Development of LNG Infrastructure in Europe
Razvoj LNG infrastrukture u Europi

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Summary

The transport sector is the fastest growing consumer of energy and producer of greenhouse gases in the European Union. With new emission regulation these days the potential application for LNG are expanding. LNG provides a greener alternative to other fossil fuels, which can significantly contribute to improve European air quality and to reduce the existing oil dependency. In Europe receiving terminals are mainly situated in Belgium, France, Greece, Italy, Netherlands, Portugal, Spain, Turkey and United Kingdom. However, infrastructure for proper function of LNG is still missing in central and Easter Europe. The aim of this paper draws basic properties of LNG as well as analyse the overview of LNG infrastructure in Europe.

KEY WORDS
biofuels
liquefied natural gas
terminal
transport

Sažetak

Transportni sektor je najbrže rastući potrošač energije i proizvođač stakleničkih plinova u Europskoj Uniji. Ovih dana se proširuju propisi emisije plinova za potencijalnu uporabu na LNG brodovima. LNG daje alternativu fosilnim gorivima, koja može znatno pridonijeti poboljšanju kvalitete zraka u Europi i smanjiti ovisnost o nafti. U Europi su terminali za prijem većinom smješteni u Belgiji, Francuskoj, Grčkoj, Italiji, Nizozemskoj, Portugalu, Španjolskoj, Turskoj i Ujedinjenom kraljevstvu. Međutim, infrastruktura za pravilno funkcioniranje LNG-a još nedostaje u Centralnoj i Istočnoj Europi. Cilj ovoga rada je prikazati osnovne značajke LNG-a i analizirati pregled LNG infrastrukture u Europi.

KLJUČNE RIJEČI
biogoriva
ukapljeni prirodni plin
terminal
transport

1. INTRODUCTION / *Uvod*

Transport is a key factor in modern economies. The growth of the economy and of the living standard cause growing demand for transport services. At the same time, there may be an increasing discrepancy between the society requiring more mobility (increase in demand for the transport services) and public opinion which is much less tolerant to chronic delays and to the poor quality of some services. European transport system will face considerable challenges in the next decade. It will be important to put a great effort to find the necessary funding for the long-term investments into the transport infrastructure as well as to avert the collapse of the road freight transport system.

According to White Paper (*Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*) European Commission calls for breaking the oil dependence of transport and sets a target of 60% greenhouse gas emissions reduction from transport by 2050 [1]. In order to reach these goals a big share of alternative fuels is required. Alternative fuels can significantly contribute to improve European air quality and to reduce the existing oil dependency. As alternative fuels are generally considered any materials or substances that can be used as fuels, other than conventional fuels. Well-known alternative fuels include natural gas and bio-methane, liquefied petroleum gas (LPG), biofuels, electricity and hydrogen. Proved reserves of natural gas made a very high potential for a significant contribution as an alternative fuel for the European transport sector. This opens the doors to LNG, the common acronym for Liquefied Natural Gas.

The potential application for LNG is expanding due to new emission regulation for inland navigation. Among these applications is the use of LNG as a marine fuel. LNG as main propulsion fuel is no longer a new invention and technology is already classified as proven. In 2001, Norway launched the first LNG fuelled ship in the world – Glutra. Since then, experience in this technology has been gaining ground in Norway where small ships have been equipped with LNG propulsion, e. g. ferries and offshore supply vessels [2]. LNG is considered to be an important opportunity for the inland waterway transport sector as well. LNG is predicted to be

Table 1 Average chemical composition of the LNG by selected countries
Tablica 1. Prosječni kemijski sastav LNG-a po odabranim zemljama

Origin	Nitrogen	Methane	Ethane	Propane	Butane +	TOTAL
	N2 %	C1 %	C2 %	C3 %	C4+ %	
Australia - Darwin	0.10	87.64	9.97	1.96	0.33	100
Algeria	0.65	90.15	7.9	0.4	0.5	100
Egypt - Damietta	0.02	97.25	2.49	0.12	0.12	100
Libya	0.59	82.57	12.62	3.56	0.65	100
Nigeria	0.03	91.7	5.52	2.17	0.58	100
Norway	0.46	92.03	5.75	1.31	0.45	100
Oman	0.20	90.68	5.75	2.12	1.24	100
Qatar	0.27	90.91	6.43	1.66	0.74	100
Russia - Sakhalin	0.07	92.53	4.47	1.97	0.95	100
USA - Alaska	0.17	99.71	0.09	0.03	0.01	100
Yemen	0.02	93.17	5.93	0.77	0.12	100

Source: Self processed based on [6]

used as fuel for the inland waterway vessels in next few years. Pursuant to the ADN Regulations (*International Carriage of Dangerous Goods by Inland Waterways*), the tanker vessel "MTS Argonon" is the first ship on inland waterways that is authorised to use LNG as fuel for the propulsion installation, subject to the condition that the vessel complies with the regulations of the ADN. One of the visions of European transport politics is that the inland ports on the Rhine-Main-Danube axis will become key distribution centres of LNG for landlocked countries [3]. Inland terminals will function as satellites to the interior, enabling LNG to reach other pioneer markets like the public (transport) sector and the heavy duty transport industry (buses, garbage collection trucks, city logistics) and the energy industry. Based on intrinsic advantages LNG has as a fuel, it can and will probably be adopted on an international basis. In response to increasing demand, construction of LNG bunkering infrastructure is under development. In this paper, we look closely to regasification terminals - plants, which represents the entrance of LNG to the European transport system.

2. BASIC PROPERTIES OF LNG / *Osnovne značajke LNG-a*

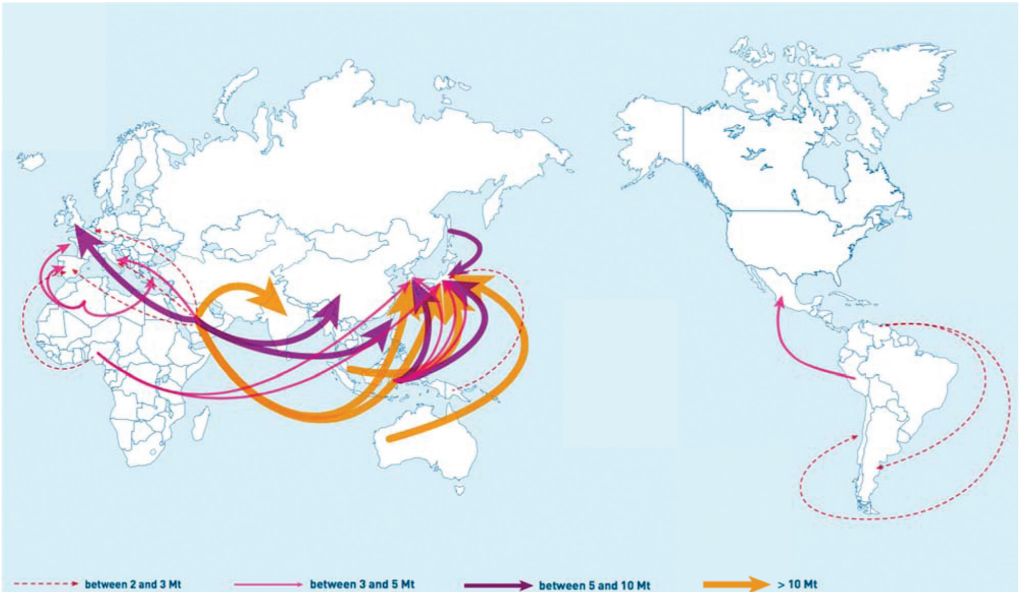
In 2013, natural gas accounted for 23.7% of primary energy consumption worldwide. It is the third largest source of energy after oil and coal. To be precise, in 2013 the world consumed 3.0 billion tons of natural gas, compared to almost 4.2 billion tons of oil and 3.8 billion tons of coal [4].

When natural gas is cooled to approximately -162°C at atmospheric pressure, it condenses to a liquid and become liquefied natural gas – LNG. This low temperature makes LNG a cryogenic liquid. The cryogenic temperature means it will freeze any tissue (plant or animal) upon contact and can cause other materials to become brittle and lose their strength or functionality. This is why the selection of materials used to contain LNG is so important. To remain a liquid, LNG must be kept in specially designed containers, which function like thermos bottles – they keep the cold in and the heat out. Natural gas in liquid form takes up about $1/600^{th}$ of its gaseous equivalent, so that is the economical reason to transport LNG [5].

LNG is odourless, colourless, non-corrosive and non-toxic. The common smell of natural gas is caused by an odorizing substance which is added to natural gas before it is sent to the distribution grid. This is due to detection of gas leaks. LNG is a mixture of various hydrocarbons, with a very high percentage of methane (generally more than 91% - see Tab. 1). Table 1 displays the average chemical compositions of the LNG reported by the different receiving terminals. Its actual composition is variable depending on the composition of the original natural gas and its liquefaction process. The LNG composition is likely to change in time ("ageing"). Ageing is the tendency of the lighter components of the LNG mixture to vaporize before the heavy components. In other words, methane will be the first component to vaporize, leaving the higher fractions [3].

3. WORLD DEMAND OF NATURAL GAS AND LNG TRADE / *Svjetski zahtjevi za prirodnim plinom i LNG trgovinom*

The largest proven reserves of natural gas are located in the Middle East - 43.2% of total share. The states with the largest reserves are Iran (18.2%), Russian Federation (16.8%), Qatar (13.3%), Turkmenistan (9.4%) and the USA (5.0%) [4].



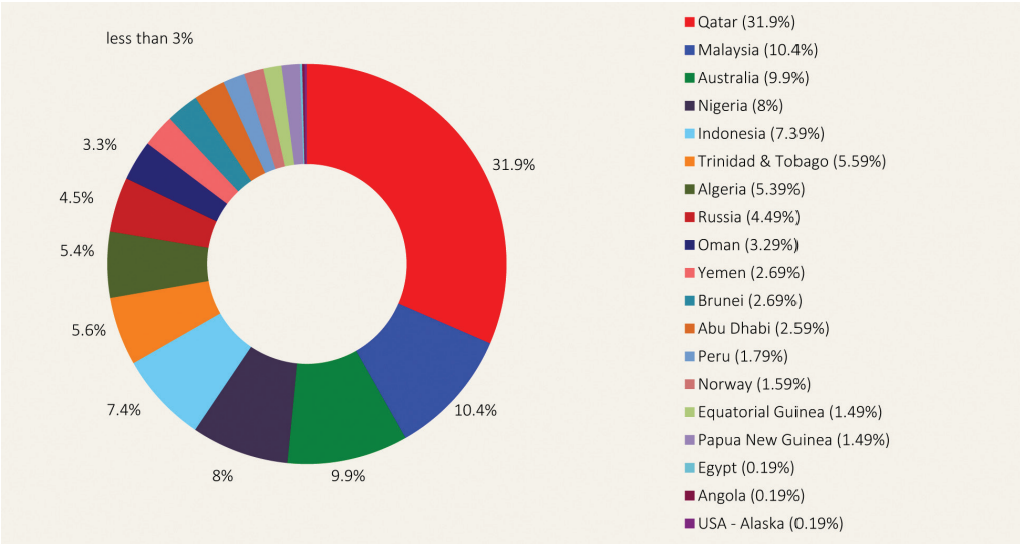
Source: [6]

Figure 1 Major LNG flows in 2014
Slika 1. Glavni LNG tijek 2014

Global natural gas production grew by 1.4% in 2013, below the historical average of 2.6% [4]. The United States accounted for 20.0% of global production and remained the world's leading producer. In 2013 growth in global LNG trade nearly came to a standstill with 0.3 % compared to last year. Increased imports into America, China and the Republic of Korea were partially offset by lower imports in France, Spain and the UK. Qatar remained the largest LNG exporter with a 31.9 per cent share of global LNG exports. In 2014, there were 19 exporting countries in the world [8] - presented in Fig 2.

In 2014, despite growth in the UK (due to an increase of deliveries from Qatar) and Turkey (where LNG demand continues to be driven by power generation), European LNG import activity overall further declined and almost all European countries recorded double-digit drops in LNG demand. Europe's share of global imports decreased to 13.6% in 2014. Several European terminal operators took special measures in order to operate in low send-out conditions to accommodate this new environment. In Table 2 we can see quantities (in 10^6 t) received in 2014 by the importing countries from the exporting countries in Europe. [8]

The United States is emerging as a potential world-leading exporter of LNG, with the country expected to build over 200 million tons per year of LNG capacity (equivalent to 2.5 times the capacity of Qatar) [8]. On the other hand, the Russian Federation is also investing heavily in the sector to reach 40 million tons per year by 2020. Other projects are also planned or under construction in Australia and Indonesia, while Malaysia and Singapore are constructing bidirectional terminals for import and export of LNG. However, geopolitical risks are also overshadowing the prospects of LNG trade as they have the potential to redefine



Source: Self processed based on [6]

Figure 2 Sources of LNG imports (2014)
Slika 2. Izvori LNG uvoza (2014)

Table 2 Quantities received by the importing countries from the exporting countries in Europe (2014, in 10^6 t)
Tablica 2 Količine koje su primile zemlje uvoza i zemlje izvoza u Europi (2014., u 10^6 t)

	Qatar	Algeria	Nigeria	Trinidad&Tobago	Norway	Peru	Oman	Equatorial Guinea	Re-exports received	Re-exports loaded	Net Imports (after re-exports)
UK	7.89	0.15	0.06	0.30	-	-	-	-	-	-	8.40
Spain	2.30	3.76	2.08	1.49	0.93	0.92	0.12	-	0.14	-3.84	7.90
Turkey	0.82	3.05	1.09	0.06	0.19	-	-	-	0.25	-	5.45
France	0.75	3.23	0.82	0.06	0.06	0.06	-	0.06	-	-0.46	4.58
Italy	3.12	0.04	-	0.06	-	-	-	-	0.06	-	3.27
Belgium	2.09	0.00	-	-	-	-	-	-	-	-1.13	0.97
Portugal	0.54	0.11	0.27	0.17	0.06	-	-	-	0.06	-0.25	0.97
Netherlands	0.09	-	-	0.16	0.51	-	-	-	-	-0.35	0.42
Greece	-	0.34	-		-	-	-	-	0.04	-	0.38
Lithuania	-	-	-		0.11	-	-	-	-	-	0.11
Total Europe	17.61	10.68	4.32	2.29	1.86	0.98	0.12	0.06	0.55	-6.03	32.44

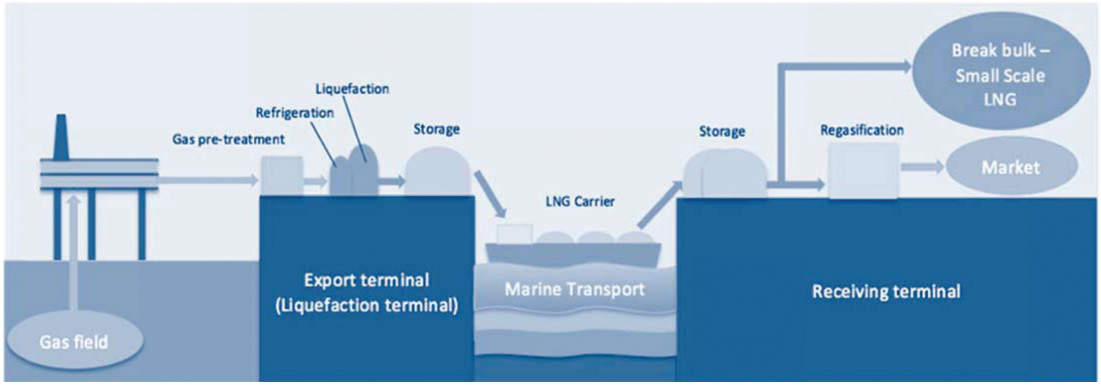
Source: Self processed based on [6]

trade patterns and routes. A case in point is the tensions between the Russian Federation and Ukraine and potential ripple effects of an escalation of the conflict on European gas importers. Thirty-four per cent of the European Union's imports of natural gas are sourced from the Russian Federation, a large portion of which transits through Ukraine by pipelines. Disruption to gas supplies could lead Europe to import more LNG by sea instead of pipelines. LNG exports from the United States or Caspian region could provide an alternative source of supply of LNG carried on vessels. This in turn will affect demand for gas carriers and LNG trade flows and direction. [6, 8]

4. LNG TERMINALS / *LNG terminali*

The global LNG business can be usually described as a process chain or value chain containing four main components. Extraction, Liquefaction, LNG Transport and Regasification. Firstly, it is extraction and production. Plentiful source of gas is needed at a price competitive with other energy sources, such as oil. Although there are plenty of reserves, they are in the wrong place and multi-billion dollar investment projects are needed to ship the gas to market. As the consequence, investors are locked into a very inflexible long-term commitment, so political stability and future pricing worries weigh heavily on their minds, often leading to delays [7].

Extraction of the natural gas from the earth's surface represents the first step along the process chain of LNG production – see Fig. 3. This is followed by liquefaction, which basically means the cleaning of the natural gas in the liquefaction plants. The largest component of the total cost of the LNG value chain is usually the liquefaction plant, while the production, shipping, and regasification components account for nearly equal portions of the remainder. A liquefaction plant represents one or more 'trains' which liquefy the gas. A train is a compressor, usually driven by a gas turbine [7]. At the end of 2012, there were 89 liquefaction trains in operation worldwide [6]. Snohvit in Norway is the only liquefaction plants in Europe. Regrettably the plant owner decided to shelve their plans for a second train due to insufficient gas reserves. Nevertheless, in the Mediterranean region there are other possibilities for export of liquefied gas to Europe – in Egypt, Algeria and Libya and also another in Nigeria, Equatorial Guinea and Trinidad & Tobago. From Middle East region there are potential imports through the Suez Canal from Abu Dhabi, Oman, Qatar and Yemen [5].



Source: [2]

Figure 3 The Large Scale LNG chain
Slika 3. LNG lanac u velikom mjerilu

The last step in the LNG process chain involves the LNG receiving terminal - regasification plants. At the receiving terminal LNG is stored in large cryogenic tanks. The liquid is re-gasified/vaporized and transported to local market via the gas grid. In some markets a portion of the LNG is broken into smaller cargoes and distributed in smaller scale by rail, road or smaller LNG vessels. Small-scale distributions can also originate from small-scale liquefaction plants. This is current practice in Norway and the US [2]. LNG services in terminals usually include:

- ***Reloading*** - transfer of LNG from the LNG tanks at the terminal into a vessel. In 2014, more than 130 operations were done and about 14 mcm (million cubic metres) LNG were reloaded in the EU.
- ***Transshipment*** – transfer of LNG from one vessel to another. This service is offered in Belgium, France, Spain, UK.
- ***Truck loading*** - LNG is loaded on tank trucks, which transport LNG in smaller quantities. In 2014 about 42,600 trucks loaded 1.9 mcm LNG.
- ***Loading of bunkering ships*** - LNG is loaded on bunkering ships, which supply to LNG-fuelled ships or LNG bunkering facilities. Available in Belgium, France, The Netherlands and Spain.
- ***Rail loading LNG*** - is loaded on rail tanks, which transport LNG in smaller quantities. This service has not been available in Europe yet.

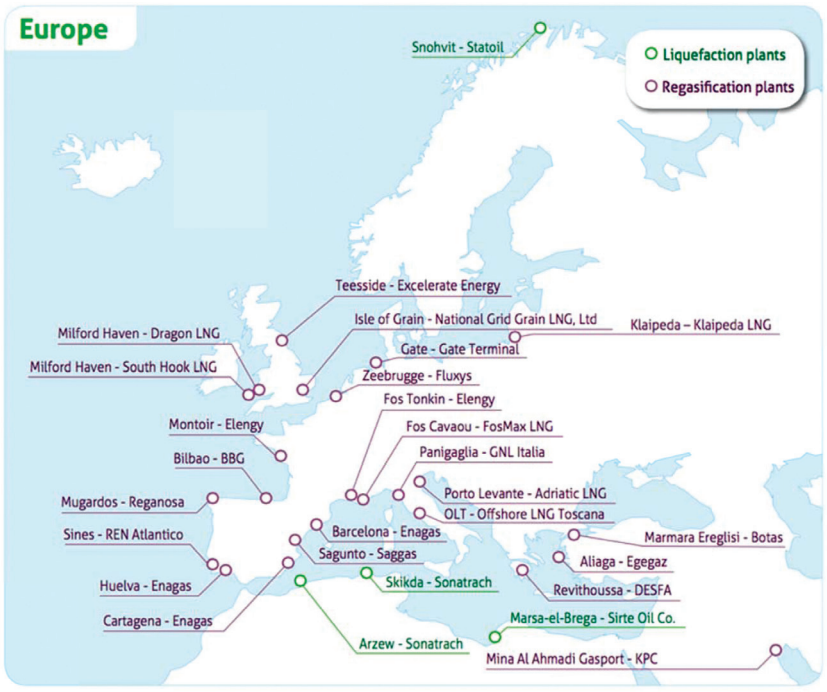
According to GIIGNL (*International Group of Liquefied Natural Gas Importers*), 104 LNG regasification terminals were in operation worldwide at the end of 2013 [6]. Another 6 new terminals were planned to start receiving LNG in 2014 [9]. A combined capacity of all terminals is 20 mtpa (million ton per annum). Five terminals are located in Asia and one is located in Europe – Lithuania (Klaipeda). In Europe we can find in operation 19 large on- shore terminals, one off-shore in Italy and 3 floating regasification facilities – see Figure 4..

New projects are announced frequently, but detailed descriptions are rarely published due to the intense competition in the emerging market. The industry is also faced with a lack of standardization within certain areas of the bunkering process. Leaving procedures open to discretion and potentially higher risk of failure [3]. Regasification plants are situated in Belgium, France, Greece, Italy, Netherlands, Portugal, Spain, Turkey, the United Kingdom and the new one in Lithuania. Total storage capacity in liquid represents 9,022 mil. m^3. In next chapter we take a look at current state of some of them.

The majority regasification units are located in Spain – Bilbao, Cartagena, Huelva, Mugardos and the biggest one in the Barcelona. The possibility to fill trucks exists in all terminals. During 2014, terminal in BBG in Bilbao has finished the construction of a new tank of 150,000 m^3 capacity, which implies a 50% increase in the storage capacity of the plant, allowing enough storage to accommodate Q-max vessels. Another modernization has been made on the improvement of the system which will be now able to reload ships in a fast and efficient way, up to a loading rate capacity of 2.500 m^3 of LNG per hour.

In the United Kingdom there are 4 regasification terminals – Milford Haven is located Dragon LNG and South Hook LNG terminals, another one is in Isle of Grain and the floating LNG facility in Teesside. On Maasvlakte in Rotterdam is located Gate terminal - the first LNG import terminal in the Netherlands. The terminal consists of three storage tanks, two jetties and a process area where the LNG is regasified. In February 2014, Gate Terminal started operations on its truck-loading bay.

In France, the use of LNG is very common. We can find here 3 regasification terminals here- Fos-Cavaou, Fos-Tonkin (Fos-



Source: [6]

Figure 4 LNG terminals in Europe with their terminal operators
Slika 4. LNG terminali u Europi sa svojim operatorima terminala

sur-Mer) and Montoir-de-Bretagne owned and operated by Elengy. All of them offered reloading and bunkering. Montoir additionally offers transhipment service and LNG truck loading. In May 2012 the construction of the new LNG terminal in Dunkirk began, which, with 9.4 mmtpa regasification unit, is expected to be the largest terminal in Continental Europe. The terminal will include 3 storage tanks of 190.000 m^3 and it will be able to accommodate Q-Max vessels.

In Turkey the use of LNG is widespread. Throughout the country there are two terminals: Marmara Ereglisi (Tekirdag) and Aliaga/Izmir with both of them being equipped with filling trays for LNG trucks. Lithuania has its own regasification unit with floating technology since October 2014.

The Klaipeda terminal started service in January 2015. It is able to reload to smaller ships and to LNG cargoes.

In the Italy, there are 3 LNG terminals in Panigaglia, Rovigo (Porto Levarte) and floating regasification unit in Livorno (OLT - Offshore LNG Toscana). In terminal Panigaglia expansion project includes the possibility to unload larger ships (up to 140 000 m3), a revamping process of the plant's main equipments involving the storage tanks and the berthing area, and the installation of a new cogeneration plant for self-production of electricity.

There are several ongoing expansions of LNG terminals in Europe. Currently the second jetty is being constructed in the port of Zeebrugge. This jetty is projected to accommodate the ships as small as 2000 m^3. Another expansion takes place in Greece – Revithoussa, where project includes construction of 3rd tank of capacity 95,000 m^3 and facilities for reloading small and medium size ships. Under construction is also another terminal in Poland – Swinoujscie, Polskie LNG S.A. is considering its further expansion which would include building a 3rd tank, reloading facilities to reload LNG to smaller vessels, bunkering installations and expansion of truck loading facilities.

Other small LNG scale terminals are located in Sweden (Nynäshamn and Lysekil LNG Terminal) and Norway (Mosjoen and Sines LNG Terminal). [6, 9]

5. CONCLUSION / *Zaključak*

There are two different transportation modes for natural gas. The land based transport is typically done via pipelines where compressed natural gas is used. On the other hand, waterborne transport uses liquefied form of natural gas - LNG. Transport of natural gas via pipeline from Russia is dominating in the European market. However, the Ukraine-Russia crisis and the start-up of six new regasification terminals worldwide reminds us that LNG is an effective tool to ensure security of supply. In 2013 Lithuania became the world's 30th importer with a floating storage and regasification unit. The outlook for LNG trade is positive in view of following facts [8]: new gas finds worldwide (Cyprus, Israel and the United Republic of Tanzania), the decline in nuclear power use, promotion of LNG in Asia region, attractiveness of gas as a greener alternative to other fossil fuels and finally, stricter legislation on shipping emissions started in January 2015 in the Atlantic basin should help stimulating the development of small scale LNG, offering new opportunities for growth as well as new challenges.

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REFERENCES / *Literatura*

[1] European Commission, 2011b. White Paper: Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. COM(2011) 144 final, Brussels.

[2] Arnet, N. M. L.: Evaluation of technical challenges and need for standardization for LNG bunkering: Project thesis. Trondheim: Norwegian University of Science and Technology. 2013.

[3] Falck RISC. Technical Evidence & Safety & Risk Assessment: Emergency and incident response study. Publ. April 2015. 140 p.

[4] BP Statistical Review of World Energy June 2014. Available at: http://www.bp.com/content/dam/bp-country/de_de/PDFs/brochures/BP-statistical-review-of-world-energy-2014-full-report.pdf

[5] Kalina, T., Grobarčíková, A.: LNG as alternative fuel for European transport system. Communications: scientific letters of the University of Žilina. 2014. Vol. 16. no. 2. pp 70-76.

[6] The LNG Industry 2014. Available at: http:/giignl.org/sites/default/files/PUBLIC_AREA/Publications/giignl_2015_annual_report.pdf

[7] Stopford, M.: Maritime Economics. London: Routledge. 2009. 840 p. http://dx.doi.org/10.4324/9780203891742

[8] Review of maritime transport 2014. Available at: http://unctad.org/en/pages/PublicationWebflyer.aspx?publicationid=1068

[9] GIE LNG map. Available at: http://www.gie.eu/index.php/maps-data/lng-map

[10] Jurkovič, M., Dávid, A.: Technological and educational requirements for inland navigation simulator in the Danube region. In Naše more = Our sea : znanstveno-stručni časopis za more i pomorstvo. 2015. Vol. 62. no. 1. pp. 13-19., http://dx.doi.org/10.17818/nm.1.3.2015