Risk-reducing problems of the Latvian gas supply

Juris Ekmanis, V. Zebergs and N. Zeltins*

Institute of Physical Energetics,
Latvian Academy of Sciences,
21 Aizkraukles Street, Riga, LV-1006, Latvia
Fax: 371 67557671
E-mail: fei@edi.lv
E-mail: zebergs@edi.lv
E-mail: zeltinsh@edi.lv
*Corresponding author

A. Davis

Latvian Gas Company, JSC 'Latvijas Gāze',
6 A. Briana Street, Riga, LV-1001, Latvia
E-mail: dace.voite@lg.lv

Abstract: This paper reviews the energy policy of Latvia as a part of the national economic policy. It describes the legislative situation in the Latvian energy sector, and discusses the measures for energy conservation policy and the tendencies of the main character parameters in the energy sector.

Keywords: energy; policy; consumption emissions; overview.

Reference to this paper should be made as follows: Ekmanis, J., Zebergs, V., Zeltins, N. and Davis, A. (2010) 'Risk-reducing problems of the Latvian gas supply', *Int. J. Global Energy Issues*, Vol. 34, Nos. 1/2/3/4, pp.78–90.

Biographical notes: Juris Ekmanis is the President of Latvian Academy of Science since 2004 and the President of National Energy Confederation since 1999. He graduated from the University of Riga in 1964 and subsequently gained the degrees of Dr. Phys. in 1973 and Dr. Habil. Phys. in 1984. He is the Director of the Institute of Physical Energetics and a Professor at Riga Technical University. He has held academic posts in different countries and is a member of numerous national and international scientific bodies. He has also published widely in the areas of energy production, conservation and risk management.

Viktors Zebergs graduated from the University of Latvia in 1951 and gained the degree of Dr. habil. Sc. Ing. in 1985. He is an Honoured President of Latvian Member Committee of World Energy Council, President of Latvian Association of Energy Economics (the Affiliate of the International Association of Energy Economics), Professor at Riga Technical University in Energy Economy, Chairman of Scientifically Council of Institute of Physical Energetics, member of Promotion Council P-12 of Riga Technical University, member of the Editorial Board of *Latvian Journal of Physics and Technical Sciences* and member of the Editorial Board of the journal *Energetika* (Lithuania).

Namejs Zeltins graduated from the University of Latvia in Theoretical Physics in 1966 and gained the degree of Dr. habil. Sc. Ing. in 1993. He is the Head of the Energy Efficiency Centre of Institute of Physical Energetics from 1994. His interests are in fuel and energy complex planning including renewables and nuclear energy; energy economy, efficiency and ecology; heat supply systems; gas supply systems and energy utilisation. His professional activities and memberships include: President of Latvian Member Committee/World Energy Council (WEC) since 2001; member of WEC Group Europe since 1990; member of Board at the National Energy Confederation since 2001. He has a total of 300 scientific publications.

Adrians Davis graduated from the Riga Technical University in 1964 and gained the degree of Dr. Sc. Ing. in 1997. He is the Chairman of the Board of Joint Stock Company 'Latvijas Gaze' since 1997. He has devoted his whole life to promote and make available natural gas to every customer in Latvia. His scientific activities are focused on efficient gas supply management with the emphasis on utilisation of underground gas storages, and most of the methods and knowledge developed by him are implemented into the real projects. He is the Vice President of the Latvian Member Committee of WEC.

1 Introduction

The most important risk-reducing measures of the gas supply (to avoid interruptions in supply) are connected with the development of the system of the gas pipelines (branching and looping of the pipes), creation of a large-capacity gas storage facility, and the expansion of the supply of liquefied natural gas (LNG). All these measures allow, to greater or lesser extent, the solution of diversified gas supply (a possibility to supply gas from several suppliers). The risk management depends on the efficiency of the measures (Ney et al., 2008a; Frormann, 2006a, 2006b; Mikelsons, 2006).

Use of LNG opens new perspectives for access to a wider market of gas and possibilities to buy gas from different suppliers at the best price. With the LNG terminals expanding and the fleet of LNG tankers growing, LNG prices will approach the price of the pipeline gas. A project for an LNG terminal is being discussed in Latvia (the central country in the Baltic region). Latvia has a well-developed gas network that is connected to the gas network of the Russian Federation and high-capacity underground gas storage (UGS) facility. The economic profit of the LNG terminal depends on the possibilities of its use both for the import and export of gas (export of the Russian gas through the Latvian LNG terminal). The UGS would allow for flexibility in the purchase of gas when LNG has good prices in the market, as well as to raise the reliability of the Latvian gas supply under conditions when the Russian gas pipeline is damaged. Considering the fact that the Latvian gas pipelines have good links with both neighbouring countries Estonia and Lithuania, the efficiency of the LNG terminal and the Latvian UGS would increase if used together by all the three Baltic countries. In the future, connection of the Finnish network to the Baltic gas networks is also expected. Finland has shown interest in the use of the Latvian UGS (Davis et al., 2006).

2 Background

Latvia and all the neighbouring countries are supplied with gas only from one supplier – the Russian Federation. According to estimates done by specialists of OAO 'Giprospecgaz' in their feasibility study regarding regional development of gas supply system in Baltic countries, Northwest Russia and Finland, the needs for natural gas by 2015 will reach in Latvia 2.8×10^9 m^3, in Latvia, 5.25×10^9 m^3 in Lithuania, 1.37×10^9 m^3 in Estonia, 6.07×10^9 m^3 in Finland, and 39.98×10^9 m^3 in Russia (bcm) (Ney et al., 2008b). Total gas demand in this region in 2015 will reach 39.98×10^9 m^3, and in 2020 41.76×10^9 m^3 (Table 1). At the same time, because natural gas in the region is and, according to prognosis, will be extensively used for heating purposes, the huge difference between gas consumption in summer and winter will remain. For example, in 2015 the monthly consumption of gas in July, according to the forecasts, will be only 36% of that in January (Khan, 2006; Mikelsons, 2004).

It is expected that natural gas consumption in Latvia will increase. The same trend of gas consumption is forecasted in the neighbouring countries. According to the estimates done by specialists of OAO 'Giprospecgaz' in their feasibility study regarding regional development of gas supply system in Baltic countries, Northwest Russia and Finland, the needs for natural gas in the following countries will be as shown in Table 1.

Table 1 Annual gas consumption volumes

Consumers	*Years*			
	2003	*2010*	*2015*	*2020*
Latvia	1.65	2.20	2.80	3.00
Lithuania	2.96	4.96	5.25	5.46
Estonia	0.85	1.10	1.37	1.50
Finland	5.11	5.62	6.07	6.10
NW Russia	19.45	22.92	24.49	25.70
Total	30.02	36.80	39.98	41.76

Note: Values in bcm.

Gas is supplied in summer to Latvia by two pipelines of 720 mm diameter and is taken over at the Russian/Latvian border approximately 40 km downstream of the Izborsk compressor station at the Korneti Gas Metering Station (see Figure 1). East of Riga, the Incukalns Underground Gas Storage (UGS) facility is linked to the both Izborsk-Riga pipelines. During winter, gas is withdrawn from the underground storage facility, used for Latvian and Estonian consumers and sent also back to Russia.

At present, Estonia is receiving gas by two pipelines Isborsk-Tartu-Rakvere (530 mm) through the whole year, and Viresi-Tallinn (720 mm) via Latvia in winter. As in Latvia, the highest monthly consumption (in winter) and the lowest monthly consumption (in summer) differ greatly by as much as five-fold.

What concerns Lithuania is that gas is supplied only by the pipeline Minsk–Vilnius (1,220 mm). It is expected that 'Lietuvos Dujos' will commission a gas-metering station on the Latvian-Lithuanian border and then the gas supply from Incukalns UGS may be supplied to Lithuania on a regular basis (not only in high emergency cases, as it is now). In Lithuania, the winter monthly gas consumption is about double that of summer.

Figure 1 Map of gas transmissions pipelines (see online version for colours)

For the northwest of Russia, gas is supplied by pipeline systems Grazovec-Leningrad, Serpuhov-Leningrad and Belousovo-Leningrad from the Nadim-Pur-Tazovsk region of Tymen Oblast.

Gas to Finland is supplied by the pipeline Leningrad-Viborg-Russian border. Both in Finland and in Northwest Russia, as in the three Baltic countries, gas consumption in the winter months is at least double that in summer.

In order to meet the changing demands of customers in this particular region, currently there are three underground gas storages in operation: Incukalns UGS in Latvia and Nevskoye and Gatchinskoe in Russia.

3 Aims of developing Latvian underground gas storages

In our opinion, the potential of Latvian underground gas storages can be well used to meet increasing and changing demands for natural gas in the region and, therefore, the Joint Stock Company Latvijas Gaze, which owns and operates the Incukalns UGS in Latvia, currently with an active gas volume of 2.3×10^9 m^3 (total volume 4.4×10^9 m^3) initiated a feasibility study regarding development of regional gas transmission network development and possibilities of using natural underground gas storage potential in Latvia, which was performed by OAO Giprospecgaz, daughter company of OAO Gazprom.

Following the request of JSC Latvijas Gaze, specialists of OAO Giprospecgaz have analysed natural gas demand in the Baltic countries: Latvia, Lithuania, Estonia and Finland and Northwest Russia, based on the information obtained from the gas companies of particular countries. The compiled results show that the unevenness of the monthly consumption and, in particular, difference in natural gas consumption in summer and winter months will remain high.

In order to meet the changing demands of consumers and compensate them, the capacity of the underground gas storages in the region have to be increased. Following the suggestions of OAO Giprospecgaz specialists, it is advised to increase the capacity of Incukalns UGS because of

- the existing structure is in place with potential for further increase
- the increase of gas consumption in the region
- the seasonal unevenness of gas consumption
- the limited options for development of other storages in the region.

Taking into consideration geological features and gas dynamics of the reservoir, it is estimated that without additional wells the active storage volume of Incukalns UGS can be increased to $2.3–2.6 \times 10^9$ m^3 and then further to 3.2×10^9 m^3. At the same time, it is expected that the active volume of Nevskoye UGS will be increased to 1.9×10^9 m^3 in 2010 and 2×10^9 m^3 in 2015, and Gatchinskoye UGS will remain at the current volume of 0.2×10^9 m^3 of active gas.

Referring to the feasibility study performed by OAO Giprospecgaz specialists, gas from Incukalns UGS can be delivered to Finnish customers, first, by pipeline Viresi-Tallinn and, later, by pipeline Tallinn-Helsinki with the length of 111 km, including 63 km submarine, which has to be constructed. In order to meet estimated demand in Finland, the diameter of pipeline shall be 700 mm with the submarine part 500 mm, and two compressor stations, one in Latvia and one in Estonia, and one reception terminal in Finland should also be built. The total estimated annual volume to be delivered to Finland in 2015 may reach 750 mio m^3.

For delivery of estimated annual gas volumes for customer needs in Lithuania, which is set on the level of 200 mio m^3 for years 2015–2020, the looping to gas pipeline Iecava-Liepaja shall be built with diameter 500 mm and length of 75 km.

It is estimated that Estonian customers in time period of 2015–2020 may need 600 mio m^3, which will be delivered by pipeline Viresi-Tallinn through gas metering station Karksi.

The Baltic States are interested in gas transit through them from Russia to Europe. In doing so, a special role could be played by Latvian UGS facilities (the existing Incukalns UGS as well as potential UGSs that could be successfully built under favourable geological conditions of Latvia). These UGSs might be used most profitably if they were filled with cheaper gas during summer time. Under monopoly conditions and with a single gas supplier from Russia this idea is difficult to actualise, however with creation of the Baltic Gas Ring (or others of the kind) this would be quite realistic. Construction of new UGS requires large investments; however these investments might become a profitable money allocation. Besides, it should be remembered that UGSs of large capacity (up to 50×10^9 m^3) situated in the centre of Europe would improve security of gas supply, especially if one takes into account the huge distances from the gas fields of Russia (3000–4000 km). Gas as highly efficient fuel can be used on a wider scale for traditional purposes (household, industry, etc.) in all Baltic countries, especially taking account of their only partial coverage with gas pipelines.

The Latvian Gas Company has its own UGS (Incukalns UGS) with active capacity of 2.2×10^9 m^3 and it is one of the biggest UGS in Europe. Taking into account the distance from gas extraction sites in CIS and Norway, this UGS can play a significant role in gas supply security in North Europe. It also can give profit if during summer time, when gas pipeline from CIS are not overloaded and gas marginal cost is approximately 30% and more cheaper than during winter time, is stored and than in winter extracted and sold.

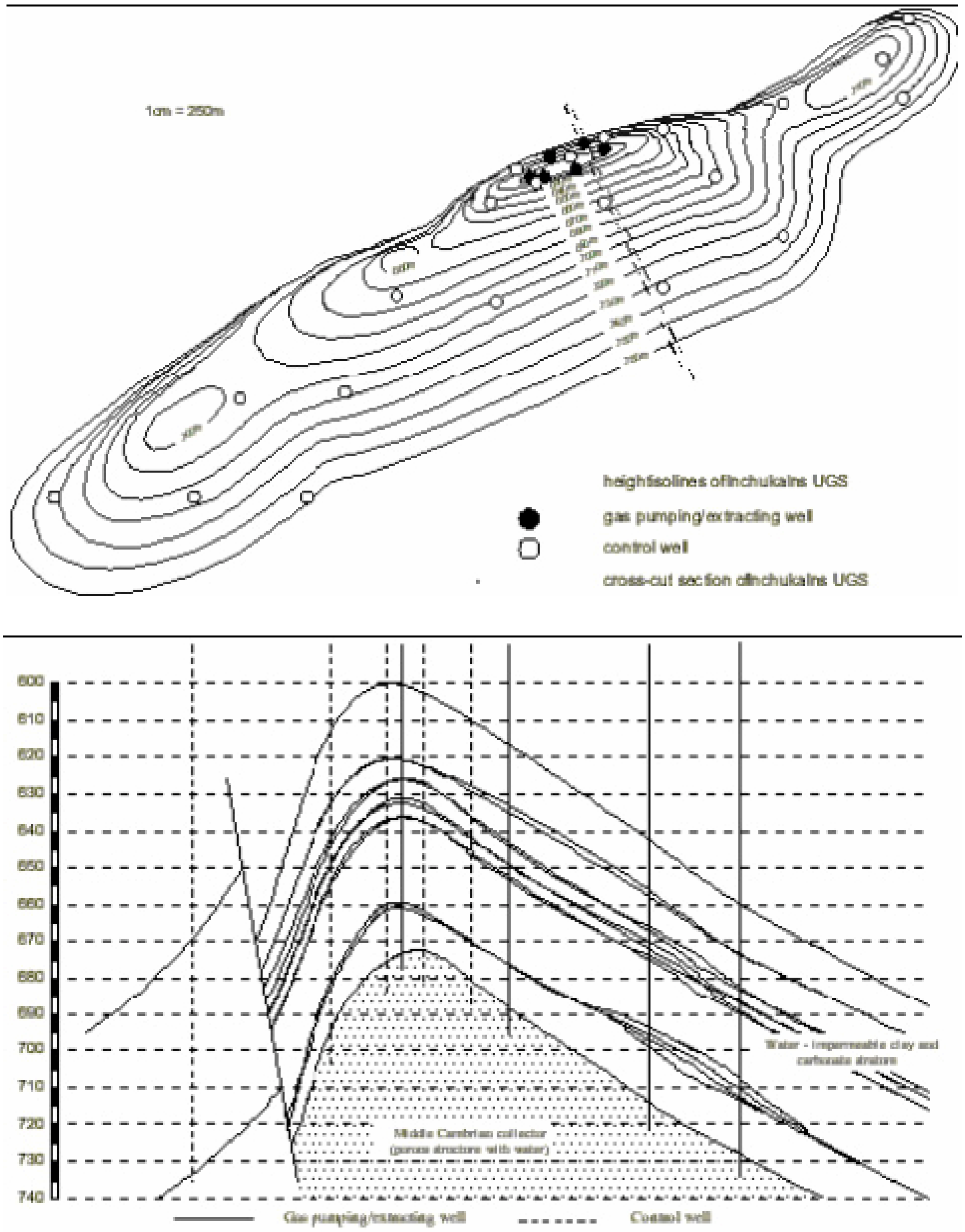
Latvia has unique geological conditions to build UGS. There already exists UGS capacity of 2×10^9 m^3, and investigations show that it is possible to build other similar storage with a capacity above 50×10^9 m^3. This can enhance not only the development of the gas supply system around the Baltic Sea but also affect the improvement of gas supply to all of Europe. There exists the Incukalns UGS in the central part of Latvia. In the perspective UGS will be distributed all over the western part of Latvia.

One of the largest and best investigated prospective UGSs is situated at Dobele. The peculiarities of the geological structure in Latvia create unique favourable conditions for setting up an underground storage. The lower of the sedimentary rocks contain Middle Cambrian limestone strata with a good satisfactory collector capacity practically everywhere. A thick water-impermeable clay and carbonate stratum covers this layer.

The existing Incukalns UGS in Latvia is the only one in the Baltic States. The depth of this Middle Cambrian collector is form 700 to 1,700 m. The designed capacity of this collector for the next 20 years is 4×10^9 m^3 (the active capacity is 2.3×10^9 m^3). In the future the Dobele UGS is envisaged. Approximately 20 prospect wells have been bored, and the total capacity of this storage is estimated at 16×10^9 m^3.

At present, the existing Incukalns UGS with a capacity 2×10^9 m^3 performs only a limited number of functions. In the summer period gas from the CIS is stored for the total consumption of all Latvia in winter (about 85% of annual consumption). In the wintertime the gas pipe to Latvia from CIS is closed. In this way, during the maximum gas consumption in winter the CIS gas pipes are unloaded. For Latvia they are used only during the summer as an extra means of gas transportation. If the additional gas transportation were calculated at marginal costs, the transportation cost of gas in long-distance pipelines (from the CIS is approximately 3,000 km) would be 30–40% of its total cost. Unfortunately, under the monopoly of gas supply (only from the CIS) there was no success in lowering its cost.

Figure 2 Illustration of geological conditions of existing Incukalns UGS

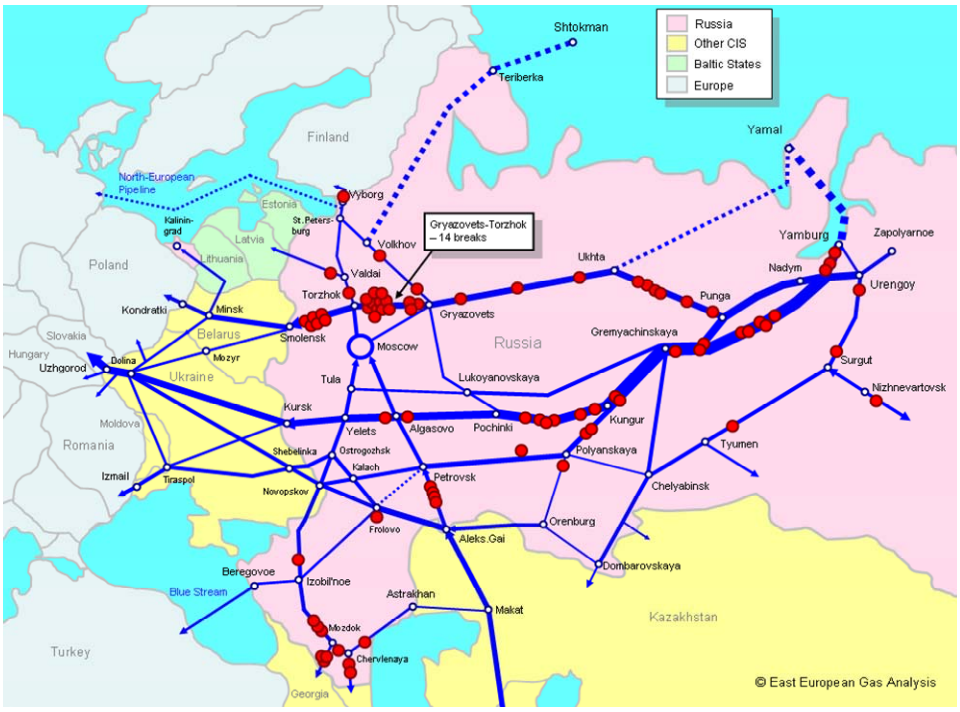


The UGS certainly performs also all the functions of raising the reliability of gas supply. Long distance gas pipes need approximately 15 days maximum gas consumption – the volume that the existing UGS can fully ensure not only for Latvia but also for the entire Baltic region.

Changes in the weather conditions effect both the variations of gas consumption in each season of the year and long-term variations (in the series of warm and cold winters). Seasonal variations are rather stable; therefore a reserve of about 40% of the annual gas consumption is necessary in the climate zone of Latvia to compensate the variations of gas consumption for heating. Considering the comparably high specific weight of heating on Latvia where practically no heavy industry is developed the total amount of the reserves for the compensation of seasonal variations may be 24–28% of the gas consumption per year. It means that the perspective UGS with the capacity of 50×10^9 m^3 could ensure these variations in the North European region with the consumption of about $150–200 \times 10^9$ m^3 a year.

An all round estimation of the use of UGS in the gas supply system is connected with the solution of several economic problems. So it is rather complicated to calculate the compensation of variations in the daily, seasonal and annual gas consumption as means of UGS in terms of profit.

Figure 3 Prospects of the developing gas supply system and number of defects in main pipelines 2000–2003 (see online version for colours)



As described above, the UGS potential in Latvia (capacity more than 50×10^9 m^3) can provide reserve capacity for the large region with annual consumption of

150–200 × 10^9 m^3. It could have a great importance for the Baltic Sea pipeline project connecting Russia with Germany for improvement of gas supply reliability that at present become even more important. This pipeline is shown in Figure 3 as the dotted line crossing the Baltic Sea. In the latest project options, branch lines to Kaliningrad, Sweden and Poland etc. are considered. In this case a branch pipeline to Latvia would be constructed and the Latvian UGS potential used for gas supply security for Europe would be improved considerably due to the possible breaks of gas pipelines in Russia because the distance from gas deposits to the Finnish Bay where the Baltic Sea pipeline starts is more than 3000 km (see Figure 3).

Based on information obtained from each country of the region regarding gas demand for the time period ending in year 2020, OAO Giprospecgas by means of computer modelling of gas flows and assessing few different scenarios, have come up with proposals on the development of gas transmission systems of the region, including Lithuania, Latvia, Estonia, Northwest Russia and Finland, and have also developed two step-by-step different feasible options for expansion of the existing Incukalns UGS.

The possibilities for using the Latvian UGS potential with a total capacity of 50 × 10^9 m^3 have not been explored sufficiently, but it could be important for the whole of Europe. It is particularly complicated to estimate the feasibility of increased gas supply reliability. As we can see in Figure 2, the number of disruptions to the main gas pipelines is considerable, and the problem of improvement of gas supply reliability for Europe is becoming more and more important.

4 Developing of LNG supply

The supply of LNG has a long production history without any significant incidents. Since 1959, when transportation of international commercial cargos started, tankers have carried 39,000 LNG cargos between seas and ports without serious faults. No essential losses of cargo and transportation incidents, as well as explosions and fires, have ever been experienced on the routes, which extend approximately 60 million miles.

Serious work has been done in order to raise the safety of the production sites of LNG. In the USA the enterprises of LNG have already been operating for 40 years without significant faults/crashes.

Monitoring systems are used to control the safety of the storage equipment by means of which it is possible to avert immediately gas escape or a fire at the production site. The strict safety rules, the inclusion advantages, and the long distance between the LNG sites, as well as their isolation from the populated areas and a safe width of the zone of forbidden access, reduce essentially the consequences of the risk of gas escape.

The use of LNG is becoming increasingly popular. Globalisation of natural gas, which is stimulated by the LNG trade, promotes the development of energetics in a new way, which, in its turn, contributes to the achievement of the aims of sustainable energy production and consumption. Although, owing to the existing trade and its potential, a stable LNG market has been created in the world, there are obstacles to successful development of this branch. They are mainly connected with the society's negative attitude towards the issues of the safe use of LNG and the development of the technological process. These problems should be solved by means of global cooperation, coordination, social interaction, dialogue and the partnership of the society and the private entrepreneur. In such a way society could be educated by explaining the role of LNG and the possibilities to promote the development of global economy.

The costs of each metric ton at the liquefaction plants have decreased from $400 (in the 1980s) to $200–250 in the year 2000. Likewise in ship-building the costs of a reservoir with the capacity of 25,000 m^3 have decreased during ten years from $260 million to $160 million. The initially low order prices of ships in the previous two years ($150 million) have increased again because of the high price of steel. The Lloyd's List (the world's leading insurance market) 19 April 2004 reports on the prognoses that in the period from the year 2007 to 2008 the cost of building a tanker having a reservoir with the capacity of 145,000 m^3 will grow to $170 million.

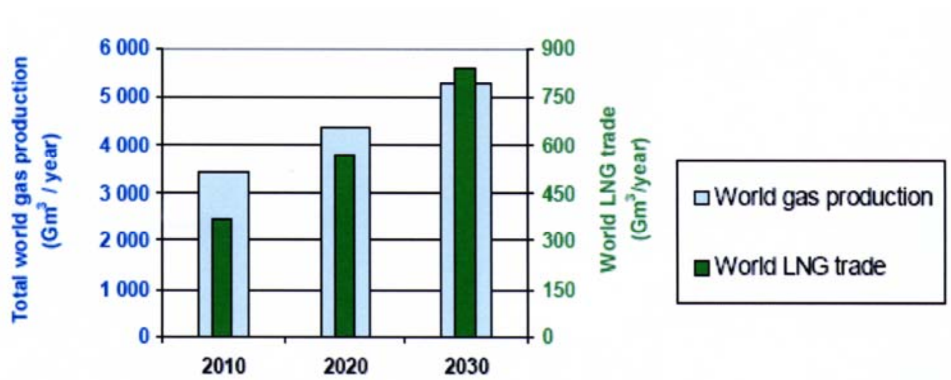
The increased dimensions of tankers promote a reduction in the total costs. The dimensions/capacity of ships have increased from 130,000 m^3 in the early 1990s to 145,000 to 150,000 m^3 now.

It is expected that the costs, depending on the fluctuations of prices, which are connected with cyclic economic factors, will continue to decrease still further. It is also expected that the total specific investments in the LNG transportation at the distance of 7,400 km (4000 sea miles) will decrease, on the average, by 25% from the year 2000 till 2020, as a result of which the full costs will fall by 20%. The calculations were made without taking into consideration the optimisation of finances or the shipping routes, assuming that the shipping route runs through the Suez Canal and taxes will not change.

It is prognosticated that the costs of liquefaction and transportation will decrease by 25% in 15 years. It is not expected that the specific costs of the terminals of LNG will decrease as well, owing to improved control of the process, first of all, because the environmentalists' activities will hamper the construction of the terminal. Owing to a good choice of site some terminals will be the winners, and their specific costs will be lower (the regasification minimum scenario), whereas the costs of the other projects might double (the regasification maximum scenario).

The trend when the LNG turnover level is higher in respect to the growth in consumption will remain 30 more years due to the LNG qualities which are profitable both for the investors and the market. Thus its importance in the entire gas trade will only grow. If in the year 2000 LNG constituted only 6% of the total gas consumption, then its share may grow to 19% by the year 2030 (see Figure 4).

Figure 4 Projected world gas production/IEA World Energy Investment Outlook 2003 (see online version for colours)



It should be mentioned that interregional trade and globalisation will favour stabilisation of the gas market during the next 30 years (see Figure 3). It is prognosticated that LNG will constitute 20% of the world's gas consumption and will become the main factor/motif in the globalisation of the gas market.

5 Evaluation of a low-risk gas supply

In order to evaluate the reliability of the gas supply in the first approximation, the following widely applied criteria can be used:

- the probability of an emergency situation (q)
- the probability of a working condition (p).

The emergency situation coefficients (χ_a) for individual elements of the gas supply system are determined according to the statistical data of the emergency situation (see Table 2).

Table 2 The emergency situation coefficient for a gas power plant

Capacity of the power plant (MW)	*Number of units*	*Probability of the emergency situation (χ_a)*
200	4	0.05
100	2	0.04
20	2	0.10

Theoretically, the UGS, the LNG terminals and the gas pipeline system can be regarded as parallel connected gas supply elements. In such a case the probability of an emergency situation is:

$$\chi_a = \chi_1 \times \chi_2 \tag{1}$$

where χ_1 is the probability of an emergency situation for the first gas supply element (the UGS or the LNG terminal); χ_2 is the probability of an emergency situation for the second gas supply element (the gas pipeline system).

Even at a very high probability of an emergency situation (χ_2 = 0.2) for the gas pipeline system from Russia (see Figure 3), if the UGS or the LNG terminal is used with a very low probability of an emergency situation (χ_1 = 0.001), the total probability of an emergency situation for the gas supply χ_a will be low too ($\chi_a = \chi_1 \times \chi_2 = 0.001 \times 0.2 = 0.0002$), but the probability of a working condition:

$$p = 1 - q \tag{2}$$

will be sufficiently high ≥ 0.999.

This motivates the efficiency of the UGS and the LNG terminal from the viewpoint of the gas supply reliability, i.e., uninterrupted gas supply to the Baltic consumers.

6 Conclusions

1. A very important risk-reducing measure of the gas supply is the development of a gas pipeline system. Based on the results of the above feasibility study, Joint Stock Company Latvijas Gaze has prepared investment plans for the first stage of Incukalns UGS expansion. However, the main condition to start the whole project is a positive decision on the construction of a submarine gas pipeline connecting the Estonian and Finnish gas grids. At present, extensive discussions between Gasum and Latvijas Gaze and Eesti Gaas is taking place, and we hope that till the beginning of the WGC 2006 we will be able to report on positive decision on construction of the above mentioned pipeline.

2. In order to minimise the gas supply risk in Latvia, underground gas storage facilities will be created. The existing Incukalns UGS is advised to increase its capacity due to

   - existing structure in place with potential for further increase
   - increase of gas consumption in the region
   - seasonal unevenness of gas consumption
   - limited options for development of other storages in the region.

   Taking into consideration geological features and gas dynamics of the reservoir, it is estimated that without additional wells active storage volume of Incukalns UGS can be increased to 2.3–2.6 × 10^9 m^3, and then further to 3.2 × 10^9 m^3.

   Further study is required regarding prospective use of 50 × 10^9 m^3 UGS capacity in Latvia that can help to solve the increasingly important problem of gas supply reliability for Europe.

3. An important perspective investigation is connected with the LNG terminal in the Baltic countries, which would improve the reliability of the gas supply as well as expand the export of the Russian gas.

References

Davis, A., Jesinska, A., Kreslins, A., Zebergs, V. and Zeltins, N. (2006) 'Increasing role of underground gas storages for reliable supply of gas to Latvia, Lithuania, Estonia, Finland and NW Russia and prospects of development of Incukalns underground gas storage', *23rd World Gas Conference*, Amsterdam, The Netherlands.

Frormann, D., Michna, J., Stania, A., Ekmanis, J., Zebergs, V. and Zeltins, N. (2006a) 'Present-day problems of energy conservation policy in Central and East-European countries', *Latvian Journal of Physics and Technical Sciences*, Vol. NR 5, pp.68–76.

Frormann, D., Michna, J., Stania, A., Ekmanis, J., Zebergs, V. and Zeltins, N. (2006b) 'Present risk management problems on energy and environmental policy in Central and Eastern Europe countries', *Latvian Journal of Physics and Technical Sciences*, Vol. NR 3, pp.66–73.

Khan, S.A. (2006) 'JSC Gazprom long-term gas reservation system as factor of reliability and economic sustainability', *23rd World Gas Conference*, Amsterdam, The Netherlands.

Mikelsons, K., Davis, A., Zebergs, V. and Zeltins, N. (2004) 'Latvian underground gas storage facilities for the development of a safe gas and power supply system of North European gas', *IRAEE International Conference on Energy & Security in the Changing World*, Teheran, Iran.

Mikelsons, K., Kreslins, V., Brinkis, K., Zebergs, V. and Zeltins, N. (2006) 'Crunch time for the European gas system: reliability of supply', *26th USAEE/IAEE North American Conference: Energy in a World of Changing Costs and Technologies*, Ann Arbor, Michigan, USA.

Ney, R., Ekmanis, J., Michna, J., Zeltins, N. and Zebergs, V. (2008a) 'The reputation risk management', *Latvian Journal of Physics and Technical Sciences*, Vol. NR 5, pp.48–59.

Ney, R., Michna, J., Ekmanis, J., Zeltins, N. and Zebergs, V. (2008b) 'Energy use and related risk management problems in CEE countries', *Latvian Journal of Physics and Technical Sciences*, Vol. NR 1, pp.41–51.