GOSPODARKA SUROWCAMI MINERALNYMI

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Importance of LNG technology in the development of world's natural gas deposits

Introduction

One of the factors indispensable for the development of the economies of individual countries and the world economy is the sufficient access to energy. Since the industrial revolution initiated in the 18th century, the role and the importance of energy has been consistently growing. It should be noted that from the beginning of the world's intensive economic development, which started over 200 years ago, the continuously increasing energy demand is covered mainly by the fossil carriers of primary energy. However, recently the technologies based on the renewable sources of energy has been developing rapidly.

The primary energy demand amounted to 12 002 Mtoe in 2010 and, in comparison with 2009, it increased by 5.6%. It should be emphasized that since 1980 the world's energy consumption has increased almost twice; in 1980 it amounted to 6624 Mtoe (BP 2002–2011). The volume of energy consumption varies in the individual world regions. It depends on the level of the economic development. The region where in 2010 the energy consumption was the highest was Asia – over 38% (4573. 8 Mtoe). It should be noted that the country which used the greatest quantity of energy was China – the volume of energy consumption amounted to 20.3% (2432.2 Mtoe) of the world's consumption in 2010. Other countries in this region of high energy consumption were: India – 4.4% and Japan – 4.2% of the world's consumption. Another region, where the substantial part of energy was used,

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was Eurasia – the level of consumption amounted to 24.8% (2971.5 Mtoe). The countries of the highest energy consumption rate in this region were: Russia – 5.8% (690. 9 Mtoe), Germany – 2.7% (319.5 Mtoe), France – 2.7% (252.4 Mtoe) of the world's consumption. The energy consumption in Poland in 2010 amounted to 95.58 Mtoe, which accounted for 0.8% of the world's consumption. Next region as concerus the energy consumption was North America where in 2010 the consumption was 2771.5 Mtoe, which accounted for 23.1% of the world's consumption. In this region the USA became the leading consumer – 2285.7 Mtoe, i.e. 19% of the world's consumption. Further in rank with regard to the energy consumption in 2010 were: the Middle East – 5.8% (2971.5 Mtoe), South and Central America – 5.1% (611.9 Mtoe), Africa – 3.1% of the world's consumption (372.6 Mtoe); Fig. 1 (BP 2002–2011).

As it has been mentioned before, the energy demand is covered mainly by the fossil carriers of primary energy, i.e. coal, crude oil and natural gas. In 2010 the share of individual carriers in covering this demand was: coal – 30%, crude oil – 34%, natural gas – 24%. However, taking into consideration the proved reserves of these carriers, the sufficiency of those reserves (R/P ratio) are as follows (Janusz 2011):

— Lignite – 300 years,
— Bituminous coal – 200 years,
— Natural gas – 60 years,
— Crude oil – 40 years.

In the context of the influence on the environment, the importance of the natural gas as a raw material, the least polluting the environment, is increasing. Additionally, gas can be used in numerous branches of industry (as a raw material or as an energy carrier), in households and in the service sector.

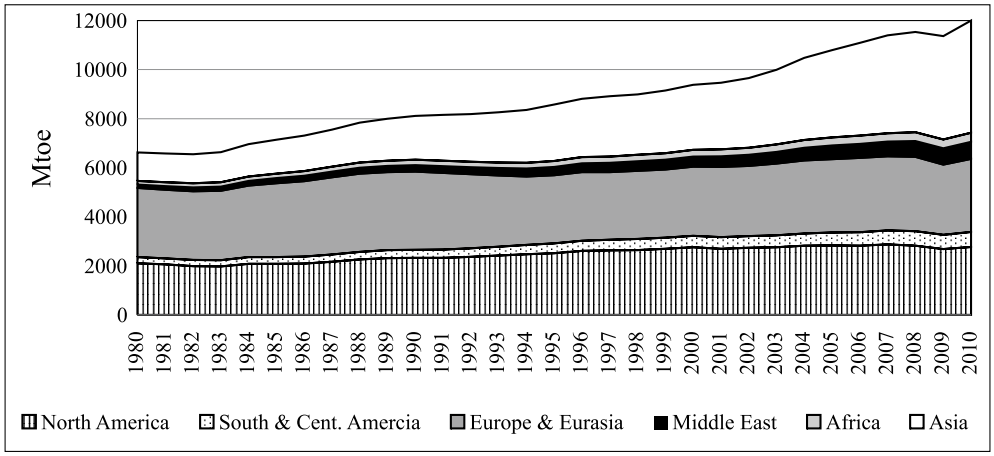


Fig. 1. The amount of primary energy consumption by region
(own work on the basis of BP 2002–2011)

Rys. 1. Wielkość zużycia energii pierwotnej w poszczególnych regionach świata
(opracowanie własne na podstawie: BP 2002–2011)

1. Natural gas resources

World's natural gas resources as well as other energy carriers reserves are located unevenly. The proved natural gas reserves in the world in 2010 was about 187 tcm and in comparison with 2000, when the volume of reserves was ca. 154 tcm, the increase of about 21% was observed (BP 2002–2011). The Middle East is the region where the greatest quantity of proved natural gas reserves occur; the quantity of these reserves account for about 40% of the total world's reserves. In 2010 the quantity of proved reserves in the Middle East increased by about 28% in comparison with 2009 (59.1 tcm). Eurasia is the second region of the world with regard to the proved reserves of natural gas. There are about 34% of the world's reserves in this area, i.e. 63.1 tcm. The increase in the volume of these reserves from the level of 55.9 tcm, i.e. by 12.7% was noticed. Other regions of the world with regard to the quantity of proved natural gas reserves are: Asia, North America, South and Central America. The proved natural gas reserves are, respectively: 16.2 tcm, which accounts for 8.7% of the world's reserves, 14.7 tcm – 7.9% of the world's reserves, 9.9 tcm – 5.3% of the world's reserves and 7.4 tcm – 4% of the world's reserves. The following changes of proved reserves observed in these regions and compared to 2000: Asia – increase of about 31.8% (12.3 tcm), Africa – increase of about 18.1% (12.5 tcm), North America – increase of about 31.7% (7.5 tcm), South and Central America – increase of 7.7% (6.9 tcm) (BP 2002–2011). The quantity and the location of the natural gas world's reserves in 2000–2010 is shown in Fig. 2.

While discussing the natural gas world's reserves, the unconventional deposits of natural gas should be mentioned. The world's reserves in such deposits are estimated to be

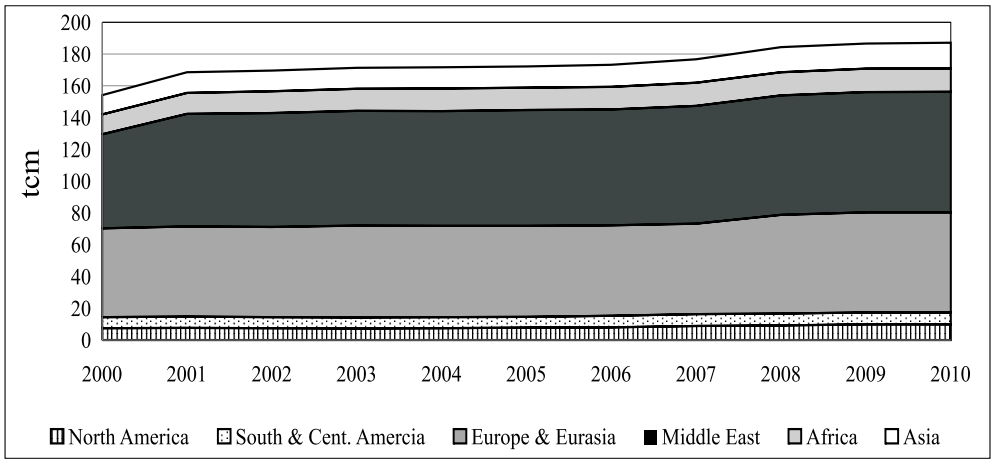


Fig. 2. Amount of proved natural gas reserves by region, 2000–2010
(own work on the basis of BP 2002–2011)

Rys. 2. Wielkość udokumentowanych zasobów gazu ziemnego w poszczególnych regionach świata w latach 2000–2010 (opracowanie własne na podstawie: BP 2002–2011)

about 650 tcm and the main location of these deposits is in the area of America, Asia and Pacific and the Middle East (Janusz, Szurlej 2009).

Together with the increasing quantity of natural gas reserves, the volume of production of this fuel is also growing. In 2010, the volume of natural gas production in the world amounted to 3193.3 bcm and it was higher in comparison with 2000 by 32% (2413.4 bcm) (BP 2002–2011). While analyzing the natural gas production by region, the situation is as follows (Fig. 3). The leading region in the natural gas production is Eurasia with the production of 1043.11 bcm of gas in 2010, which accounts for about 32.6% of the world's production. Compared to 2000, the increase of 11.1% (938.9 bcm) was noticed. Another world region with regard to the production is North America with the production of 8261.3 bcm of gas, which accounted for 26% of the world's production. Compared to the year 2000, the increase of 8.2% (763.7 bcm) was observed. Asia is the third region with regard to the gas production. In 2010 493.2 bcm of gas were produced, which accounted for 15.4% of the world's production. Compared to 2000, the increase of production in this region was as much as 81.2% (272.1 bcm). Other world regions classified with regard to the natural gas production are, respectively: the Middle East, Africa, South and Central America. In 2010 in the Middle East 460.1 bcm of gas were produced, which accounted for 14.4% of the world's production. The exploitation of natural gas deposits in Africa was 209 bcm, which accounted for about 6.5% of the world's supply while from the deposits located in the area of South and Central America was 161 bcm of gas supplied to the world markets, which accounted for 5% of the world's production (BP 2002–2011).

While analyzing the quantity of proved natural gas reserves and its production in selected regions of the world, the consumption of this fuel should also be mentioned. Natural gas

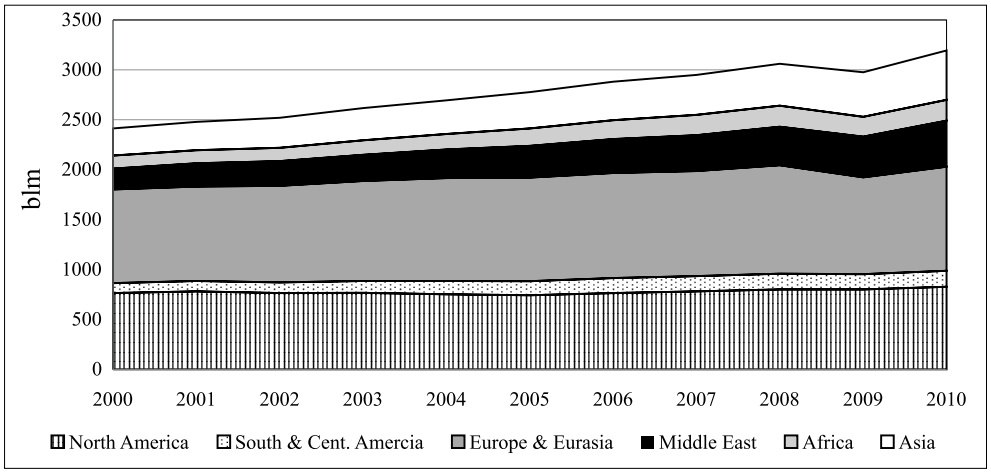


Fig. 3. Volume of natural gas production, 2000–2010
(own work on the basis of: BP 2002–2011)

Rys. 3. Wielkość wydobycia gazu ziemnego w poszczególnych regionach świata w latach 2000–2010
(opracowanie własne na podstawie: BP 2002–2011)

consumption in the world in 2010 amounted to 3169 bcm. Compared to 2000, the consumption of gas increased by over 31.4% (2411.7 bcm) (BP 2002–2011). Eurasia was the region with the greatest consumption – 1137.2 bcm, which accounts for 35.8% of the world's consumption. Another region with regard to the natural gas consumption was North America with the consumption of 846.1 bcm of gas, which accounts for 27% of the world's consumption. Other regions classified with regard to the natural gas consumption are: Asia – 565.6 bcm (17.9%), the Middle East – 365.5 bcm (11.5%), South and Central America – 147.7 bcm (4.7%) and Africa – 105 bcm (3.3%) (Fig. 4).

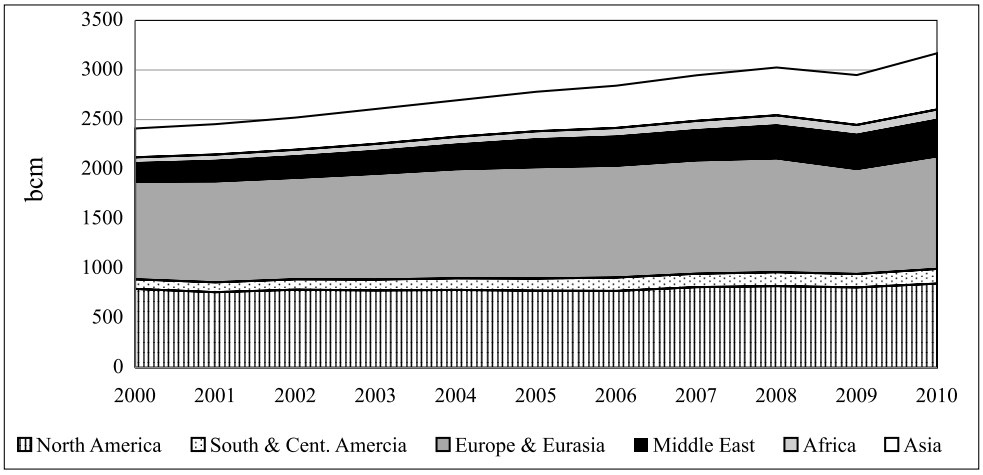


Fig. 4. Natural gas consumption by region, 2000–2010
(own work on the basis of: BP 2002–2011)

Rys. 4. Zużycie gazu ziemnego w poszczególnych regionach świata w latach 2000–2010
(opracowanie własne na podstawie: BP 2002–2011)

On account of the differences in location of proved natural gas reserves comparing to the regions where it is used, in recent years, the considerable development of technologies can be observed enabling natural gas transport from the places it is produced to the places it is consumed otherwise than using the 'traditional' ways of natural gas distribution, i.e. a gas pipelines. The pipeline transport of natural gas is considered to be the most economical, however it has its complexity and some limitations (Janusz, Szurlej 2009; Trzop 2005). Among limitations the long-term arrangements between the natural gas recipients and the suppliers need to be mentioned. Moreover, after building the pipeline there exist some limitations which unable the increase its capacity.

2. Technologies of natural gas deposits development

Although in recent years there has been a significant growth of natural gas production, the proved reserves of this fuel also increase. Due to the technological progress in geophysical

and drilling methods, the growth of proved reserves quantity is possible which enables the exploration and availability of the new hydrocarbon deposits in the regions considered to be inaccessible. It should be emphasized that the part of natural gas deposits, explored as a result of technological progress, was discovered in the regions which were considered to be inaccessible. Taking into account the fact that in many cases these deposits are located in a considerable distance from the existing transportation routes of the fuel, the development modern of technologies allow to exploit these deposits effectively. The main technologies aiming to develop gas deposits located in the distant regions and small deposits, partly exploited and located within a considerable distance from the pipeline transmition systems, are as follows (Janusz 2011):

— Compressed Natural Gas (CNG),
— Gas To Liquid (GTL),
— Gas By Wire (GBW),
— Liquefied Natural Gas (LNG).

Compressed Natural Gas – is made by compressing natural gas at ambient temperature up to the pressure of 250–276 bar. Natural gas is compressed up to the required pressure and then injected into special modules on the board of ships. These modules consist of single cylinders adapted to keep appropriate pressure. Both loading and unloading the CNG tankers may take place while anchoring to the wharf or with the use of buoys located in some distance from the shore. CNG technology is now at the stage of development and the first projects should be implemented in 2011. One of the advantages of this technology is significantly lower investment cost in comparison with the LNG technology.

Gas To Liquid – technology using the Fischer-Tropsch process enabling the conversion of natural gas into a superior quality petroleum products such as: light petroleum distillates, fuel oil, jet fuel, engine oil, paraffin wax. GTL technology supports and even supplants the LNG because of the easier transport and storage of products and, in a longer term, lower the production costs. GTL technology is applied for exploitation the less cost-effective deposits but can also be used in system deposits. It need to be emphasized that fuels produced in this technology are less contaminated with impurities than the typical fuels produced from the crude oil.

Liquefied Natural Gas (LNG) – at present this technology is essential to the natural gas transport. The gas liquefaction technology was developed by Carl von Linde in 1855. Natural gases consisting mostly of methane (up to 98%) after liquefaction diminish their capacity by ca. 600–630 times. It is very profitable from transport economics the point of view, however it should be borne in mind that liquefied gas need to be kept at a temperature of –161.6°C. The first natural gas liquefaction plant was built in the USA in 1941 and the first waterway transport project for transporting liquefied gas was developed in 1954 also in the USA. LNG was to be shipped in specially separated containers placed on the barges which were to be pulled by tugboats on the Mississippi River and the system of canals. According to the analysis conducted, this form of transport was to be more

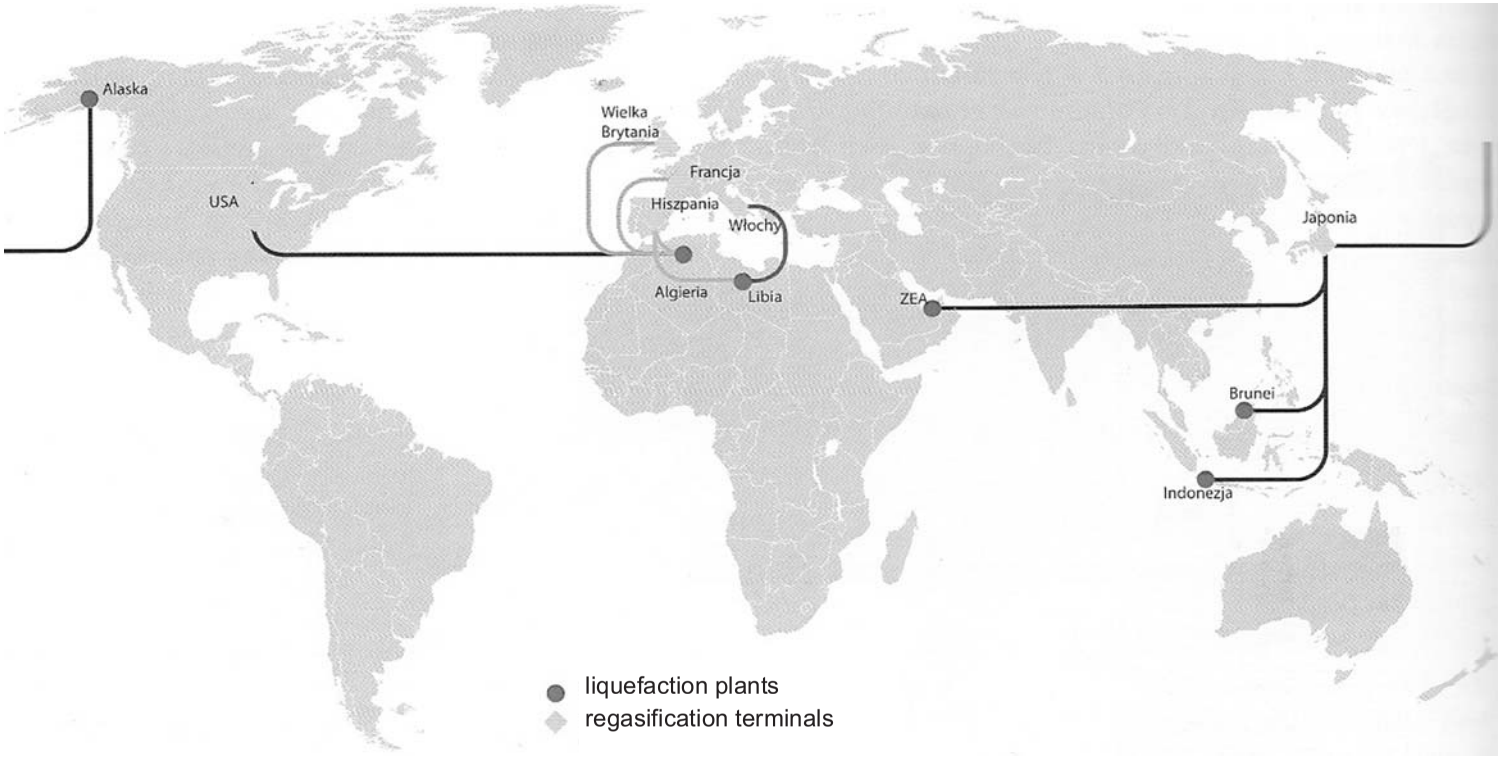


Fig. 5. Liquefied natural gas market in 1980 (Janusz, Szurlej 2009)

Rys. 5. Rynek skroplonego gazu ziemengo w 1980 roku (Janusz, Szurlej 2009)

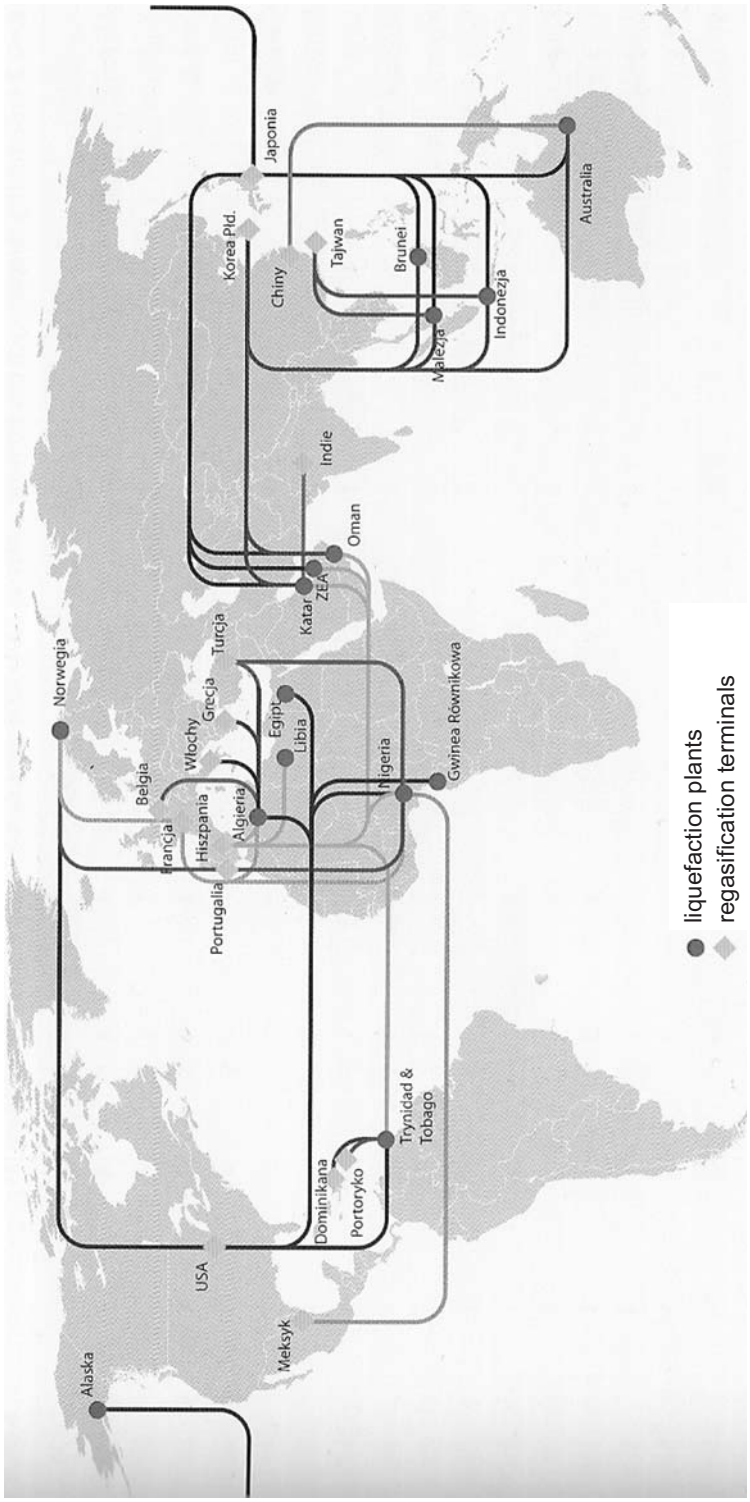


Fig. 6. Liquefied natural gas markets in 2007 (Janusz, Szurlej 2009)

Rys. 6. Rynek skroplonego gazu ziemnego w 2007 roku (Janusz, Szurlej 2009)

economical than building a pipeline. There were only a few LNG test-transits on the river since the authorities claimed that the containers structure on the barges was not safe enough. However, gained experience allowed to introduce LNG ship-borne transport (Janusz 2011). In 1959 the first LNG ship-borne transport took place. The ship "Methane Pioneer" set off to England from the North American Lake Charles harbor with 5000 cm of LNG (Trzop 2005). However, it was a rebuilt ship and earlier it had served other purposes. The first ships especially designed to LNG transport were "Methane Princess" and "Methane Progress". In 1964 they began the liquefied natural gas deliveries from Arzew in Algieria to England. Since then a regular growth of the volume of natural gas sent in a liquefied form occurred. The LNG transportation routes by sea from the places where the liquefaction took place to its recipients are shown in the Figuures 5 and 6. While analyzing the pictures, a significant growth of the number of both exporters and importers of the natural gas delivered in a liquefied form can be observed. It is also noteworthy that from 1980 to 2007 the distances to which LNG is transported increased considerably.

The analysis conducted by gas companies reveals that the effectiveness of LNG transport by pipelines diminishes rapidly with the increase the distances in which gas is transmitted. The analysis presents that transmitting gas by pipelines from the places of its exploitation to the places of its consumption is the most profitable to the distance of about 2200 km. If the distance is longer, the transmission of liquefied natural gas (LNG) is more effective. It should be emphasized that in case of liquefied natural gas the transport effectiveness lowers only slightly with grawing distance (Fig. 7).

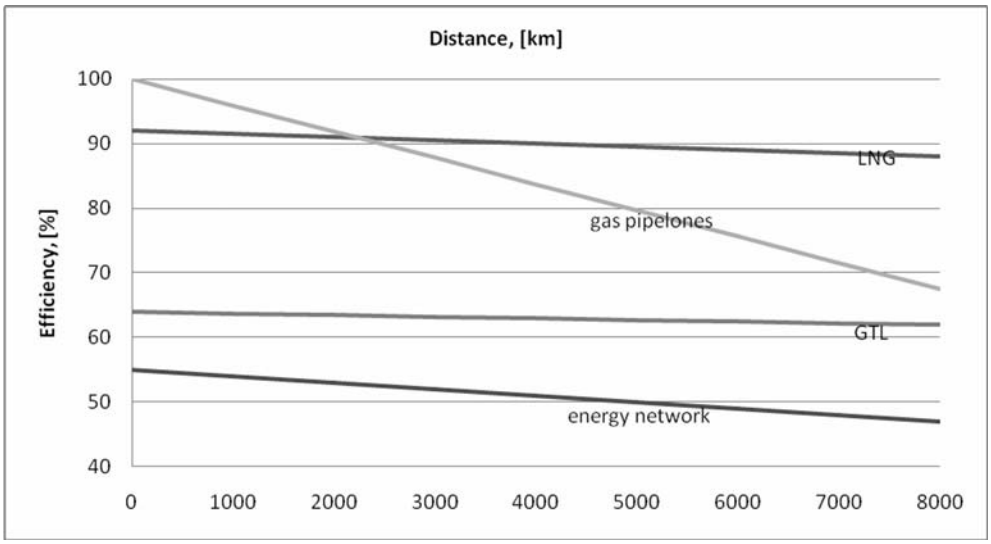


Fig. 7. Gas and its products mass transmission effectiveness by different means of transport (Janusz, Szurlej 2009)

Rys. 7. Efektywność przesyłu masowego gazu i jego produktów różnymi środkami transportu (Janusz, Szurlej 2009)

3. Characteristics of natural gas production and demand

According to the forecasts of International Energy Agency (IEA) published in 2011 in the New Policies Scenario, the world's demand for primary energy in 2035 will be 16.9 bln toe which will account for the increase of 36% in comparison to 2008. An average annual growth should be 1.2%. In the Current Policies Scenario it is planned that the average growth of primary energy consumption will be 1.4% annually. In scenario 450, the increase in demand for the primary energy will be only by 0.7% per year. Fossil fuels – crude oil, natural gas and coal – remain the dominant sources of energy in every of these three scenarios. Nevertheless, their share in the total primary fuels balance vary considerably (World Energy Outlook 2011). In Table 1 the IEA forecasts of the energy balance structure in 2035 are presented.

TABLE 1

World primary energy demand by scenario [Mtoe]
(World Energy Outlook 2011)

TABELA 1

Światowe zapotrzebowanie na nośniki energii pierwotnej według poszczególnych scenariuszy [Mtoe]
(World Energy Outlook 2011)

Specifity	New Policies Scenario		Current Policies Scenario		450 Scenario	
	2020	2035	2020	2035	2020	2035
Coal	4 083	4 101	4 416	5 419	3 716	2 316
Oil	43 384	4 645	4 482	4 992	4 182	3 671
Gas	3 214	3 928	3 247	4 206	3 030	3 208
Nuclear	929	1 212	908	1 054	973	1 664
Hydro	377	475	366	442	391	520
Biomass and waste	1 495	1 911	1 449	1 707	1 554	2 329
Other renewables	287	690	256	481	339	1 161
Total	14 769	16 961	15 124	18 302	14 185	14 870

Due to a growing interest in natural gas and changes in climatic policy of the developing countries, in 2011 International Energy Agency published another forecast of energy carriers consumption, that anticipated the growing natural gas significance. It is evident from the scenario presented in 2011 that from 2010 the consumption of natural gas will rise by more than 50% and in 2035, the share of natural gas in the world's structure of primary energy consumption will be over 25% (World Energy Outlook 2011 – Special Report).

TABLE 2

World primary energy demand by Gas Scenario [Mtoe]
(World Energy Outlook 2011 – Special Report)

TABELA 2

Światowe zapotrzebowanie na nośniki energii pierwotnej według Scenariusza Gazowego
(World Energy Outlook 2011 – Special Report)

Specifity	2008 Demand [Mtoe]	2008 Share in energy mix [%]	GAS Scenario		New Policies Scenario WEO – 2010	
			2035 Demand [Mtoe]	2035 Share in energy mix [%]	2035 Demand [Mtoe]	2035 Share in energy mix [%]
Coal	3 315	27	3 666	22	3 934	23
Oil	4 059	33	4 543	27	4 662	28
Gas	2 596	21	4 244	25	3 748	22
Nuclear	712	6	1 196	7	1 273	8
Hydro	276	2	477	3	476	3
Biomass	1 225	10	1 944	12	1 957	12
Other renewables	89	1	697	4	699	4
Total	12 272		16 767		16 749	

As it is shown in Table 4, in North America the increase of production is predicted. It will be possible mainly thanks to exploitation from the unconventional resources.

To cover steadily growing demand for primary energy it is necessary to deliver the fossil energy carriers to the place where there is a demand for it. Taking into account the increase in the natural gas consumption and the fact that the deposits exploited at present diminish regularly and also that the recently proved reserves occur in the remote regions of the world, it is obvious that there is a great interest in technologies enabling gas transport without the necessity of incurring considerable costs on pipeline construction.

As it has been mentioned before, from 2000 to 2010 the increase of the world's gas consumption was ca. 31% (BP 2002–2011). Certain part of this fuel was delivered either by pipelines or in the form of LNG to the countries which are in no possession of their own reserves. In 2001 the volume of gas transmitted by pipelines for commercial purposes was 411.32 bcm and in 2010 this volume increased to 677.59 bcm. The observed growth of the volume of gas transmitted by pipelines was almost 64%. In 2001, the world's LNG trade was 142.95 bcm whereas in 2010 this quantity increased of about 108% up to the volume of 207.63 bcm (Fig. 8) (BP 2002–2011: (Siemek et al. 2011b).

TABLE 3

Primary natural gas demand by region in the Gas Scenario [bcm]
(World Energy Outlook 2011 – Special Report)

TABELA 3

Zużycia gazu ziemnego według regionu zgodnie ze Scenariuszem Gazowym [mld m^3]
(World Energy Outlook 2011 – Special Report)

Specifity	2008	2015	2020	2025	2030	2035	2008–2035*	Change vs. NSP 2035**
OECD	1 540	1 615	1 690	1 773	1 865	1 950	0.9%	192
North America	815	841	872	924	986	1 052	0.9%	138
United States	662	661	668	700	741	786	0.6%	122
Europe	555	574	608	636	653	667	0.7%	38
Pacific	170	200	210	213	226	231	1.1%	15
Japan	100	118	122	123	127	127	0.9%	10
Non-OECD	1 608	2 070	2 328	2 612	2 913	3 183	2.6%	405
E.Europe/Eurasia	701	755	786	824	857	876	0.8%	38
Russia	453	474	487	504	522	528	0.6%	25
Asia	341	576	715	864	1 049	1 244	4.9%	309
China	85	247	335	430	535	634	7.7%	239
India	42	81	104	134	176	234	6.5%	57
Middle East	335	428	470	536	592	632	2.4%	23
Africa	100	139	154	164	170	173	2.1%	9
Latin America	131	172	203	224	245	258	2.5%	26
Brazil	25	48	66	76	88	98	5.1%	21
World	3 148	3 685	4 018	4 385	4 778	5 133	1.8%	597
European Union	536	553	587	609	612	636	0.6%	38

* Compound average annual growth rate.
** NSP is New Policies Scenario.

TABLE 4

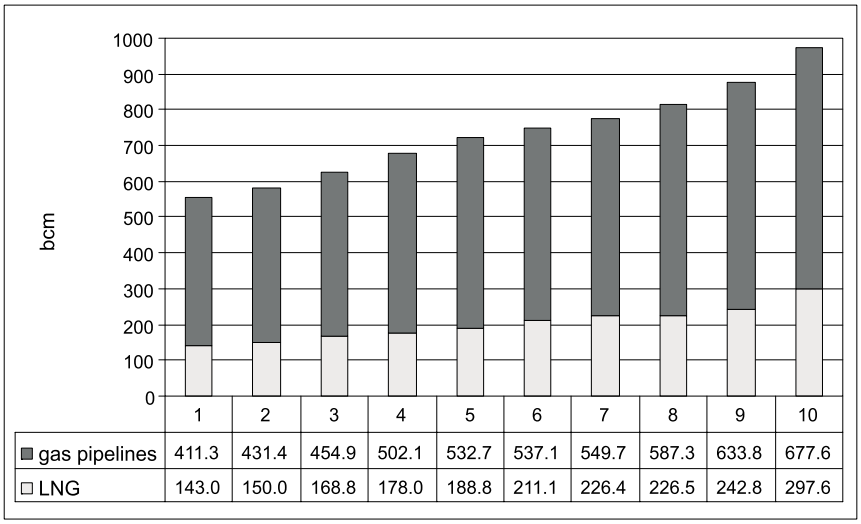
Natural gas production by region in the Gas Scenario [bcm]
(World Energy Outlook 2011 – Special Report)

TABELA 4

Wydobycie gazu ziemnego według regionu zgodnie ze Scenariuszem Gazowym [mld m^3]
(World Energy Outlook 2011 – Special Report)

Specifity	2008	2015	2020	2025	2030	2035	2008–2035*	Change vs. NSP 2035**
OECD	1 157	1 176	1 237	1 280	1 342	1 404	0.7%	216
North America	797	805	837	891	961	1 035	1.0%	189
Canada	175	149	166	184	189	192	0.3%	18
United States	575	608	618	647	709	779	1.1%	173
Europe	307	281	270	250	232	213	–1.4%	6
Norway	102	106	114	123	128	127	0.8%	5
Pacific	53	90	130	139	149	156	4.1%	21
Australia	45	84	126	136	147	155	4.7%	21
Non-OECD	2 010	2 510	2 781	3 105	3 435	3 727	2.3%	381
E.Europe/Eurasia	886	967	1 019	1 136	1 203	1 257	1.3%	80
Russia	662	706	720	801	842	881	1.1%	67
Turkmenistan	71	83	104	116	127	136	2.4%	8
Asia	376	512	604	673	748	823	2.9%	170
China	80	137	185	222	264	303	5.0%	119
India	32	67	88	102	119	135	5.5%	34
Indinesia	74	87	95	102	109	119	1.8%	9
Middle East	393	550	594	657	793	917	3.2%	116
Iran	130	143	154	179	226	279	2.9%	44
Qatar	78	166	182	197	238	260	4.5%	35
Saudi Arabia	74	95	100	107	125	139	2.3%	15
Africa	207	288	331	386	415	438	2.8%	3
Algieria	82	121	136	156	163	168	2.7%	6
Nigeria	32	42	57	79	102	119	5.0%	6
Latin America	148	193	233	253	276	292	2.6%	12
World	3 167	3 686	4 018	4 385	4 777	5 131	1.8%	597
European Union	216	185	165	136	113	93	–3.1%	0

* Compound average annual growth rate.
** NSP is New Policies Scenario.



	1	2	3	4	5	6	7	8	9	10
gas pipelines	411.3	431.4	454.9	502.1	532.7	537.1	549.7	587.3	633.8	677.6
LNG	143.0	150.0	168.8	178.0	188.8	211.1	226.4	226.5	242.8	297.6

Fig. 8. Share of liquefied natural gas in world gas trade (BP 2002–2011)

Rys. 8. Udział skroplonego gazu ziemnego w światowym handlu gazem (opracowanie własne na podstawie: BP 2002–2011)

4. LNG Suppliers

From 2001 to 2010, 16 countries supplied liquefied natural gas to the world markets. In 2001 23 gas liquefaction plants were operating and 10 years later 29 gas liquefaction plants were operating (Natural Gas Information 2002–2011). In Tables 5 and 6 the number of gas liquefaction plants and their liquefaction capacity by countries is shown.

The volume of LNG traded worldwide by selected countries varis significantly. In 2001 over 142 bcm of natural gas in a liquefied form was exported. It is noteworthy that the main exporter was Indonesia – over 22% of produced LNG. Taking into con- sideration the export growth, Indonesia remained the leader until 2005. Since 2006, as a result of new gas liquefying plants commissioned, Qatar has been a leading country exporting LNG worldwide (over 14%) (BP 2002–2011; Natural Gas Information 2002–2011). In 2010 the LNG supply structure was as follows: Qatar – 26%, Indonesia – 11%, Malaysia – 10%, Australia – 9%, Nigeria – 8%, Trinidad & Tobago – 7%, Algieria – 6%, Russia – 5%, Oman – 4%, Egypt – 3%, Brunei – 3%, United Arab Emirates – 3%, Yemen – 2%, Guinea – 2%, Norway – 2%, Peru – 1%, USA – 0.3%, Libya – 0.1% (World LNG Report 2010; Natural Gas Information 2002–2011).

In Table 7 the detailed list of LNG supply countries are presented.

Additional analysis of selected countries liquefaction capacities and the quantity of LNG supplied worldwide shows that the anticipated liquefaction capacities over the period from 2001 to 2010 were used in ca. 86% (Natural Gas Information 2002–2011).

TABLE 5

Number of natural gas liquefaction plants in 2001–2010
(own work on the basis of: Natural Gas Information 2002–2011)

TABELA 5

Liczba instalacji skraplających gaz ziemny w okresie 2001 – 2010 roku
(opracowanie własne na podstawie: Natural Gas Information 2002–2011)

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Algeria	4	4	4	4	4	4	4	4	4	4
Australia	1	1	1	1	1	2	2	3	2	2
Brunei	1	1	1	1	1	1	1	1	1	1
Egypt	0	0	0	0	2	2	2	2	2	2
Equatorial Guinea							1	1	1	1
Indonesia	8	9	7	2	2	2	2	2	3	3
Libya	1	1	1	1	1	1	1	1	1	1
Malaysia	2	2	3	3	3	3	3	3	3	3
Nigeria	1	1	1	1	1	1	1	3	1	1
Norway							1	1	1	1
Oman	1	1	1	1	1	1	1	2	1	1
Qatar	2	2	2	2	2	2	2	3	3	3
Peru										1
Russia									1	1
Trynidad & Tobago	1	1	1	1	1	1	1	1	1	1
U.A.E.			1	1	1	1	1	1	1	1
USA	1	1	1	1	1	1	1	1	1	1
Yemen									1	1
Total	23	24	24	19	21	22	24	29	28	29

5. LNG Recepients

According to information published by IEA, at end-2010 natural gas in a liquefied form was supplied to 22 countries which in total had 81 regasification terminals. The total regasification capacity of these terminals achieves 847 bcm per annum (Natural Gas Information 2002–2011). During the past 9 years, the number of regasification terminals increased by over 100%. At present, about 30% of operating LNG terminals is located in

TABLE 6

Liquefaction capacities of selected countries
(own work on the basis of: Natural Gas Information 2002–2011)

TABELA 6

Zdolności skraplające posiadane przez poszczególne państwa
(opracowanie własne na podstawie; Natural Gas Information 2002–2011)

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Billion cm per year of gas									
Algeria	27.5	31.6	34.9	26.8	27.7	27.7	27.7	27.6	27.5	27.5
Australia	10.3	10.3	10.2	16.0	16.0	27.3	27.3	25.5	25.6	26.9
Abu Dhabi	7.4	7.4								
Brunei	9.2	9.2	9.8	9.8	9.8	9.8	9.8	9.8	9.8	9.8
Egypt					16.4	16.6	16.6	16.6	16.6	16.6
Equatorial Guinea							5	5.0	5.0	5.0
Indonesia	42.3	46.8	39.4	39.6	39.6	36.8	36.8	36.7	36.8	36.8
Libya	3.6	3.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Malaysia	21.0	21.0	30.3	30.3	30.3	31.0	31.0	30.8	30.9	30.9
Nigeria	8.0	12.2	13.1	13.8	19.0	24.2	24.2	29.5	29.5	29.5
Norway							5.8	5.4	5.8	5.8
Oman	9.0	9.0	10.0	9.6	14.7	15.0	15.0	14.6	14.6	14.6
Qatar	16.9	19.4	20.3	27.4	35.3	35.3	35.3	41.7	73.4	94.1
Peru										6.1
Russia									13.0	13.0
Trinidad & Tobago	3.9	8.7	13.5	13.9	20.2	20.2	20.2	20.5	20.5	20.5
U.A.E.			7.8	7.6	7.6	7.6	7.6	7.6	7.6	7.6
USA	1.8	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Yemen									4.6	9.1
Total	160.9	181.0	192.0	197.5	239.3	254.2	265	274.0	313	340

Japan. Another country with regard to the number of terminals is the USA – 11 terminals, followed by Spain and China with 6 terminals each and Great Britain and South Korea with 4 terminals each. The detailed list of the number of terminals and their regasification capacities by countries is presented in Tables 8 and 9. The regasification capacities in selected countries vary considerably. It depends on how important the liquefied natural gas for the energy economy of a given country is. Japan, the USA and Korea hold the majority of the world's LNG regasification capacity. The total regasification capacity of 27 receiving

TABLE 7

Volume of LNG supplied worldwide by country
(own work on the basis of: BP 2002–2011)

TABELA 7

Wielkość LNG dostarczonego na światowe rynki przez poszczególne kraje
(opracowanie własne na podstawie: BP 2002–2011)

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	bcm									
USA	1.79	1.70	1.64	1.68	1.84	1.72	1.18	0.97	0.86	1.64
Trinidad & Tobago	3.65	5.32	11.91	13.99	14.01	16.25	18.15	17.36	19.74	20.38
Peru										1.82
Norway							0.14	2.19	3.17	4.71
Russia									6.61	13.40
Oman	7.43	7.96	9.21	9.03	9.22	11.54	12.17	10.90	11.54	11.49
Qatar	16.54	18.59	19.19	24.06	27.10	31.09	38.48	39.68	49.44	75.75
U.A.E.	7.08	6.85	7.11	7.38	7.14	7.08	7.55	7.54	7.01	7.90
Algieria	25.54	26.88	28.00	25.75	25.68	24.68	24.67	21.87	20.90	19.31
Egypt					6.93	14.97	13.61	14.06	12.82	9.71
Equatorial Guinea							1.42	5.18	4.72	5.16
Libya	0.77	0.63	0.75	0.63	0.87	0.72	0.76	0.53	0.72	0.34
Nigeria	7.83	7.84	11.79	12.59	12.04	17.58	21.16	20.54	15.99	23.90
Australia	10.20	10.03	10.52	12.17	14.85	18.03	20.24	20.24	24.24	25.36
Brunei	9.00	9.14	9.67	9.50	9.15	9.81	9.35	9.20	8.81	8.83
Indonesia	31.80	34.33	35.66	33.49	31.46	29.57	27.74	26.85	26.00	31.36
Malaysia	20.91	20.52	23.39	27.68	28.52	28.04	29.79	29.40	29.53	30.54
Taiwan	0.41									
Yemen									0.42	5.48
Total	142.95	149.79	168.84	177.95	188.81	211.08	226.41	226.51	242.50	297.10

terminals operating in Japan is 264 bcm per annum. Such a significant number of terminals results from the fact that Japan do not have any pipeline connection with the potential gas suppliers. Japanese economy is based on the LNG supplies. Other countries of a considerable number of terminals are the USA with 11 terminals of a regasification capacity of 157.9 bcm per annum and Spain possesing 6 operating terminals of a regasification capacity of 63.3 bcm per annum. Also Korea is one of the major countries operating on the LNG market – 4 terminals of a regasification capacity of 110 bcm per annum (BP 2002–2011; Natural Gas Information 2002–2011).

TABLE 8

Number of regasification terminals
(own work on the basis of: Natural Gas Information 2002–2011)

TABELA 8

Liczba instalacji regazyfikujących
(opracowanie własne na podstawie: Natural Gas Information 2002–2011)

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Argentina									1	1
Belgium	1	1	1	1	1	1	1	1	1	1
Brazil									2	2
Canada									1	1
Chile									1	2
China	1	1	1	1	1	2	2	4	6	6
Dominican Republic			1	1	1	1	1	1	1	1
Dubai										1
France	2	2	2	2	2	2	2	2	3	3
Greece	1	1	1	1	1	1	1	1	1	1
India					2	2	2	2	2	2
Italy	1	1	1	1	1	1	1	1	2	2
Japan	24	24	25	25	26	27	27	30	27	27
Korea	2	3	3	3	4	4	4	4	4	4
Kuwait									1	1
Mexico						1	1	2	2	2
Portugal			1	1	1	1	1	1	1	1
Puerto Rico	1	1	1	1	1	1	1	1	1	1
Spain	3	3	4	4	4	5	6	6	6	6
Turkey	1	1	1	1	1	2	2	2	2	2
United Kingdom					1	1	1	2	4	4
USA	3	3	4	4	4	5	5	9	9	11
Total	40	41	46	46	51	57	58	69	77	81

As it has been mentioned before, the number of terminals and their regasification capacity is dependent on the primary energy balance structure of a given country. Two opposite approaches can be distinguished. According to the first approach, almost entire volume of natural gas consumed in a given country is supplied in a liquefied form (Japan is the example here since almost 100% of consumed gas is supplied in a liquefied form). According to the

second approach, regasification terminals serve as a security in case any disturbances in the pipeline transmission of gas occur (BP 2002–2011). Thus, the constant flow of gas supplies is possible.

TABLE 9

Regasification capacities by country
(own work on the basis of: Natural Gas Information 2002–2011)

TABELA 9

Zdolności regazyfikacyjne poszczególnych państw
(opracowanie własne na podstawie: Natural Gas Information 2002–2011)

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	billion cm per year of gas									
Argentina									3.2	3.2
Belgium	5.3	5.3	5.3	5.5	5.5	5.5	5.5	9.5	9.5	9.5
Brazil									7.9	7.9
Canada									10.6	10.6
Chile									3.9	6
China	6.3	6.3	24.3	24.3	24.3	29.5	29.5	42.9	44.5	47.2
Dominican Republic			2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Dubai										3.2
France	15.3	15.3	17.3	16.4	18	18	18	18	26.6	25.1
Greece	2.2	2.2	2.2	2.5	1.4	1.4	1.4	1.4	5.3	5.3
India					11.1	10.9	11	11	16.8	16.8
Italy	3.7	3.7	3.5	3.5	3.5	3.5	3.5	3.5	11.9	11.9
Japan	233	241.1	242.9	240.7	243.6	251.4	254.7	252.6	263.4	264.2
Korea	49.9	69.1	69.3	79.3	103.6	84.8	101.2	107.6	110	110
Kuwait									7.5	7.5
Mexico						5.6	7.1	19.1	19.1	19.1
Portugal			5.8	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Puerto Rico	4	4	4	4	4	4	4	4	4	4
Spain	16.1	18.3	27.1	31.2	39.3	52.2	57.4	60.5	63.3	63.3
Turkey	1.7	6.5	6.3	6.5	6.5	12.8	12.8	12.8	12.9	12.9
United Kingdom					4.9	4.9	4.9	19.1	47.6	53.9
USA	16.5	16.5	26.6	31.1	47.2	51.9	53.3	114.1	162.3	157.9
Total	354	388.3	437.1	452.9	520.8	544.3	572.2	684	838	847

While analyzing data from Table 9, it becomes evident that in case of European countries the largest growth of regasification capacities can be noticed in Spain and Great Britain. Comparing Tables 6 and 9, in the USA there are both liquefaction plants as well as regasification terminals. The capacity of the latter is definitely larger than that of liquefaction capacity plants. However, bearing in mind the growth of gas exploited from the unconventional deposits, thus the USA being the world leader in natural gas production, the investments in gas liquefaction plants construction can be expected in upcoming years (Siemek et al. 2011). The confirmation of it can be the agreement signed between the Spanish company Gas Natural Fenosa and the North American company Cheniere Energy. By virtue of this agreement, the American company is to supply gas to Spain, the quantity of which is to amount 5 bcm per annum, starting from 2017. The American company is planning the construction of a gas liquefaction plant near Cameron Parish, Louisiana. The plant is to use, among others, shale gas resources from Haynesville Shake deposit.

Conclusion

As a result of natural gas deposits regular exploitation, initiating the production from the deposits not yet developed and oftentimes located in the remote world regions becomes indispensable. In connection with the fact that the produced gas needs to be supplied, application of technologies allowing the most effective gas supply to the receipients becomes necessary. At present, LNG technology allows transport of considerable quantities of gas to the remote destinations. It also makes shipping the gas in the specially constructed tankers possible. Application of this technology enables a fast diversification of both the sources as well as the directions of gas supplies. At present, there exist some limitations in the LNG availability due to the lower natural gas liquefaction capacity in comparison with the regasification capacities. Taking into account certain environmental aspects, natural gas consumption will be increasing and therefore the development of a gas transmission infrastructure, particularly liquefaction and regasification plants, will become necessary.

As a result of a further development of this technology, the drop in investment costs considering the construction of the infrastructure will be extremely probable. The lowering investment costs will be the additional driving factor allowing the construction of new plants and expanding the already existing ones.

Gainings from the experience of previous years when the LNG supplies on the European market under spot agreements, compared to under long-term agreements, were price competitive, serves as an additional argument for construction the LNG terminal in Świnoujście. Thanks to this investment, in 2014 Poland will join the countries importing gas in the LNG form. It is also of some probability that Poland may join the countries exporting gas in case when the quantity of a domestic gas production from the unconventional deposits rises.

It should be expected that the development of technologies allowing the exploitation of unconventional natural gas deposits will be an additional factor stimulating LNG world market expansion.

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ZNACZENIE TECHNOLOGII LNG W ZAGOSPODAROWYWANIU ŚWIATOWYCH ZŁÓŻ GAZU ZIEMNEGO

Słowa kluczowe

Gaz ziemny, gaz skroplony (LNG), zapotrzebowanie na energię pierwotną

Streszczenie

W ostatnich latach obserwuje się wzrost zapotrzebowania na energię pierwotną, a szczególnie na gaz ziemny, który znajduje szerokie zastosowanie zarówno jako nośnik energii, jak i ważny surowiec w przemyśle chemicznym. Pomimo dynamicznego rozwoju wykorzystania odnawialnych źródeł energii światowe zapotrzebowanie na energię pokrywane jest przede wszystkim przez kopalne nośniki energii pierwotnej, tj. węgiel, ropę naftową i gaz ziemny. Światowe zasoby gazu ziemnego są rozmieszczone nierównomiernie – największymi zasobami dysponuje Środkowy Wschód. Artykuł poświęcony jest głównie technologii LNG, która ogrywa coraz ważniejszą rolę w transporcie gazu ziemnego. Przybliżono głównych dostawców i odbiorców LNG oraz zaakcentowano najważniejsze zmiany jakie zaszły na rynku gazu skroplonego w ciągu ostatnich dziesięciu lat.

Key words

Natural gas, LNG, primary energy demand

Abstract

Increase of primary energy demands can be observed in last few years, especially it concerns the natural gas, which finds wide application as an energy carrier, as well as an important raw material in the chemical industry. Despite dynamic growth of usage of renewable sources of energy, the world demand for energy is covered mainly by fossil carriers of primary energy, such as coal, crude oil and natural gas. The world's natural gas deposits are located unevenly – mainly in Middle East. The article is dedicated mainly to LNG technology which starts to play more and more important role in the natural gas transport. The authors show the most important suppliers and receivers of LNG. Moreover, they present principal changes which took place in liquefied gas market in few recent years.