnel and staff
- Curricula & lessons material for students focusing on logistics
- Pilot simulations, e-learning and practical training tools
- Pilot classes for all staff categories

Masterplan (Strategy & Recommendations)
- MASTERPLAN: Strategy & Recommendations for deployment of LNG in inland waterway transport

Pilot Deployments
LNG terminals & onshore infrastructure
- Small-scale LNG terminal in Ruse in Bulgaria (Bulmarket)

LNG vessels & other vehicles
- LNG-fuelled retrofitted container vessel Eiger (Danser Group)
- LNG-fuelled type G tanker Sirocco (Chemgas Barging)
- LNG-fuelled type C tanker EcoLiner (Damen)
- LNG-fuelled trucks (Bulmarket)
### Beneficiaries (project partners)

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<th>Logistikum</th>
<th>Port of Antwerp</th>
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Rhine/Meuse-Main-Danube: LNG ARTERY FOR EUROPE

Inland navigation functions as pioneer consumer and facilitator

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LNG Masterplan Infrastructure & Vehicles

- LNG-fuelled vessel
- LNG carrier/bunker vessel
- LNG carrier
- LNG terminal
- LNG bunker facility for vessels
- LNG truck-fuelling station

Other LNG Infrastructure
(relevant for Rhine-Main-Danube axis)

- existing/planned