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CNG – a New Way of Maritime Natural Gas Supplies

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Among other conventional energy sources, on the present level of technology development, natural gas is a primary energy source, which has the lowest level of harmful substances emission both for humans and the environment. Comparing to coal – in the burning process of the natural gas there is a very low emission of pollutants: trace amounts of sulphur and carbon dioxide, which established natural gas' position as an environmentally friendly fuel. CO_2 emission expressed in CO_2 kg/kWh of fuel during burning process of lignite amounts to 0.40; of hard coal – 0.33; of heavy fuel oil – 0.28; of light fuel oil – 0.26 and 0.20 of gas.

The use of natural gas as a fuel instead of other kinds of fossil fuels, e.g.: coal, results in decreasing harmful substances emission. Therefore, CO_2 emission or sulphur dioxide emission is much smaller. What's more, lower CO_2 emission means decreasing the greenhouse effect and lower sulphur dioxide emission reduces the amount of acid rains.

Natural gas system is different than networks, such as water supply, heat or electricity in such way that, in Poland it is necessary to acquire most of the distributed medium from the sources located outside Polish borders.

A basic problem of gas supplies for Polish recipients is that the resources of this raw material that are located in Poland are not able to fulfil the existing demand. Therefore, it is necessary to import natural gas.

Major suppliers of natural gas that is transferred via pipelines for European recipients are Russia and Norway. Natural gas may be also transported in a liquefied form (LNG – Liquefied Natural Gas). In order to liquefy natural gas, it has to be cooled down to the temperature below -160ºC (the temperature for liquefying methane amounts to -161ºC[1]). Volume of the liquefied gas decreases by around 600 times. These properties enable LNG transport by sea, which is economically favourable on long distances. The biggest LNG supplies for Europe are provided by Algeria and Qatar. Other LNG suppliers, which are quite significant for Europe are Nigeria, Egypt and Trinidad and Tobago. Natural Gas in form of LNG is delivered , among others, to unloading terminals, as presented in Fig. 1.

Natural gas supplies may be delivered by pipelines (gas pipelines) or by sea (ships delivering LNG, CNG[2]); it depends on the available gas infrastructure, how big the target market is, what is the distance from the gas source, etc. In case of LNG/CNG supplies on a small scale, it is possible to use rail transport or road transport. Fig. 2 presents schemes of the main methods of natural gas deliveries for the traditional way of natural gas deliveries and for the sea transport.

Advantages of LNG and CNG deliveries by sea:

- political and economic independence from suppliers – there are many potential suppliers,
- introducing a new supply source – more flexibility in gas flow management regarding existing entry points,
- ability to trade gas on the global markets, which creates additional income sources,
- new customers,
- ability of arbitration on international markets,
- ability of fast supplies complementing in case of gas shortage in the system,
- more flexibility in negotiations with current suppliers.

[1] Source: Molenda Jacek "*Gaz Ziemny"*
[2] CNG – Compressed Natural Gas

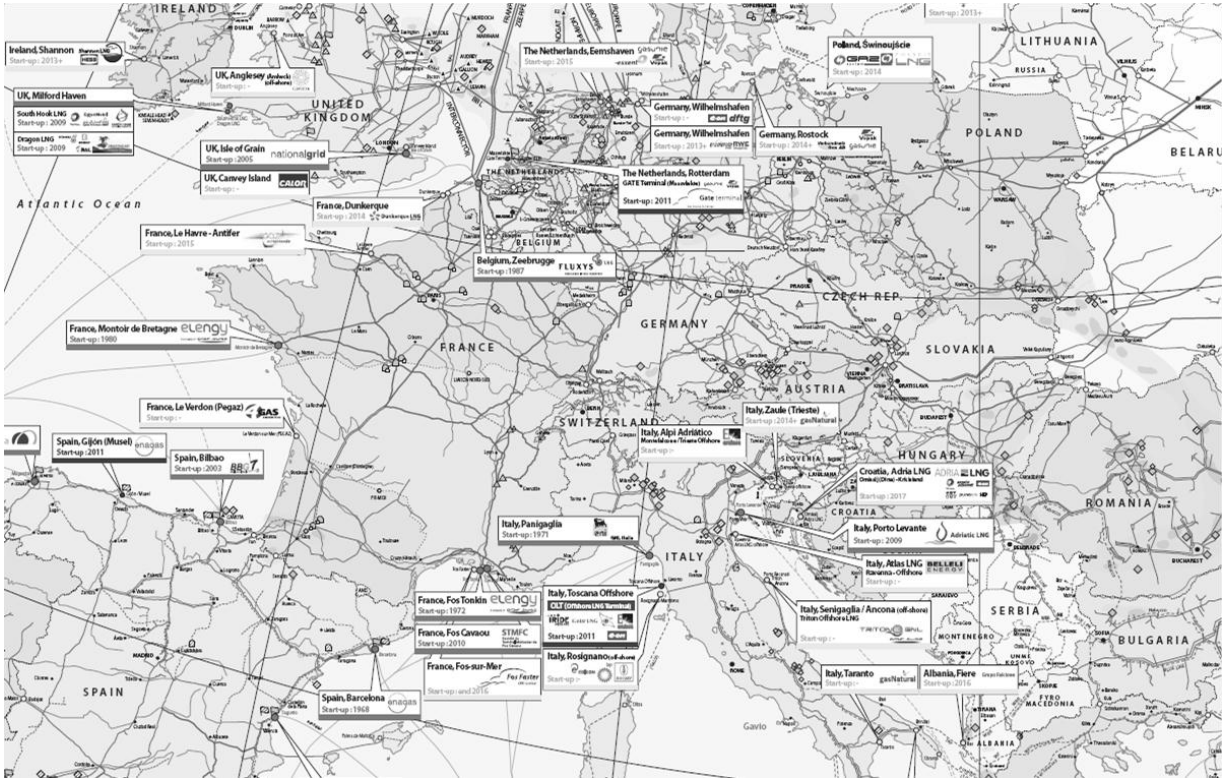


Fig. 1. Fragment of the European gas transmition system and LNG terminals (source: Gas Infrastructure Europe)
Rys. 1. Fragment europejskiego systemu gazociągów przesyłowych oraz terminale LNG (źródło: Gas Infrastructure Europe)

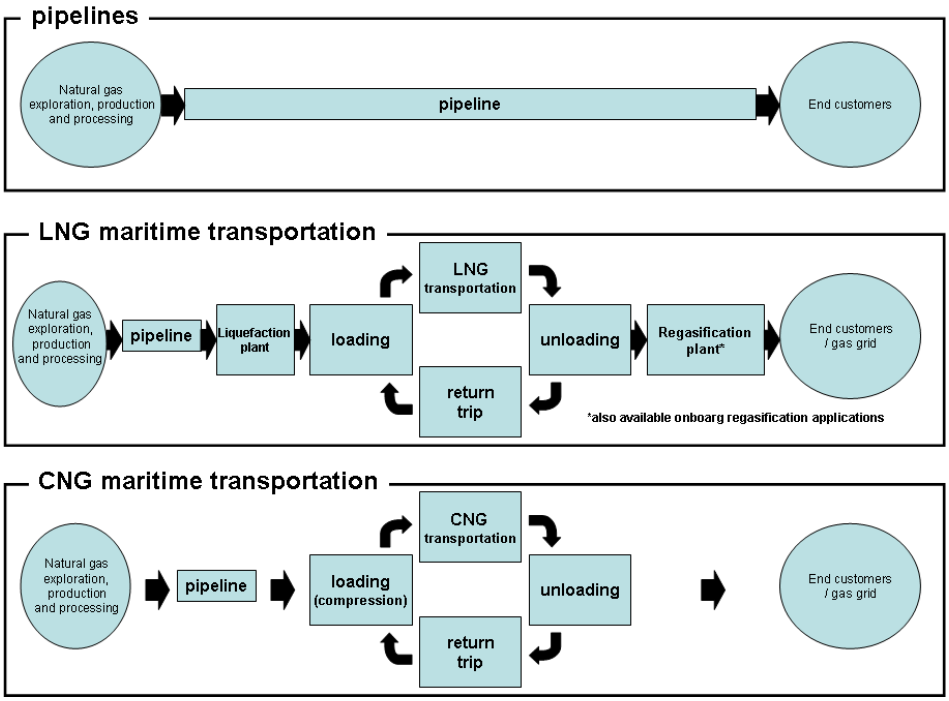


Fig.2. Schemes of different natural gas delivery possibilities (own source)
Rys. 2. Schematy różnych możliwości dostaw gazu ziemnego (opracowanie własne)

Natural Gas Company has a wide experience in scope of implementing supplies of natural gas using pipelines and sea deliveries of LNG. What's more, there is a lot of detailed information regarding this topic in specialist literature. However, technologies concerning CNG supplies by sea are less known. We don't have much experience in this field, as the gas market still awaits for such project to be implemented. Further in this article, more information concerning new way of gas supplies is presented.

CNG abbreviation stands for Compressed Natural Gas. Compressed natural gas (CNG) is used mainly in road transport (trucks, busses), where it is used instead of petrol, fuel oil or liquefied petroleum gas (LPG). CNG can also be used as a mean of providing extra natural gas supplies using sea transport.

Sea transport of CNG is a technology that enables natural gas supplies using special ships. Transportation system is prepared for shipping gas of even 250 bar (depending on the technology), usually in the ambient temperature. Solutions that are currently available, involve compressing gas into special modules consisting of separate containers (except for the solution of the SeaNG Company – system of modules consisting of high-pressure pipes wrapped around a special frame) adjusted for keeping the right gas pressure. CNG ships may be loaded and unloaded both when mooring at the jetty using high-pressure hoses and using loading/unloading buoys located away from the shore. There are CNG transport technologies available, which have classificatory certificates issued by acknowledged classification societies confirming ability to execute and employ such transportation systems.

Most of all, CNG technology is meant for gas transport from sources such as:

- Stranded Gas – deposits, which have medium or low reserves of natural gas – starting a traditional production is hindered for economic or operational reasons,
- Mature Areas – deposits, which have been exploited but further exploitation in a traditional way became unprofitable,
- Associated Gas – oil production associated gas management.

CNG transport is economically justified on routes up to 2000 nautical miles[3]. Over 2000 nautical miles, it is much more efficient to transport LNG. However, it doesn't exclude CNG e.g.: in case of competitive natural gas purchase prices in the FOB (loading point).

Fundamental advantage of CNG supplies is that costs regarding loading/unloading infrastructure are relatively small. Nonetheless, the highest capital cost is connected with CNG shipping fleet (around 80%)[4]. Other elements of the delivery chain connected with natural gas production and processing as well as gas distribution to final users are identical with other methods of natural gas delivery.

Potential use of CNG technology includes, for example: projects for which, due to their characteristic, launching pipeline deliveries or

[3] according to companies working on such technologies
[4] according to companies working on such technologies

liquefied natural gas (LNG) deliveries is not profitable. This type of delivery isn't, however, competitive for neither pipeline supplies nor LNG supplies. It is a complementary form of deliveries, which also gives the opportunity to reinforce diversification of gas supplies (additional delivery route, additional sources).

Below, an overview of solutions enabling natural gas transport in the form of CNG is presented. Solutions that are mentioned are at the moment just conceptual and attached pictures of ships present how the CNG ships may look like using different technologies.

CNG transport systems solutions suppliers[5]

CNG transport technologies by sea are compiled mainly by the following companies.

- Knutsen OAS Shipping – PNG™ – Norway,
- SeaNG – Coselle™ – Canada,
- EnerSea – VOTRANS™ – USA,
- Ocean Trans Gas – Canada,
- TransCanada – GTM™ – Canada,
- CeTech – Norway.

Estimated gas volume, which can be transported at once usually doesn't exceed 5 to 20 mln nm^3 of natural gas. The amount depends on the size of a ship and chosen technology. It is possible to use an existing ship and convert it (CNG transport system installation). In this case, ship's capacity would depend on the size of its hull and on the chosen CNG transport system.

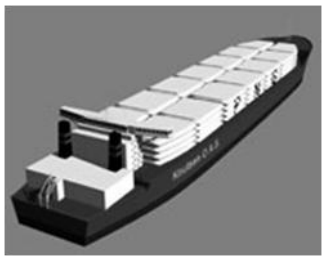
KNUTSEN OAS Shipping

According to a system of the Knutsen company gas would be transported in steel containers under pressure of 250 bar in ambient temperature. Containers are gathered in special modules that are placed on the ship.

[5] Source: Marine CNG Transport and Development conference, London 2010

Basic parameters:

KNUTSEN – PNG™	
Gas pressure [bar]	250
Transport temperature	ambient
Material of containers	Modified steel X80

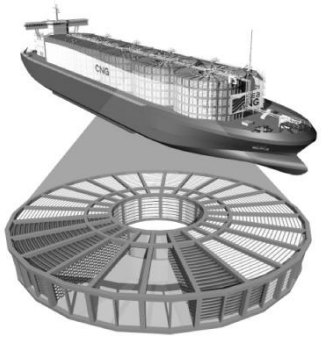


SeaNG

According to a Coselle™ system of a Canadian company SeaNG, gas transportation would be in steel modules. Each model is made of a proper steel pipe wound up around a special coil. Shipping capacity of ships with Coselle™ system is increased by adding more modules.

Basic parameters:

SeaNG – Coselle™	
Gas pressure [bar]	250
Transport temperature	ambient
Material of containers	Modified steel X70



EnerSea

Votrans system of the EnerSea Company enables natural gas transport in vertical and horizontal containers made of steel.

Basic parameters:

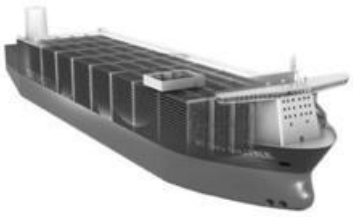
EnerSea – VOTRANS™	
Gas pressure [bar]	120
Transport temperature [^{o}C]	- 30
Material of containers	Modified steel X80 / X70

CETech

CE Tech technology enables natural gas transport in horizontal containers made of steel.

Basic parameters:

CETech	
Gas pressure [bar]	250
Transport temperature	ambient
Material of containers	Modified steel X80

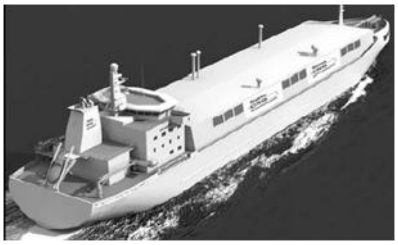


Trans Canada

GTM™ technology enables natural gas transportation in horizontal containers made of composite materials. In carrying out this transportation system materials such as, modified X80 steel, glass fibres, special resins are used.

Basic parameters:

Trans Canada GTM™	
Gas pressure [bar]	250
Transport temperature	ambient
Material of containers	composite



Trans Ocean Gas

GTM™ technology enables natural gas transportation in vertical and horizontal containers made of composite materials without steel. In carrying out this transportation system materials such as, HDPV, glass fibres, special resins are used.

Basic parameters:

Trans Ocean Gas	
Gas pressure[bar]	250
Transport temperature	ambient
Material of containers	composite

For both, loading and unloading CNG ship it is possible to use two methods:

Loading/unloading at the jetty (Fig. 3)

In this case, the ship moors by the jetty and, using elastic high-pressure hoses, gas is transferred onto the ship or to the CNG receiving point.

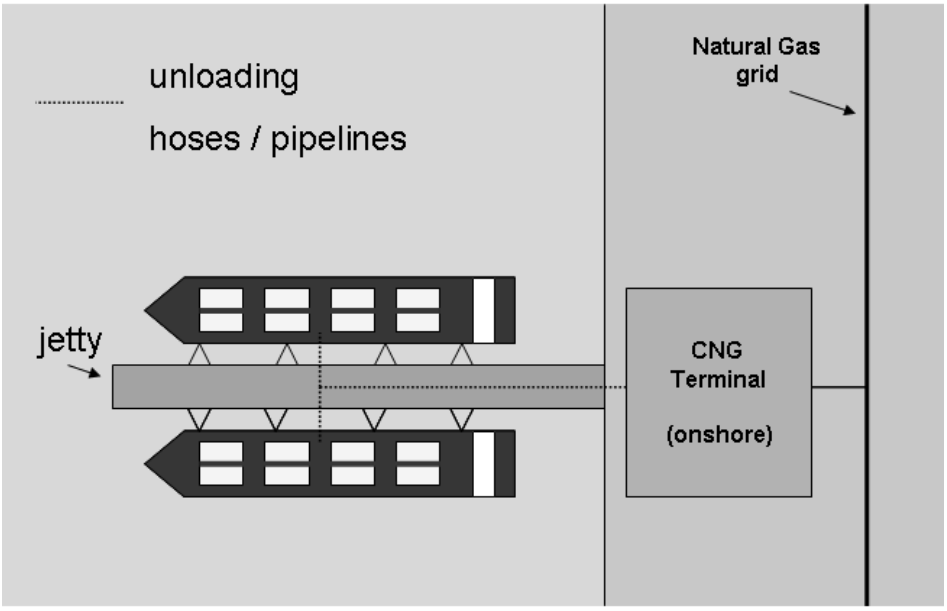


Fig. 3. Exemplary scheme of unloading CNG tanker at the jetty – own source
Rys. 3. Przykładowy schemat rozładunku tankowców CNG przy nabrzeżu (pirsie) – opracowanie własne

Loading/unloading using floating buoys (Fig. 4)

It is a system that doesn't require a jetty. Gas transfer is possible thanks to connection with an unloading buoy (or tower) located in a certain distance from the shore. The ship has to approach the buoy and after being connected to it (many connection possibilities depending on the system) loads/unloads the gas. The buoy is connected with an underwater pipeline with the land-based part of the CNG terminal. Direct connection system of a CNG ship and a buoy depends on the chosen solution. Buoys can be either floating on the surface of water connected to the ship by high-pressure elastic pipes or underwater, connected with the ship directly by entering a special "nest" (connection system) located on the hull.

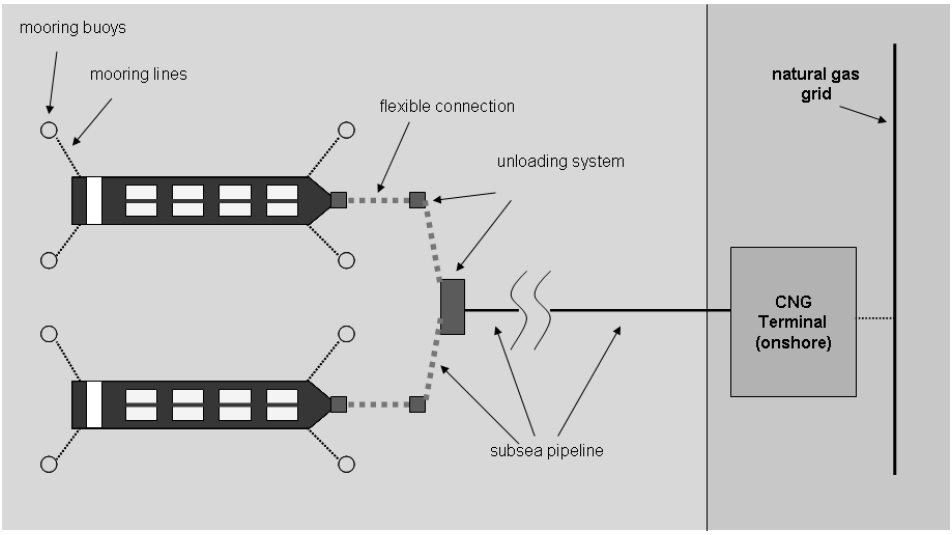


Fig. 4. Exemplary scheme of unloading CNG tanker at the open sea – own source
Rys. 4. Przykładowy schemat rozładunku tankowców CNG na otwartym zbiorniku wodnym – opracowanie własne

Among the elements, which had an influence on the development of CNG sea transport supplies technology were: development of materials enabling construction of high-pressure containers (including high-quality steel), development of shipyard industry and accessibility to

high-pressure transfer systems (including e.g. different kinds of buoys). All the above mentioned elements in connection with CNG transporting systems gave the opportunity to work out ships constructions, which are approved by the acknowledged classificatory companies. Nonetheless, this sector of the natural gas market still awaits it first commercial project for natural gas supplies by CNG ships, which will successfully combine the available technology with commercial aspects of such natural gas supplies.

Thanks to its properties, e.g. low emission level during burning process, natural gas will play a more and more significant role comparing to other primary energy sources. It will possibly increase the economy's dependence on this sort of fuel. Therefore, it will lead to a greater pressure for providing the safety of permanent supplies of this raw material, which will result in necessity of finding new sources of natural gas and providing diversified ways of supply. This will undoubtedly increase the potential of a new way of natural gas supplies, i.e. maritime transportation of CNG.

CNG – nowy sposób morskich dostaw gazu ziemnego

Streszczenie

Zastosowanie gazu ziemnego jako paliwa w miejsce innych rodzajów paliw kopalnych, takich jak, np. węgiel, przynosi efekt w postaci ograniczenia emisji szkodliwych substancji do atmosfery. Zmniejszeniu ulega bowiem, między innymi, emisja dwutlenku węgla, dwutlenku siarki. Zmniejszanie wielkości emisji dwutlenku węgla do atmosfery wpływa na obniżenie skali zjawiska cieplarnianego. Natomiast zmniejszenie emisji dwutlenku siarki skutkuje redukcją ilości kwaśnych deszczy

Podstawowym problemem zaopatrzenia w gaz ziemny odbiorców w Polsce jest to, że zasoby tego surowca energetycznego zlokalizowane na terenie naszego kraju nie są w stanie zaspokoić istniejących zapotrzebowań. Koniczne jest więc importowanie gazu ziemnego.

Dostawy gazu ziemnego, w zależności od dostępnej infrastruktury gazowej, wielkości danego rynku zbytu, odległości od źródła gazu oraz innych uwarunkowań, mogą być realizowane z wykorzystaniem rurociągów (gazocią-

gów) lub też drogą morską (statki dostarczające LNG z ang. Liquefied Natural Gas, statki dostarczające CNG z ang. Compressed Natural Gas).

Podstawową zaletą łańcucha dostaw CNG są stosunkowo niewielkie nakłady związane z infrastrukturą załadunkową i rozładunkową. Niemniej największym nakładem kapitałowym jest flota statków CNG (około 80%). Inne elementy łańcucha dostaw związane z wydobyciem i obróbką gazu ziemnego jak również z rozprowadzeniem gazu do odbiorców końcowych gazociągami są tożsame z innymi sposobami dostaw gazu ziemnego.

W pracy przedstawiono przegląd proponowanych rozwiązań umożliwiających transport morski gazu ziemnego w postaci CNG. Przedstawione rozwiązania to w chwili obecnej koncepcje, a załączone rysunki statków przedstawiają możliwy wygląd statków CNG z zastosowaniem różnych technologii.