LNG as an alternative fuel: the steps towards European implementation

L. Simmer, G. Aschauer, O. Schauer & S. Pfoser
Logistikum – the center for logistics competence, University of Applied Sciences Upper Austria, Austria

Abstract

In the current discussion about alternative energy supply and strategies in Europe, Liquefied Natural Gas (LNG) comes to the fore. Today the LNG share in global gas trading is at about 30%, in Europe at only 15.5%. Most notably LNG is used in industry and pipeline feeding. For the use of LNG as fuel, which could reduce the dependence on oil, there are currently only limited supply options for end users. The infrastructure is still in a developing stage.

The aim of this work is a detailed analysis and assessment of the developments around the implementation and applications of LNG. With specific focus, the potential of LNG as an alternative fuel for vehicle fleets and ships is being investigated. For this purpose, extensive literature research was carried out as the first step.

There is an impressive amount of work and projects that aim to break through these barriers and to implement LNG as alternative energy and fuel source. Currently in Europe there are about 40 LNG filling stations, which supply about 200 trucks and buses. Due to stringent emissions requirements, the LNG-powered ship market has grown in the last decade. About 20 ships are already in transit on the coast of Norway. For inland vessels, LNG as a fuel in Europe is still banned, but nevertheless there are currently two barges operating with a certificate of exemption between Basel and Rotterdam. The results of this paper should point to the problem areas as well as the potentials for LNG as a fuel and make a significant contribution towards further implementation steps.

Keywords: Liquefied Natural Gas, LNG, energy supply, alternative fuel.

WIT Transactions on Ecology and The Environment, Vol 186, © 2014 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/ESUS140791

1 Introduction

An already several decades old but for some years now rapidly expanding technology in the use of natural gas is the liquefaction of natural gas. This liquid form of gas results of the cooling to about -162°C at ambient pressure conditions and shrinks the volume of the gas 600 times (Kumar *et al.* [1]).

Internationally, there is already diverse and extensive experience in dealing with LNG. Today the LNG share in the global gas trading is at about 30%, in Europe at 15.5% (BP [2]). In the EU, mainly the countries of Spain, Britain, Italy and France are established in the LNG business. Once LNG has arrived at the LNG import terminal, the liquid natural gas is usually regasified to normal natural gas and fed into the gas grids. Currently so called "small scale" LNG projects getting into focus. These include small liquefaction plants, the LNG transshipment of large vessels to smaller vessels and trucks, the storage of LNG in satellite stations and the use of LNG as a fuel (Natural Gas Europe [3], Nogueras [4], PwC [5]). In contrast to the large scale LNG market the small scale LNG market is still new. Thus, there are limited LNG supply options for end users and as LNG is very cold and a different type of fuel than oil, adoption in the transport sector requires the set-up of a new infrastructure and the development of LNG based vehicles. The consequence of a new market is that there is a lot of uncertainty in the start-up phase and pioneers face various hurdles (PwC [5]). Although some obstacles must be overcome in order to establish LNG as a fuel in Europe, LNG has some advantages. As the European transport-sector has a 96% oil dependence and transport accounts for around a third of final energy consumption and for more than a fifth of EU greenhouse gas emissions in 2011 (EEA [6], Eurostat [7]), drivers for the use of LNG as fuel are on the one hand, the independence of oil and lower fuel costs; on the other hand LNG wins importance by increasingly stringent emission regulations. This applies both to the waterway transport as well as for the heavy traffic sector. Compared to diesel the use of LNG reduces SO_x emissions and particulate matter by almost 100%, NO_x emissions by 80–90% and CO_2 emissions by almost 20% (Kumar *et al.* [1], Baumann *et al.* [8]). For this reason there is an impressive set of projects to break through the mentioned barriers.

The aim of this work is a detailed analysis and assessment of the developments around the implementation and applications of LNG. With specific focus, the potential of LNG as an alternative fuel for vehicle fleets and ships is being investigated. For this purpose an extensive literature research was carried out in a first step.

2 Results and discussion

2.1 Emission regulation

One of the main factors for why LNG is in the discussion as an alternative fuel is the increasingly stringent emission regulations. This applies both to road transport as well as waterway transport.

2.1.1 Road transport

The Directive 2005/78/EC for heavy-duty vehicles specifies the Euro V emission standards, which contain the following emission limits: 2 g/kWh NO_x, 0.46 g/kWh HC, 1.5 g/kWh CO and 0.02 g/kWh PM (Lindqvist [9], Schweighofer and Seiwerth [10]). In 2009, the most recent legislation (595/2009) was adopted. This Directive lays down the Euro VI standards to be applied from January 2014 for all new trucks. These stricter regulations (0.4 g/kWh NO_x, 0.01 g/kWh PM) should lead to a reduction of 80% NO_x and 66% PM compared to Euro V limits. The emission limits for hydrocarbons (HC) are also set to 0.13 g/kWh (Lindqvist [9]). To comply with this legislation, more complex and complicated (and therefore also more expensive) filtering techniques are becoming necessary. With the use of LNG as fuel, a simple three-way catalyst or a diesel particulate filter and a selective catalytic reduction are sufficient to achieve emission standards (Deal [11]).

2.1.2 Waterway transport

The International Maritime Organization (IMO) regulates emission with the "International Convention for the Prevention of Pollution from Ships" (known as MARPOL 73/78). There are general maximum global emission limits and significantly stricter emission limits in certain areas, commonly referred as Emission Control Areas (ECA). Recently the MARPOL Convention has been modified with Annex VI "Regulations for the Prevention of Air Pollution from Ships". This appendix contains limit values for NO_x and SO_x emissions, which gradually come into force over the next few years. Concretely, those regulations stipulate a reduction of the sulfur content in marine fuels from 1% to 0.1% from the year 2015 in ECAs. For new ships also stricter rules for NO_x emissions apply from the year 2016 in ECAs. Therefore NO_x emissions should be reduced to 3.4 and 2 g NO_x/kWh, depending on the engine speed. In addition, either in 2020 or 2025 the global limits on sulfur will be reduced from the current 3.5% to 0.5% (Semolinos *et al.* [12], GLE [13], Nyhus [14]).

With the European Directive 2012/32/EU, dated 21 November 2012, which is aligned with the IMO Annex VI, there is no possibility in Europe to move the 0.5% sulfur limit on post 2020 (Semolinos *et al.* [12]). In addition, it is currently under discussion to introduce the stringent requirements of ECAs in all EU waters (Nyhus [14]).

With the Directive 2009/30/EC the maximum sulfur content of all inland navigation fuels may be only 10 ppm since 2011 (Schweighofer [15]). For inland navigation engines currently apply the Directive 2004/26/EC standards. These emission limits have been defined with 5 g/kWh CO, 7.2 to 11 g/kWh NO_x and HC and between 0.2 and 0.5 g/kWh PM, depending on the size of the cylinder and the cylinder capacity (European Commission [16]). By 2016, these limits should be tightened again (Pauli and Schweighofer [17]).

2.2 Fuel price

The LNG price lies at the core of the economic discussion on the use of LNG as fuel and within the EU there are large price differentials. This results on the one hand by the difference between oil-linked long-term contracts and hub-based contracts and on the other hand of the nonexistence of a uniform global gas market. In the first four months of 2013 the average monthly wholesale price was between 25 and 35 €/mWh. Great Britain, Spain and Belgium pay lower prices for LNG as Italy, France and Greece. Portugal prices are volatile, but are usually more in the lower price group (European Commission [18]).

From an end user's perspective, it is not the level of the LNG price which is the most important driver but the price relative to alternatives, i.e. diesel for truck owners or marine gas oil (MGO) or heavy fuel oil (HFO) for ships (PwC [5]).

The LNG price to end users includes the infrastructure cost of the LNG refuelling system, the distribution cost of LNG, and the cost of the refuelling operation. The current lack of LNG bunkering infrastructure and supply chain networks presents an uncertain picture for the LNG fuel price (Wang and Notteboom [19]), but compared with Middle Distillates (Diesel and Gasoil) LNG is attractive. With expected higher demand for these products post 2015 after the new legislation comes into force, the price differential could stay or even improve, again this also depends on the development of global LNG markets in the second half of this decade. As it is hard to bring widely supported forecasts on the future energy prices, certain suppliers offer LNG contracts to fleet and ship owners with a price linked to the price of diesel guaranteeing a fixed price advantage. With a maturity of up to five years, these contracts hedge the price risk for the end users, which is a major advantage as it reduces the risk of an investment in LNG. But also the level of fuel taxes is one of the drivers of the uptake of small scale LNG (PwC [5]).

2.3 LNG as fuel for heavy transport

In 2010 more than a billion vehicles were on the road worldwide (Sousanis [20]). Approximately 18 million of these were operated with natural gas, mostly in Argentina, Brazil, Iran and Pakistan (Garthwaite [21]). In the course of this the use of LNG as a fuel for heavy vehicles is becoming increasingly common. Nevertheless, the lack of infrastructure is still the biggest challenge for the spread of LNG as fuel. There are about 40 gas stations in Europe which supply approximately 200 vehicles with LNG (Lage [22]). Besides the lack of gas stations, low acceptance or ignorance of consumers and the high price of vehicles preclude a large scale introduction (Amt für Veröffentlichungen [23]). However, the cost of a truck could be reduced with a roll-out of infrastructure and acceptance of LNG as the preferred fuel. Currently, a new LNG truck is still around 45,000–55,000 € more expensive compared with a diesel truck. These additional costs are explained by higher material costs, higher security requirements and a low production number. Retrofitting a diesel truck costs at least 15,000–20,000 €, mainly due to the expensive LNG tank (PwC [5]).

Despite expensive investment costs LNG offers several advantages as a fuel. The two most important are the outstanding potential regarding fuel costs and environmental friendliness (Schmidt [24], Chrz and Emmer [25]). A disadvantage of LNG is among other things the need for a fairly consistent vehicle use because the LNG in the tank is getting warmer despite insulation. Thus a part of the LNG vaporizes and the pressure in the tank increases. If this pressure is not reduced (through driving the vehicle), it reaches a level which opens the first relief valve to discharge a part of the steam from the tank. The time interval between the LNG refuelling and tank venting is referred as holding time. Typical holding times are about a week when the vehicle is not driven (ANGA [26]). Operating distance of diesel trucks are at about 1,900 km that of LNG trucks between 600 and 1,000 km. Thereby LNG vehicles must be refuelled more often (Willms [27], PwC [5]). Due to currently limited availability of LNG infrastructure, additional kilometres may apply to go to the gas station (PwC [5]). There should also be standards for refuelling couplings in order to fill up all LNG vehicles (ANGA [26]), because on the one hand the company Chart offers a single tube with a working pressure of seven to ten bar for filling, on the other hand, for example, the company Indox provide a double hose with a working pressure of 18 bar. This complicates the possibility to develop a harmonized network of LNG filling stations (Lage [22]).

2.3.1 Projects and pilot applications

Despite many barriers there are successful pilot applications in Europe. One is the use of LNG in the municipal transport buses from Krakow. The problem of exhaust gas emissions is especially acute in Krakow. To enable an improvement in living standards, the VTC (Vehicle Transport Company) has purchased 15 articulated buses SM18 LNG and 16 standard buses SM12 LNG. The buses were supplied by the Polish company Solbus and equipped with Cummins engines from the USA. The construction of the LNG fuelling station was built by the company KRI SA (Cebrat and Anacker [28]).

Another example is the LNG fuelling station in the Netherlands, opened in 2010 by Vos Logistics together with Mercedes-Benz Netherlands, LNG Europe, Van Ganswinkel and Indox CryoEnergy Spain. Vos Logistic owns already 14 LNG trucks, further 50 to 100 should follow (Verhoeven [29], Verhoeven [30]).

In Germany LNG vehicles were subjected a four-week practical test by the company Hellmann Worldwide Logistics. Now, the first LNG vehicles are ordered and a permit for the building of a gas station is also available (Huelemeyer [31]).

In order to promote the topic LNG professionally, placing it politically and underpinning it legally, there are many projects and activities. The “LNG Blue Corridor Project” is an EU project funded with eight million euro (Call FP7-TRANSPORT-2012-MOVE-1), which aims to improve the knowledge and awareness of LNG as an alternative fuel for the medium and long distance road transport. The core of the project consists of four corridors (west–east, south–north, Atlantic and Mediterranean), along 14 new LNG or LCNG stations should be set up in order to operate about 100 trucks (Denys [32], Blue Corridor [33]).

The “BiMe” (Liquid biomethane and methane diesel technology in trucks) was a national LNG corridor project in Sweden, which expired at the end of 2013. The aim of this project was 100 LNG powered heavy long haul vehicles and the construction of at least three gas stations (Gothenburg, Stockholm, Malmo) (Larsson [34], Persson [35]).

In 2011, under the name “Green Deal”, the Dutch government launched a program of cooperation between industry and government to achieve emission targets. More than 150 so-called “Green Deals” were signed. One of these is the Green Deal “Rhine and the Wadden Sea”. Aims of this project are 50 LNG inland and 50 sea-going vessels and 500 LNG powered trucks by 2015 (Rotterdam Climate Initiative [36], Kager [37], Cnubben [38]).

2.4 LNG as fuel for ships

LNG has served as a marine fuel for many years, but primarily on LNG carriers as “the boil off” gas. It was utilized in marine boilers or dual fuel engines. It is only within the last decade that the LNG powered ship market has grown in Europe (Herdzik [39]). More than 25 vessels use LNG as their main fuel now. Most of these vessels, including ferries, chemical tankers, patrol vessels and supply vessels, are in operation in Norway, where they can be refuelled at four stations (Karlsen [40], Marhaug [41], Koslowski [42]). This growth is mainly due to stringent environmental regulations in coastal areas. Nearly a decade of small scale LNG driven ships experience has proven the reliability of the technology, but the lack of a distribution network is still a big challenge. Therefore, dual-fuel or three-fuel engines are often used, which can, in the case of gas shortage, be operated at heavy fuel oil or marine diesel (Herdzik [39]). The investment costs for new ships are about 10-20% higher compared to conventional drive systems. This investment pays for itself through lower fuel consumption, a cheaper fuel and reduced maintenance costs over the entire life cycle of a ship (Bagniewski [43], Würsig [44], Tellkamp [45]). The figures range from nearly equal to 50% lower maintenance costs (Meling [46], CNSS [47]). In a review of 33 studies, the maintenance costs for LNG were evaluated as a positive element (Wang and Notteboom [19]).

2.4.1 Projects and pilot applications

In order to advance the theme of LNG as an alternative fuel in the shipping industry, many ongoing projects focus on the implementation.

One of these projects is the “North European LNG Infrastructure Project” of the Danish Maritime Authority, together with 14 partners. The project is part of the “Trans-European Transport Network (Ten-T) program” and the main purpose of this project is recommendations for the establishment of an infrastructure for the use of LNG as a marine fuel. The recommendations are aimed at the problems in the development of such an infrastructure, the necessary measures to resolve these problems and the main actors that can contribute to overcome these problems (Forsman [48], Gahnström and Molitor [49], Danish Maritime Authority [50]).

Another project is the “Clean North Sea Shipping project”, under the “North Sea Region Programme”, which includes 18 partners from six different countries. The Hordaland County Council took over the project management. The goal is to improve the environmental and health situation caused by air pollution and greenhouse gases due to shipping. A study should include the LNG supply chain, bunker procedure, legal framework, security issues, environmental impacts, cost-benefit analyses, market and trend analyses, stakeholder requirements, project examples, scenarios and emission modelling and policy and strategy developments (CNSS [47], CNSS [51]).

Further projects are the "Clean Baltic Sea Shipping project", the "ITRANSFER project" (Innovative Transport Solutions for Fjords, Estuaries and Rivers) and the "Martech project" (Marine Competence, Technology and Knowledge).

For inland vessels LNG as fuel is currently still banned in Europe, because permitted are only fuels with a flash point higher than 55°C. The flash point of LNG is approximately -187 to -135°C (Kumar *et al.* [1], EnCana Corporation [52]). Nevertheless, there are already two successful examples of barges, which operate with a certification of exemption between Basel and Rotterdam. The Argonon is operating with a mixture of 80% LNG and 20% diesel (Argonon Shipping [53]), the Green Stream is powered with 100% LNG. Soon also a third ship, the Green Rhine should go into operation (ZKR [54]). The only gas station for LNG barges is situated in the port of Rotterdam (Kok [55]).

Through a proposal for a Directive on the introduction of an infrastructure for alternative fuels, the European Commission relies on LNG. In all maritime and inland ports along the Trans-European Transport Network (TEN-T) LNG bunkering stations should be built. Within the framework of the TEN-T Call 2012 seven LNG projects receive financial support. One project is the "LNG Masterplan for the Rhine-Main-Danube" (NGVA [56]). It is a multi-partner project consisting of 33 members (industry, research, interest groups) from 12 EU Member States. The project will provide a European strategy and pilot deployments for LNG as fuel for inland vessels as well as for LNG as cargo being transported on waterways and distributed via inland ports. The action consists of a set of feasibility studies, technical concepts, technical trials and pilot deployments of vessels and terminals (Seitz [57]).

3 Conclusion and outlook

Due to increasingly stringent emission regulations, the demand for LNG is rising. While the use of LNG as fuel will help to reach environmental targets with regards to emissions of sulphur and particulate matters, with regards to the CO_2 targets the use of LNG will have to be complemented on the long run by more energy efficient engines. Another option is the use of liquefied biogas. After appropriate treatment, purification and liquefaction this fuel help to reduce emissions, as well as the dependence on fossil fuels.

LNG will globalize the gas market and flexibility in the transportation of natural gas. So more and more gas sources are available. If Europe wants to benefit from this development, the infrastructure in all areas of the supply chain must be established. As the introduction as fuel is a complex transition process, it requires actions in various fields. The topic LNG continues to provide sufficient space for research and implementation projects and a number of open issues must be clarified in the future. It is important in defining unified and regulatory frameworks and safety standards for the handling of LNG.

Flexibility, independence sourcing, price advantages, alternative export markets but also new emission control regulations make LNG an increasingly attractive energy and fuel option and the use of LNG could be an important decision for further research into the use of and on the transition to hydrogen.

References

[1] Kumar, S., Kwon, H., Choi, K., Lim, W., Cho, J.H., Tak, K., Moon, I., LNG: An eco-friendly cryogenic fuel for sustainable development. *Applied Energy,* **(88)**, pp. 4264–4273, 2011.

[2] BP Energy Outlook 2030, http://www.bp.com/content/dam/bp/pdf/statistical-review/BP_World_Energy_Outlook_booklet_2013.pdf

[3] Natural Gas Europe, Small Scale: Big Opportunities for LNG, http://www.naturalgaseurope.com/small-scale-lng-europe

[4] Nogueras, F.I., LNG Trucking: A First Step to the Development of LNG for Fuel for Transportation. Small Scale LNG Forum. Enagas. Fleming Europe. Rotterdam, 2013.

[5] PwC, Ökonomische Auswirkungen von LNG im Transportbereich, http://www.nationaallngplatform.nl/wp-content/uploads/PwC-Economic-impact-of-small-scale-LNG_STC.pdf

[6] European Environment Agency (EEA), Transport, http://www.eea.europa.eu/themes/transport/intro

[7] Eurostat, Energetischer Endverbrauch nach Sektor, http://epp.eurostat.ec.europa.eu/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=tsdpc320&language=de

[8] Baumann, K., Kruyt, B., Van der Burg, L., LNG-activities in Dutch-German cooperation. (MariTIM, LNG-Initiative Nordwest, WattenStart). Small Scale LNG Forum. MARIKO GmbH. Fleming Europe. Rotterdam, 2013.

[9] Lindqvist, K., Legislation on vehicles and fuels; Air Pollution & Climate Secretariat, http://www.airclim.org/legislation-vehicles-and-fuels

[10] Schweighofer, J., Seiwerth, P., Environmental Performance of Inland Navigation, European Inland Waterway Navigation Conference. Via donau. Hungary, 2007 http://www.donauschifffahrt.info/fileadmin/group_upload/5/Newsroom/2007/paper_EIWNC_June2007.pdf

[11] Deal, A.L., What Set of Conditions Would Make the Business Case to Convert Heavy Trucks to Natural Gas? A Case Study, National Energy Policy Institute (NEPI), http://nepinstitute.org/wp-content/uploads/2012/12/Natural_Gas_for_Heavy_Trucks_201211051.pdf

[12] Semolinos, P., Olsen, G., Giacosa, A., LNG as marine fuel: challenges to be overcome. 17th International Conference & Exhibition on Liquefied Natural Gas, TOTAL Gas & Power, Houston, 2013 http://www.gastechnology.org/Training/Documents/LNG17-proceedings/7-2-Pablo_Semolinos.pdf

[13] GLE (Gas Infrastructure Europe), Position Paper: Overcoming barriers in the Small Scale LNG development, http://www.gie.eu/index.php/publications/gle/cat_view/3-gle-publications

[14] Nyhus, E., Environmental regulations towards 2020. http://www05.abb.com/global/scot/scot293.nsf/veritydisplay/c6e91be48c5b0eb2c1257a8a003aea7a/$file/ABB%20Generations_17%20Environmental%20regulations%20towards%202020.pdf

[15] Schweighofer, J., Cleanest Ship: Theoretische Grundlagen, Praxisbeispiele. via donau – Österreichische Wasserstraßen GmbH (Wien). St. Pölten, 2010, http://www.wko.at/wknoe/verkehr/oewsv/symposium2010/schweighofer.pdf

[16] European Commission, Directives on emissions from non-road mobile machinery, 2013 http://ec.europa.eu/enterprise/sectors/mechanical/documents/legislation/emissions-non-road/

[17] Pauli, G., Schweighofer, J., Abgasemissionen auf Binnenwasserstraßen. http://www.donauschifffahrt.info/uploads/talks_downloads/Abgasemissionen_und_Binnenwasserstrassen.pdf

[18] European Commission, Quarterly Report on European Gas Markets. Market Observatory for Energy, Second quarter 2013, http://ec.europa.eu/energy/observatory/gas/doc/20130814_q2_quarterly_report_on_european_gas_markets.pdf

[19] Wang, S., Notteboom, T., LNG as a ship fuel: perspectives and challenges, http://www.porttechnology.org/images/uploads/technical_papers/LNG_LR.pdf

[20] Sousanis, J., World Vehicle Population Tops 1 Billion Units. http://wardsauto.com/ar/world_vehicle_population_110815

[21] Garthwaite, J., For Natural Gas-Fuelled Cars, Long Road Looms Ahead. http://news.nationalgeographic.com/news/energy/2013/09/130904-long-road-ahead-for-natural-gas-cars/

[22] Lage, M., The use of Natural Gas in the transportation Industry. European LNG Blue Corridors. NGVA Europe (Natural & bio Gas Vehicle Association). Lissabon, Spanien, 2012, http://www.apvgn.pt/documentacao/lage_agn_out12.pdf

[23] Amt für Veröffentlichungen, Arbeitsunterlage der Kommissionsdienststellen Zusammenfassung der Folgenabschätzung: Begleitunterlage zum Vorschlag für eine Richtlinie über den Aufbau der Infrastruktur für alternative Kraftstoffe /* SWD/2013/06 final */, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SWD:2013:0006:FIN:DE:HTML

[24] Schmidt, B., Lastwagen mit LNG. Die Kühlkette darf nicht reißen, 2013 http://www.faz.net/aktuell/technik-motor/auto-verkehr/lastwagen-mit-lng-die-kuehlkette-darf-nicht-reissen-12149186.html

[25] Chrz, V., Emmer, C., LNG directly to customer stations. 15th International Conference & Exhibition on Liquefied Natural Gas. Chart Ferox. Barcelona, 2007.

[26] ANGA (America's Natural Gas Alliance), U.S. and Canadian Natural Gas Vehicle Market Analysis: Liquified Natural Gas Infrastructure, http://www.anga.us/media/content/F7D3861D-9ADE-7964-0C27B6F29D0A662B/files/11_1803_anga_module5_cng_dd10.pdf

[27] Willms, O., Alternative Antriebe. LNG-Antrieb von Iveco, http://www.eurotransport.de/test/alternative-antriebe-lng-antrieb-von-iveco-6508186.html
[28] Cebrat, G., Anacker, C., Documentation and Evaluation of International Case Studies. Compiled within the European research project. Deriving effective least-cost policy strategies for alternative, Forschungsgesellschaft Mobilität – Austrian Mobility Research, 2010 http://www.google.at/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CDMQFjAA&url=http%3A%2F%2Fwww.alter-motive.org%2Findex.php%2Fpublic-documents%2Fdoc_download%2F357-d6casestudiesfv&ei=SDRyUtu2K8OBtAbnk4GoDQ&usg=AFQjCNF8KrOxEC_K2lz2_RCEuOBbVlXvuQ&bvm=bv.55819444,d.Yms
[29] Verhoeven, F., Vos Logistics strengthens sustainable transport fleet by introducing LNG trucks for regional distribution, http://www.voslogistics.com/News%20and%20Information/News/Vos%20Logistics%20strengthens%20sustainable%20transport%20fleet%20by%20introducing%20LNG%20trucks%20for%20regional%20distribution/$id3494
[30] Verhoeven, F., Vos Logistics opens first LNG filling station in the Netherlands. http://www.voslogistics.com/News%20and%20Information/News//Vos%20Logistics%20opens%20first%20LNG%20filling%20station%20in%20the%20Netherlands/$id1984/
[31] Huelemeyer, D., Alternative Antriebskonzepte – Feldversuch Liquid Natural Gas (LNG), http://www.wirtschaft-pro-klima.de/default.asp?Menue=597&Firma=2802013
[32] Denys, T., Alternative fuels for road transport. Workshop: Mobility: Technology Priorities and Strategic Urban Planning. Finnland, 2013 http://www.iea.org/media/workshops/2013/egrdmobility/TobiasDenysAlternativefuelsforroadtransport.pdf
[33] Blue Corridor, LNG Blue Corridors http://www.lngbluecorridors.eu/
[34] Larsson, H., BiMe Trucks. Developing the Uptake of Liquid Biomethane in Heavy Duty Transport. Global Biomethane Conference. Business Region Göteborg. Brüssel, 2012.
[35] Persson, Y., Corridor of liquefied biomethane for road transports. Final Conference Scandria. Malmö, Schweden, 2012.
[36] Rotterdam Climate Initiative, Introduction of LNG as transport fuel will generate billions of euros and thousands of jobs, http://www.rotterdamclimateinitiative.nl/en/english-2011-design/news?news_id=1154
[37] Kager, P., Small Scale LNG. Current State of Play in Europe and Outlook for the next Decade. NV Nederlandse Gasunie, http://www.gie.eu/conference/presented/2013/S4_03_Gasunie_PKager.pdf
[38] Cnubben, P., TaskForce LNG Noord-Nederland. The Northern interregional approach. Energy Valley Foundation. Fleming Europe. Rotterdam, 2013.

[39] Herdzik, J., LNG as a Marine Fuel – Possibilities and Problems, 2011 http://ilot.edu.pl/kones/2011/2_2011/2011_herdzik_lng_as_a_marine_fuel.pdf
[40] Karlsen, L., Approval of Ships using LNG as fuel, Norwegian Maritime Authority, 2012 http://norwegen.ahk.de/fileadmin/ahk_norwegen/Dokumente/Presentasjoner/lng/KARLSEN_How_do_authories_approve_LNG_ships.pdf
[41] Marhaug, L.A., Small Scale LNG. Reduce Emissions – Expand Potential, Gasnor AS, Norwegian University of Science and Technology, 2012 http://www.ipt.ntnu.no/~jsg/undervisning/naturgass/lysark/LysarkMarhaug2012.pdf
[42] Koslowski, C., LNG bald die Nummer 1 unter den Schiffstreibstoffen?, http://www.vng.de/VNG-Internet/de/zz_Dokumente/medium_gas/medium_gas_2013_2.pdf
[43] Bagniewski, M., LNG fuel for ships. A chance or a must? DNV, 4, 2010 http://www.dnv.pl/Binaries/LNG%20fuel%20for%20ships_tcm144-520589.pdf
[44] Würsig, G.M., LNG for Ships – some key elements, DNV Norway, 2012 http://www.dnv.com/binaries/2.%20lng%20as%20ship%20fuel%20dnv%20nor-shipping%202013%20drop-in%20seminar_tcm4-553764.pdf
[45] Tellkamp, J., LNG als Schiffsantrieb, DNV Hamburg, Germany, 2010 http://www.dnv.de/Binaries/DNV_LNG-Kompaktinformation_tcm70-486640.pdf
[46] Meling, J.F., LNG as fuel, http://smm-hamburg.com/fileadmin/img/content/programme/downloads/programmpunkte_de/491_7341_4.%20meling.pdf
[47] Clean North Sea Shipping (CNSS), A review of present technological solutions for clean shipping, http://cnss.no/wp-content/uploads/2011/10/Summary-brochure10.pdf
[48] Forsman, B., North European LNG Infrastructure Project: Appendix J Safety Aspects/Risk Assessment. A feasibility study for an LNG filling station infrastructure and test of recommendations, 2011 http://www.dma.dk/themes/LNGinfrastructureproject/Documents/Documents/LNG_draft_FR_20111128_app_J.pdf
[49] Gahnström, J., Molitor, E., North European LNG Infrastructure Project: Appendix G Port and Terminal Aspects on LNG Bunkering. A feasibility study for an LNG filling station infrastructure and test of recommendations, 2011 http://www.dma.dk/themes/LNGinfrastructureproject/Documents/Documents/LNG_draft_FR_20111121_app_G.pdf
[50] Danish Maritime Authority, North European LNG Infrastructure Project. A feasibility study for an LNG filling station infrastructure and test of recommendations, 2011 http://www.dma.dk/themes/LNGinfrastructureproject/Documents/Final%20Report/LNG_Full_report_Mgg_2012_04_02_1.pdf

[51] Clean North Sea Shipping (CNSS), LNG fuelled ships as a contribution to clean air in harbours. CNSS Work package 4, Showcase LNG. http://cnss.no/wp-content/uploads/2013/08/CNSS-LNG-report-4mb.pdf
[52] EnCana Corporation, Material Safety Data Sheet. Liquid Natural Gas Fuel, 2011 http://www.encana.com/pdf/business/contractors/msds/lng.pdf
[53] Argonon Shipping B.V., Argonon, sustainable ship. First inland barge on dual fuel, http://www.deenshipping.com/files/documents/Argonon%20PressMap_LRES.pdf
[54] Zentralkommission für die Rheinschifffahrt (ZKR), Die Präsidentin der ZKR tauft das MS "Greenrhine", ein zu 100% mit LNG betriebenes Tankschiff, das künftig auf dem Rhein verkehren soll, http://www.ccr-zkr.org/files/documents/cpresse/cp20130903de.pdf
[55] Kok, J., LNG went Far East. Natural gas use has long way to flow, http://media.veth.net/media/727-LNG_Special_Veth_-_No_1_MbH_Jan-Feb_2013.pdf
[56] Natural and bio Gas Vehicle Association (NGVA) Europe, European Commission selects 7 LNG projects as winners in TEN-T call 2012, http://www.ngvaeurope.eu/european-commission-selects-7-lng-projects-as-winners-in-ten-t-call-2012
[57] Seitz, M., LNG as fuel for inland vessels and as a cargo on the rhine-main-danube. Small Scale LNG Forum. Pro Danube International. Rotterdam, 2013.