USING GAS STORAGE TO MANAGE THE PRODUCTION OF NATURAL GAS

Piotr Kosowski*, Jerzy Stopa*, Stanisław Rychlicki*, Sławomir Hinc**
*AGH University of Science and Technology in Krakow
** Polish Oil and Gas Company in Warsaw

Introduction

Natural gas consumption in Poland is strongly dominated by seasonal fluctuations on annual, weekly and daily bases. On the other hand, gas flow stability is very important for natural gas exploitation and transmission. The production conditions providing stability of gas field operation result from individual properties of the exploitation wells and frequently depend on a number of factors, e.g. geological and reservoir conditions, properties of formation rocks, design of the borehole and surface infrastructure. Ensuring optimal operation of the reservoir necessitates pressure difference exerted on the reservoir to be possibly constant and lower than the admissible level, which limits the attainable rate of production. This can eliminate or reduce the negative impact of formation waters (elimination of water cones, cutting off parts of the reservoir) and destabilization of the reservoir structure around the wellbore (migration of sand).

Thus, oil and natural gas reservoirs should be exploited in a stable way, with optimum production rate determined on the basis of measurements and calculations, with no rapid changes involved. Maintaining uniform gas production is also a key factor from the perspective of optimization of costs of natural gas exploitation.

Managing natural gas exploitation which is subject to seasonal changes necessitates gas storage in the periods of lower demand to maintain the stability of gas production. Bearing in mind the natural seasonal character of gas consumption in Poland, it is necessary to use definite working gas volume of underground gas storage facilities (UGS) to maintain a suitable level of gas production from domestic sources in the periods of low gas consumption. Thus, the gas storage installations or their parts used for the realization of this purpose should be treated as elements of the exploitation system; they should be considered differently to other gas storage facilities used for other purposes. The third-party access (TPA) rule should not apply especially to gas storage facilities or their parts, including the virtual ones, playing a regulating role in oil and gas production.

It should be noted, that according to the third energy liberalization package announced in September 2007 by the European Parliament and the Council to facilitate access to gas storage, the storage volumes necessary for gas recovery can be reserved by the gas producing company and can be excluded from the TPA rules [1, 3]. However, the company must demonstrate what amount of working capacity is necessary to carry out gas production operations. This task is not minor because gas streams from extraction, import and storage are mixed in the transmission system and direct measurement is not possible.

All import contracts signed by Polish Oil and Gas Company (PGNiG S.A.) have the „take or pay" clause. These contracts usually impose the obligation to buy a minimum annual amount of natural gas, including predefined quantities of gas in the summer period. Such clauses are common practice when assuming long- and average-length contracts and constitute a basic warranty for gas producers. Assuming the priority of gas imported on the basis of long-term contracts over gas from Polish deposits („take or pay" principle), the UGS have to be used for regulating the domestic gas production level in the summer period.

Another important task of UGS is providing strategic reserves for possible breaks in gas deliveries, which is especially important for countries strongly reliant on import of this energy resource. Poland produces but also imports natural gas, therefore the correct evaluation of required working capacity is essential, particularly in the aspect of the probable increase in Polish production.

Aims

The aim of the paper is to investigate the impact of gas storage on gas production strategy from domestic fields based on the example of Poland, and to calculate the amount of gas which should be stored to optimize gas production.

Methods

Natural gas market balance can be illustrated with the following equation:

$$P + I + UGS_p = C + UGS_i + R \qquad [1]$$

where:

P – deliveries from domestic sources, Nm^3,

I – deliveries from import, Nm^3,

UGS_p – deliveries from UGS, Nm^3,

C – consumption (including export), Nm^3,

UGS_i – injection to UGS, Nm^3,

R – other (losses, use for technological needs, change of amount of gas in the transmission system), Nm^3,

The amount of stored natural gas after time t can be described as:

$$S(t) = S_p + \int_{t_0}^{t} [p(\tau) + i(\tau) - c(\tau) - r(\tau)] d\tau \qquad [2]$$

where:

S – stored natural gas, nm3,

S_p – initial state, Nm^3,

p(t) – deliveries from domestic sources, Nm^3/d,

i(t) – deliveries from import, Nm^3/d ,

c(t) – consumption, Nm^3/d,

r(t) – other, Nm^3/d,

The required working capacity is equal to Z = max[S(t)] for . $t \in [0, T]$ [3]

On the assumption that imported gas has to be used first, the UGS injection rate for gas from domestic sources can be calculated from the formula:

If $p(t) > c(t) + r(t)$ then UGS injection rate equals to $q(t) = r(t)$ [4]

If $p(t) \leq c(t) + r(t)$ and simultaneously $i(t) + p(t) > c(t) + r(t)$ then
$q(t) = p(t) - [c(t) + r(t) - i(t)]$ [5]

Otherwise, $q(t) = 0$ [6]

Results

The above presented method of calculations has been applied to the historical data of methane-rich and nitrogen-rich gas supply and demand in Poland. Methane-rich gas consumption in Poland has been lately characterized by a gradual increase and seasonality, mainly connected with the climatic conditions (fig. 1). The peak of gas consumption is usually observed in January and the minimum during the summer vacation period. At the same time the imported and domestic gas deliveries cannot be arbitrarily adjusted to the consumption level. The variability of import deliveries is significantly limited, which results from the realization of contracts, especially reception of minimum annual and summer quantities („take-or-pay") as well as technical parameters of the gas transfer network.
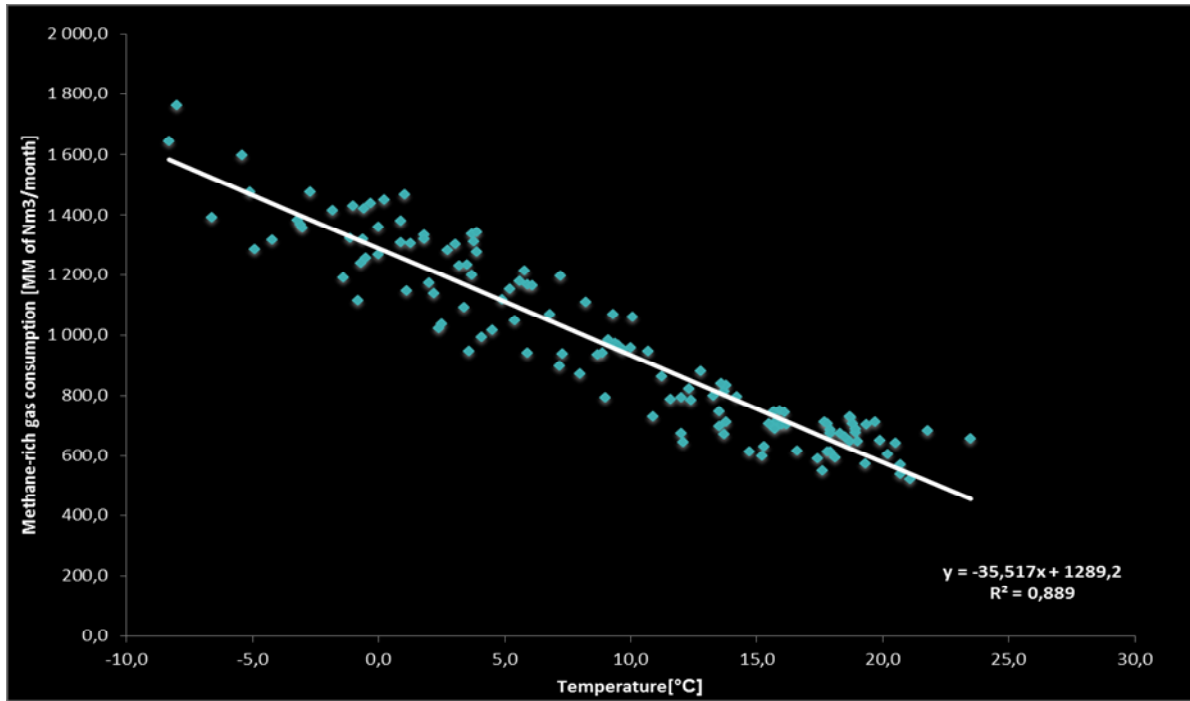
Fig. 1. Monthly consumption of methane-rich natural gas vs. temperature in Poland in 2000-2010 (calculations based on temperature data from www.ogimet.com)

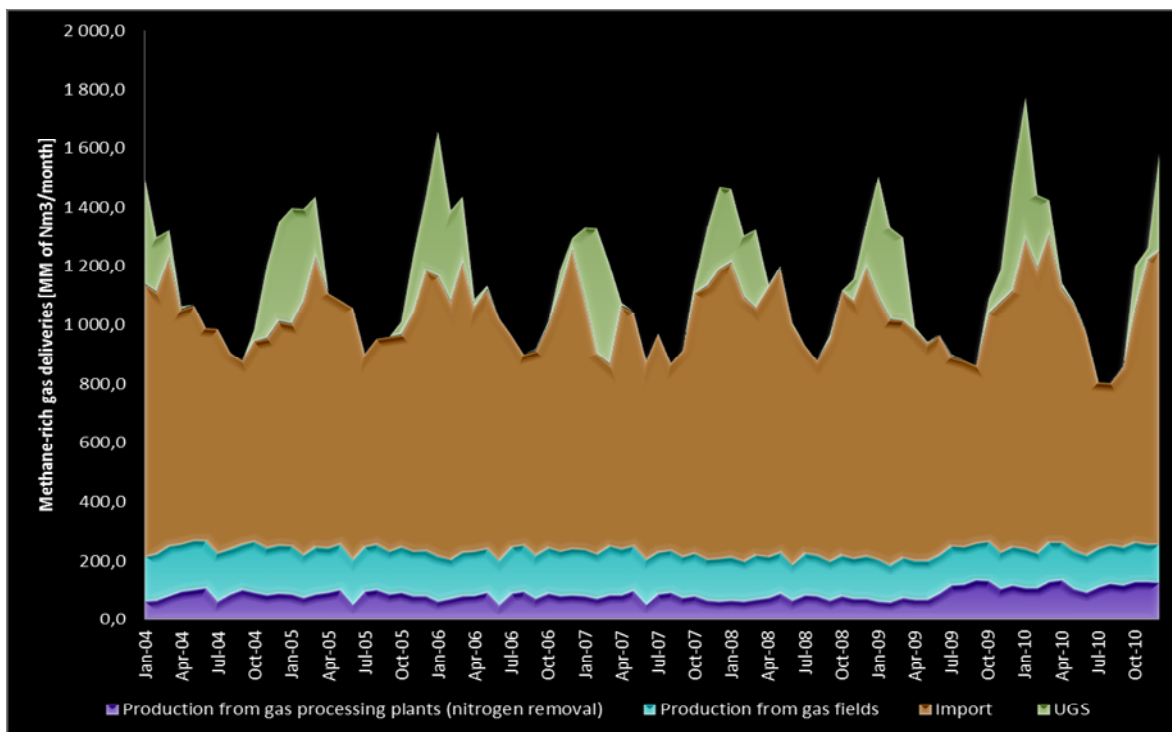Hence, the fluctuations can be balanced by using underground gas storage facilities(figs. 2 and 3).

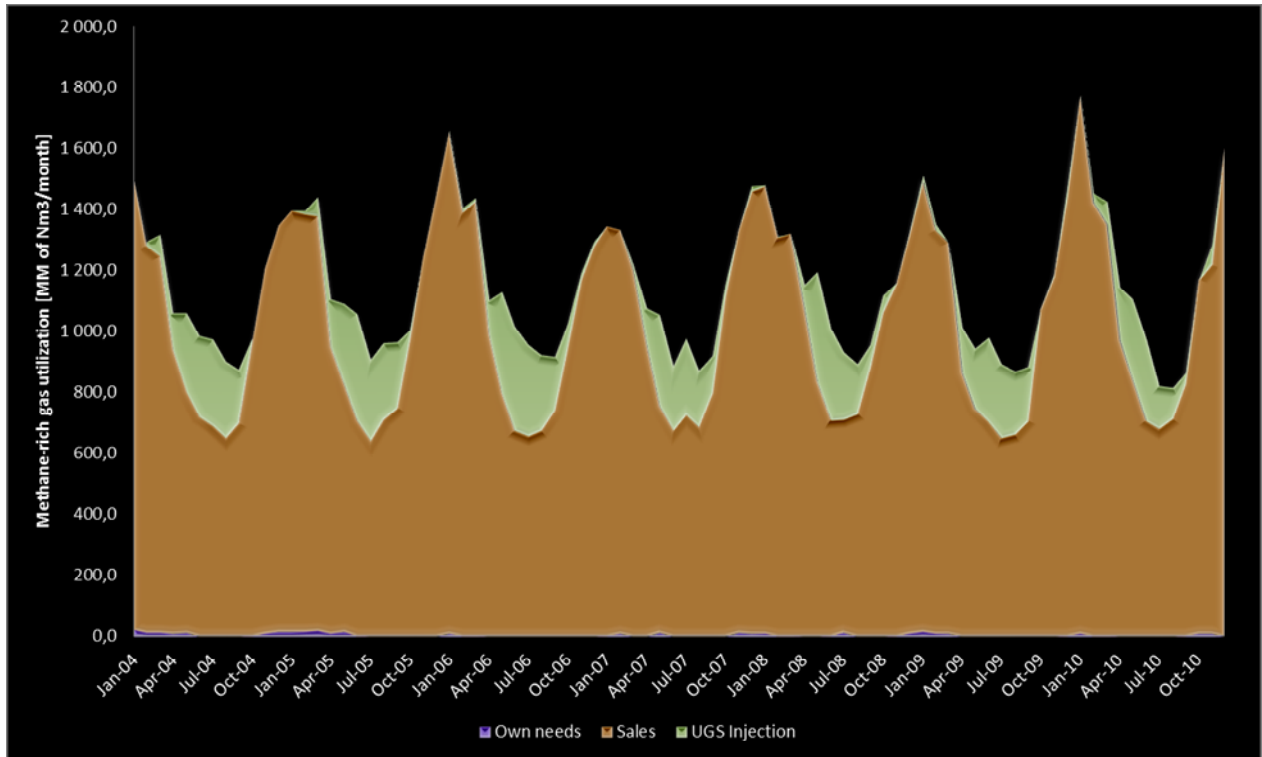Fig. 2. Structure of delivery sources of methane-rich natural gas in Poland (source: PGNiG S.A.)

Fig. 3. Structure of methane-rich natural gas utilization in Poland (source: PGNiG S.A.)
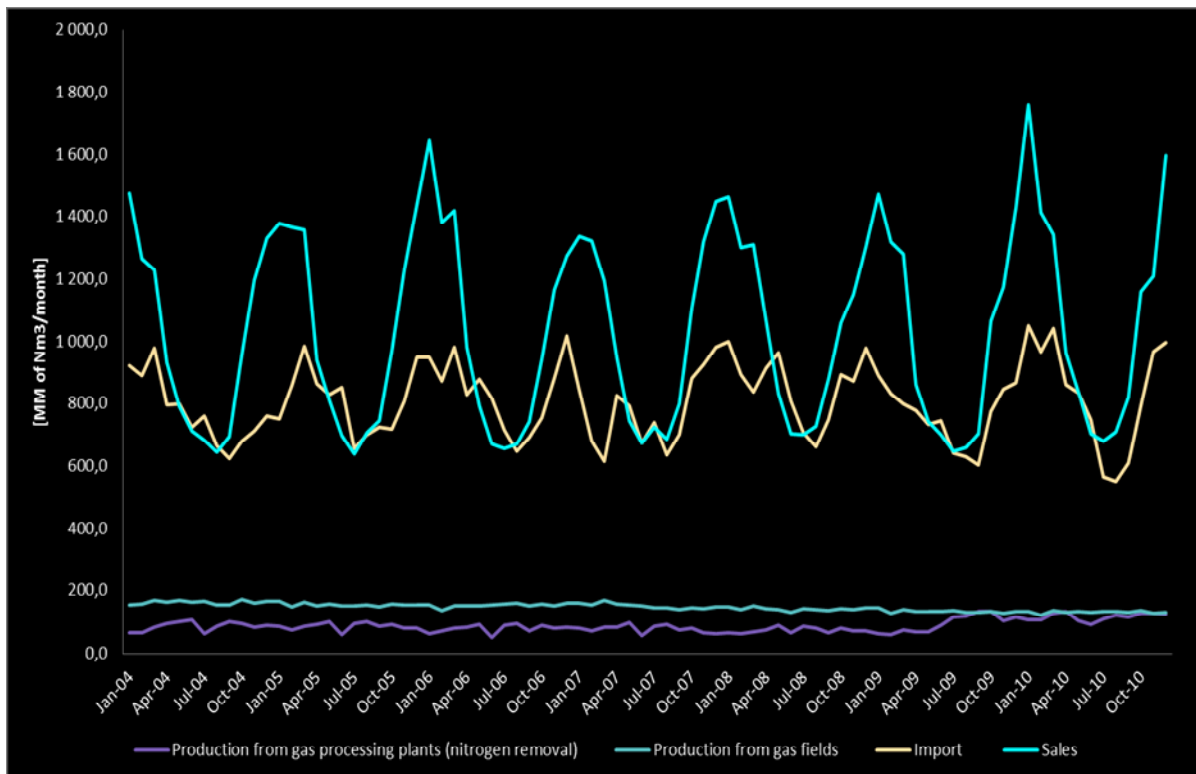

Fig. 4. Consumption, import and domestic production of methane-rich natural gas in Poland (source: PGNiG S.A.)

PGNiG S.A., as a gas producer, is obliged to correctly manage production, i.e. they should try to maintain a uniform level. This task is successfully fulfilled and compared to the strongly seasonal methane-rich gas consumption, the domestic production is stable. This state was achieved owing to the use of UGS, thanks to which the seasonality of consumption can be balanced and stable domestic production maintained.

Fig. 5. Location of UGS in Poland on the background of the gas transmission system (source: Gas Infrastructure Europe)

If the UGS (fig. 5) were not used, the domestic production in summer months would have to be considerably reduced, contracts could not be realized and a gas deficiency in the winter season would be fact. These limitations would be considerable, as imported gas is consumed first. This would lead to unstable and potentially hazardous exploitation of domestic reservoirs. Fulfilling the increased demand for natural gas during the winter months would be hindered as well.

Assuming that imported gas is used first, then gas from domestic sources, and the potential shortages are covered from the UGS, the demand for natural gas is met according to the structure as presented in figure 6.
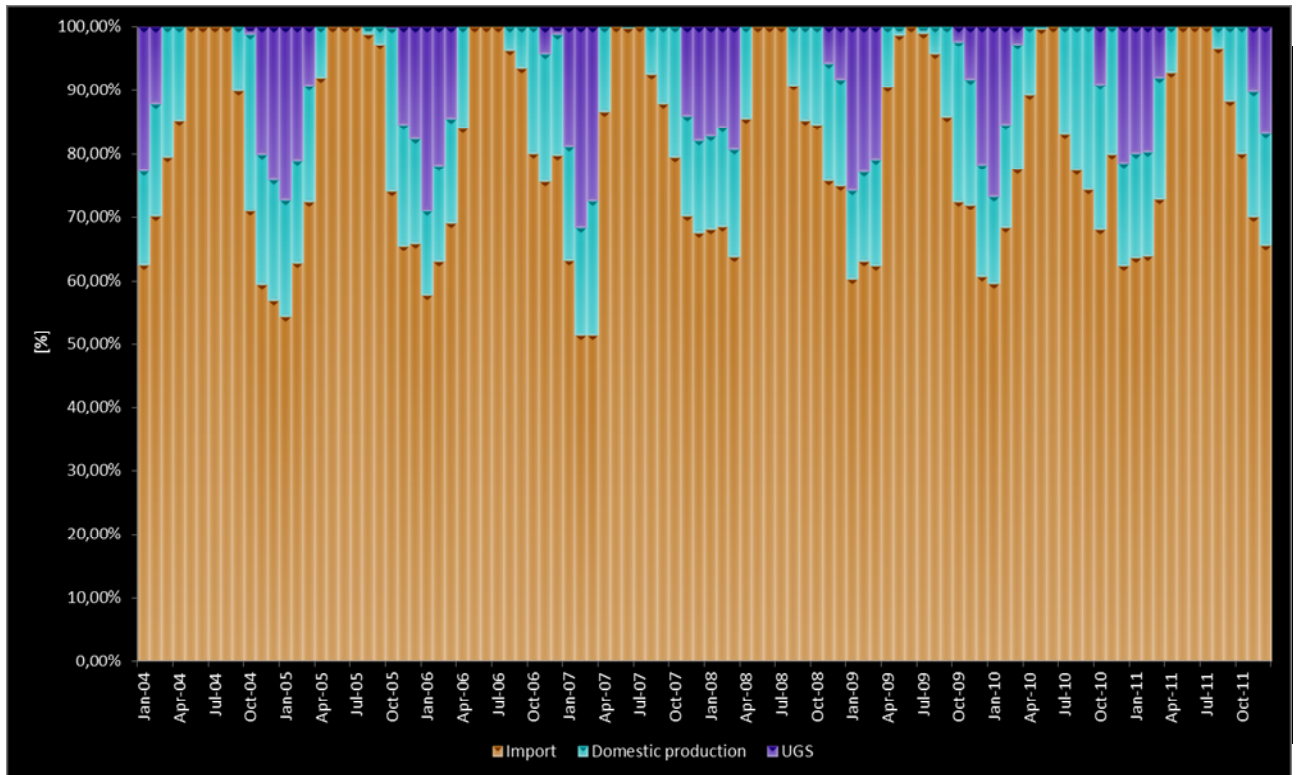
Fig. 6. Structure of meeting demand for methane-rich gas in the years 2004-2010, on the assumption that imported gas is used first

As a consequence of using this consumption model a considerable amount of domestic gas has to be stored during the summer period (fig. 7). It comes from reservoirs in southeastern Poland and gas processing plants, which remove nitrogen from nitrogen-rich gas exploited in the Polish Lowland.
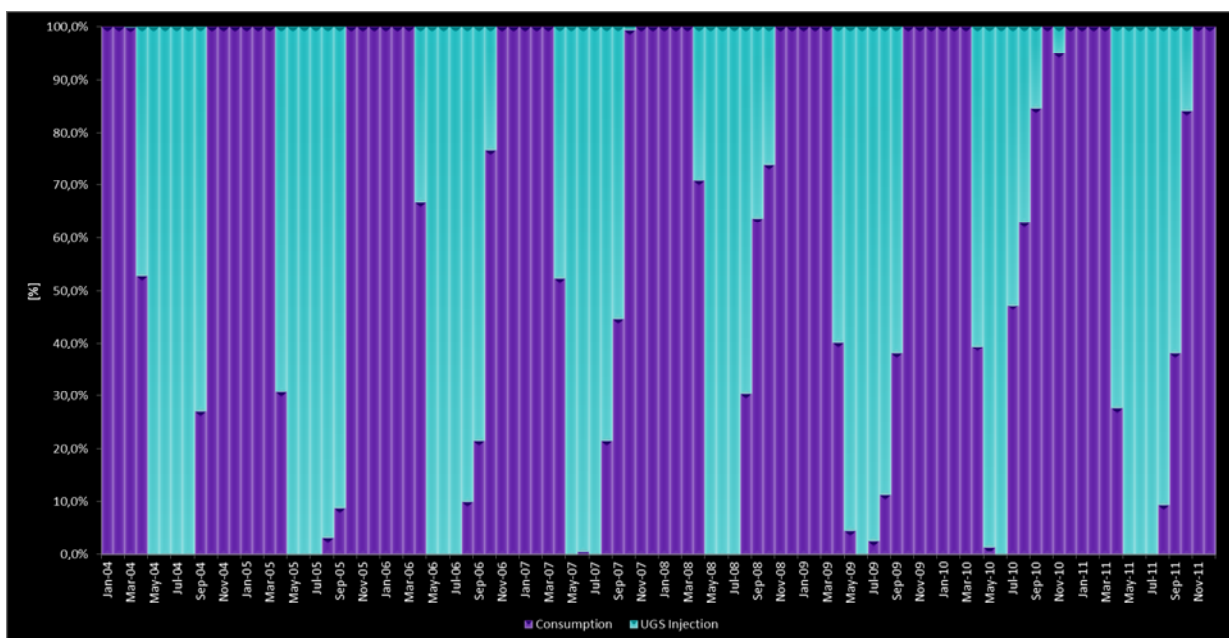

Fig. 7. Structure of usage of domestic production of methane-rich gas in the years 2004-2010, on the assumption that imported gas is used first
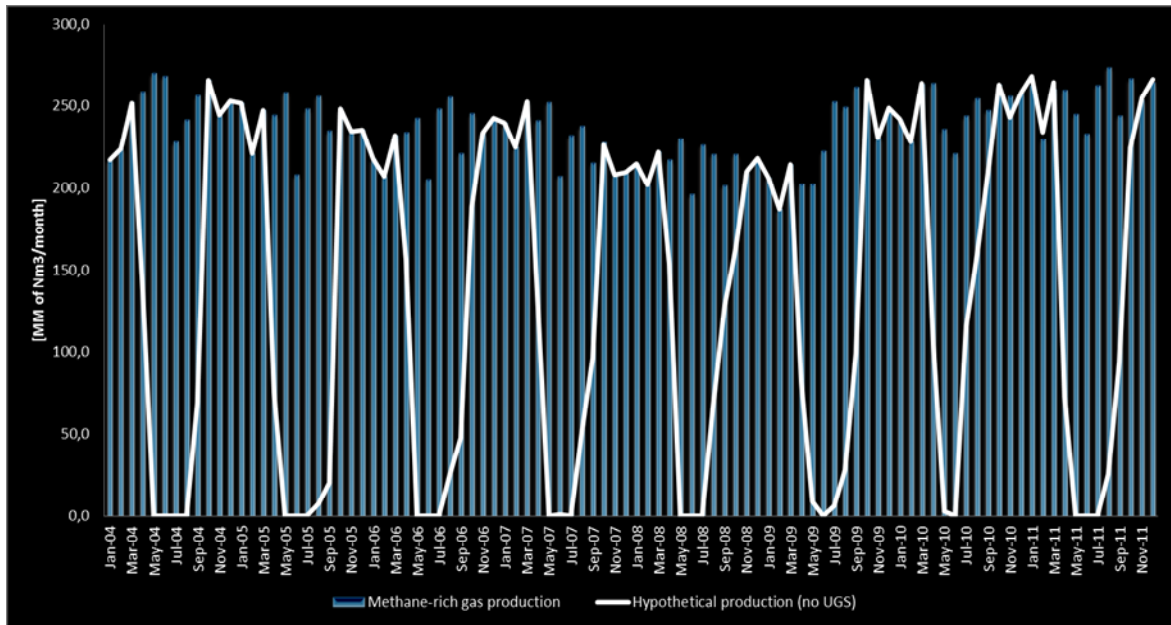
Fig. 8. Monthly production of methane-rich gas and hypothetical production if the UGS had not been used in Poland in 2004-2011

Thanks to use of USG, the production of methane-rich gas in Poland is not very seasonal and relatively stable (Fig. 8, 9).
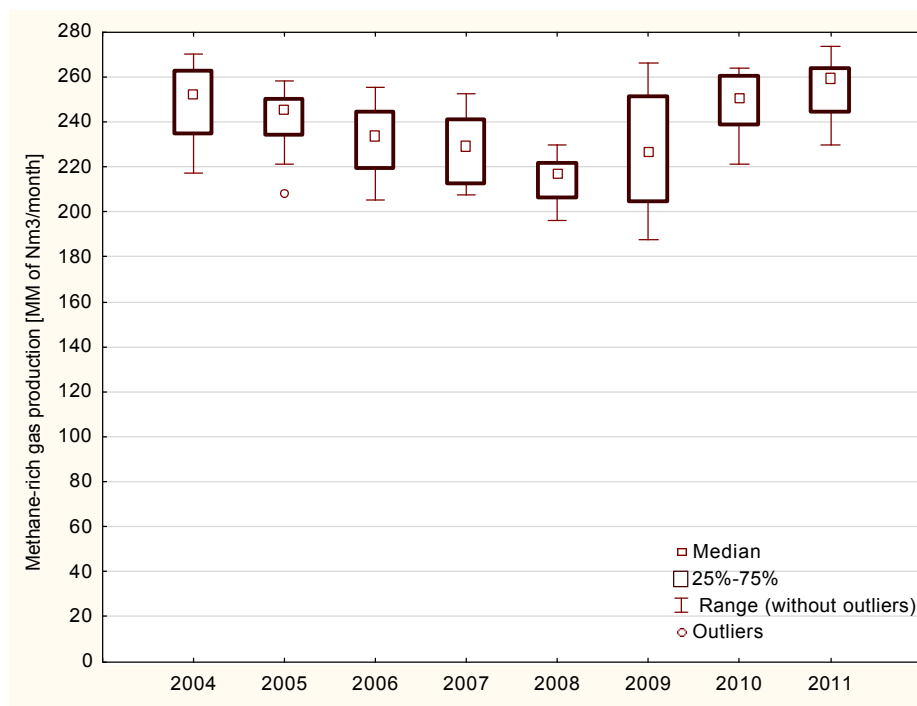

Fig. 9. Variability of the monthly production of methane-rich gas in Poland in 2004-2011

The storage capacity needed for providing stable production, calculated according to formulas presented in this article was about 1.42 bn of Nm3 in the last year, which means that 45.44% of yearly domestic production was stored.

Apart from the methane-rich system, two nitrogen-rich gas subsystems are operating in Poland (fig. 10). Those gas systems are regional closed systems, i.e. without the possibility of arbitrarily supplementing with gas deliveries from other transmission systems. The UGS were not used for storing nitrogen-rich gas in the past, therefore production from nitrogen-rich gas fields was increased in the winter and lowered during summer months. At present PGNiG S.A. has at its disposal two nitrogen-rich gas storages: UGS Daszewo and UGS Bonikowo.
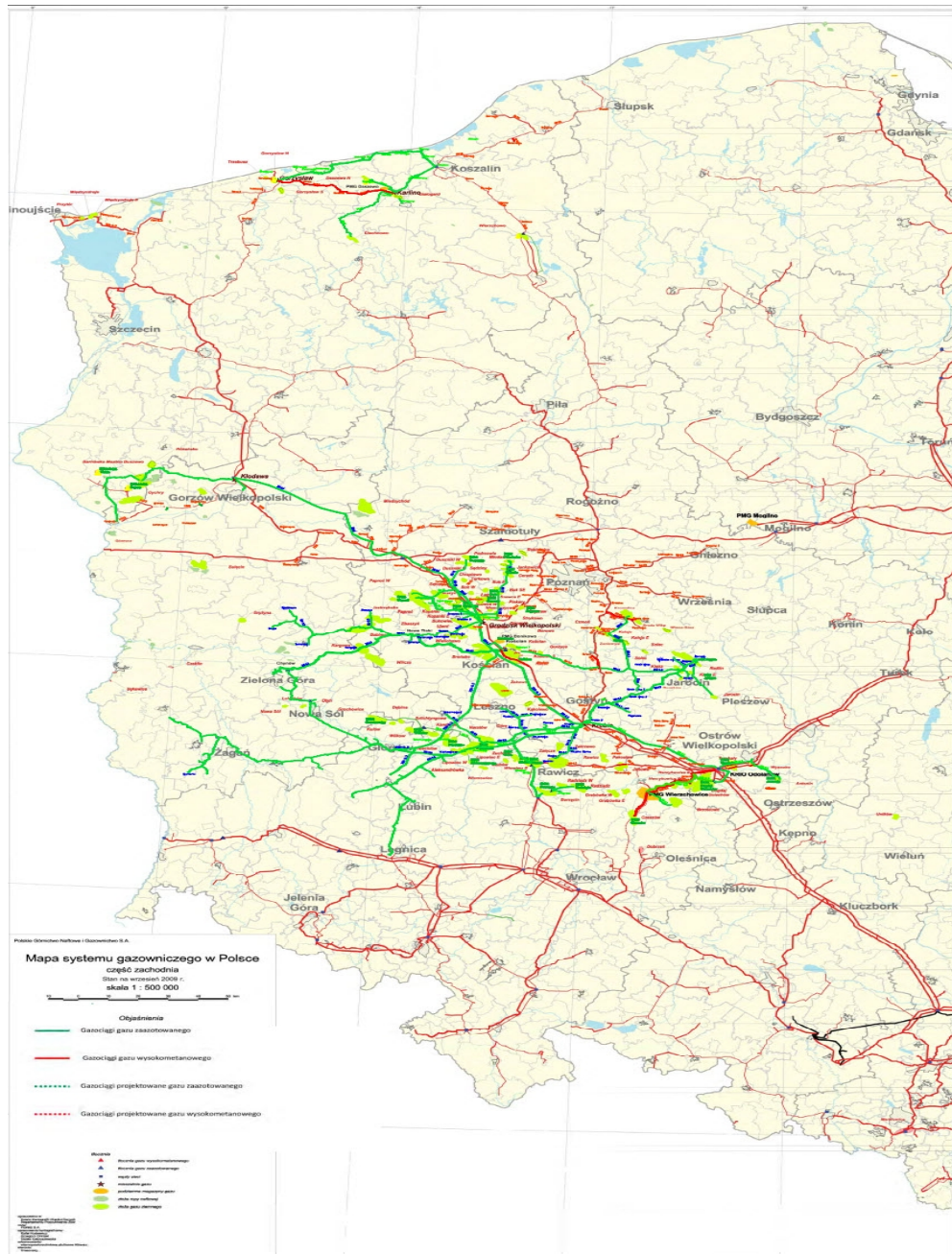

Fig. 10. Systems of nitrogen-rich gas (green) and methane-rich system (red) in the west part of Poland (source: PGNiG S.A.)
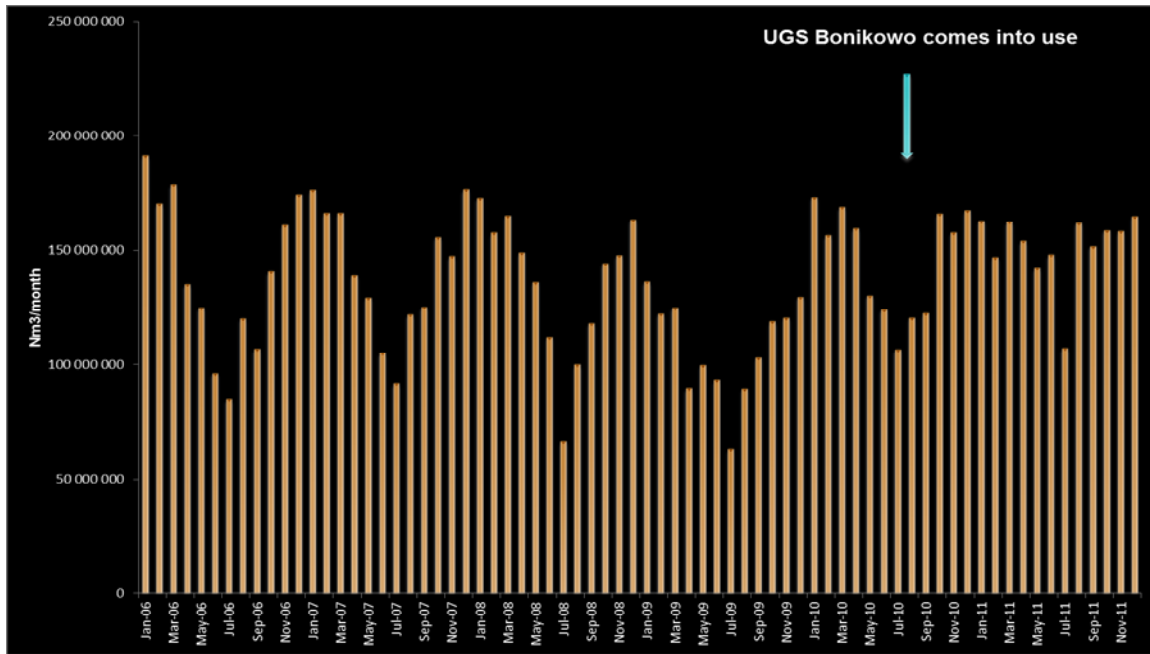
Fig. 11. Monthly production of nitrogen-rich gas from fields linked in to the nitrogen-rich gas subsystem in 2006-2011 (source: PGNiG S.A.)

The example of UGS not being used is clearly visible in the plots (fig. 11 and 12) illustrating production from the nitrogen-rich gas fields. Contrary to the production of methane-rich gas, here we observe high seasonality, reduced only from mid 2010 owing to the start of UGS Bonikowo operation.
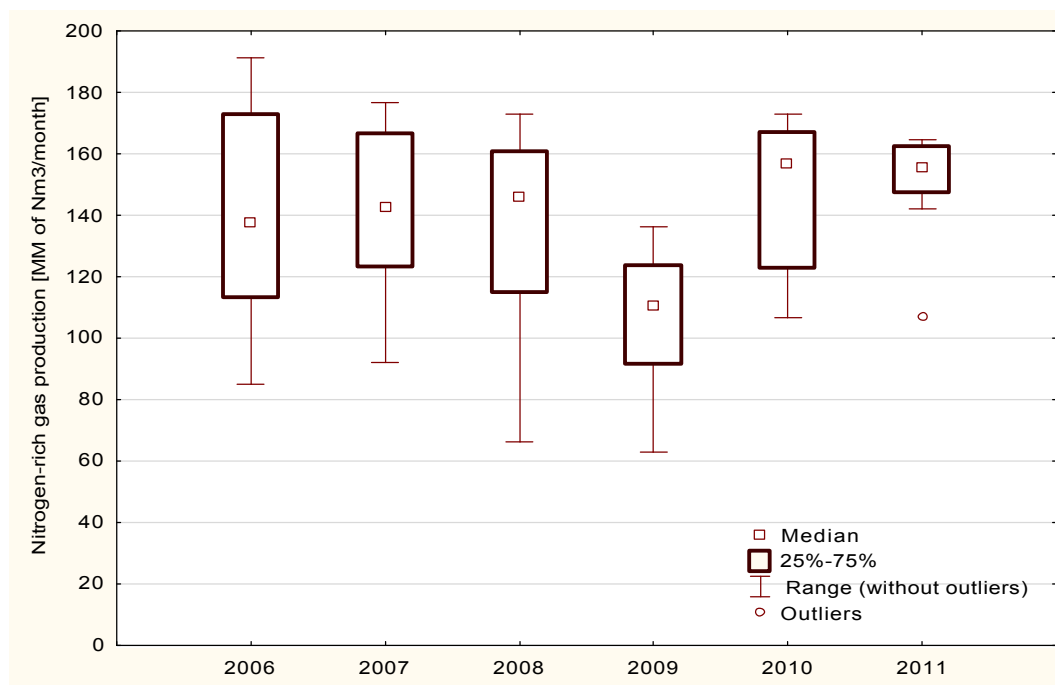

Fig. 12. Variability of the monthly production of nitrogen-rich gas from fields linked in to the nitrogen-rich gas subsystem in 2006-2011.

When calculating the storage capacity needed for stabilizing nitrogen-rich gas production, the assumption was made that the calculation will be based on a hypothetical average production level between April and March. To run the production at a constant level over such a period of time, there should exist UGS which could store the production excess and cover the shortages in the period of increased demand. Their minimum working capacity can be calculated by analyzing deviation of the actual production from the assumed average level, and then accumulating them. The minimum storage capacity is the maximum value of accumulated deviations from the average production.

For each April-March season, the calculations were made in the following way:

$$p = \frac{1}{T}\int_0^T p(t)\,dt \qquad [7]$$

$$S(t) = S_p + \int_0^t [p - c(\tau)]\,d\tau \qquad [8]$$

where:

S – accumulated reserves, Nm^3,

S$_p$ – initial state, Nm^3,

$\bar{p}$ – average level of production between April and March, Nm^3,

p(t) – production, Nm^3/d,

c(t) – consumption, Nm^3/d.

Required minimum working capacity Z = max[S(t)] for $t \in [0,T]$.

Working capacity needed for regulating the production of nitrogen-rich gas and calculated according to above presented formulas is about 200 MM of Nm^3.

Conclusions

Underground gas storage constitutes an important element of natural gas production, transport and distribution. One of the most important functions of UGS is optimization of the process of natural gas exploitation. The working capacity of UGS needed for the realization of the optimization process depends on a number of factors, e.g. demand and supply of natural gas, strategy of gas utilization, geological and formation conditions, as well as technical standards of exploitation, transport and storage infrastructure.

Managing the production in conditions of strong gas demand fluctuations necessitates calculating required working capacities of UGS, to be used for its regulation. The formulae presented in this paper are a proper tool for doing so.

The use of UGS enabled stable exploitation of methane-rich gas fields and steady production levels in gas processing plants. In addition no major fluctuations were observed in the aspect of high seasonality of natural gas consumption (related to climate and the structure of the gas consumers in Poland). In the summer season methane-rich gas imports exceed demand and its flexibility is strongly limited, which results from the realization of contracts, especially the obligation of receive minimum annual and summer amounts of gas („take-or-pay"), and technical parameters of the transmission network. By using methane-rich UGS in the analyzed period there was neither correlation between the monthly amount of production and consumption of high-methane gas, nor between the size of production and temperature. This state was achieved by storing almost half (45.44%) of yearly domestic production of methane-rich gas,

In the case of the closed nitrogen-rich gas system there have recently been large fluctuations caused by not using UGS. Since then a new UGS (Bonikowo) has come into use, thanks to which production could be, to a considerable degree, stabilized.

References and Data Sources

1. Directive 2009/73/EC of the European Parliament and of the Council of 13 July 2009, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0073:en:NOT
2. Gas Infrastructure Europe, www.gie.eu
3. Interpretative note on directive 2009/73/ec concerning common rules for the internal market in natural gas third-party access to storage facilities, http://ec.europa.eu/energy/gas_electricity/interpretative_notes/doc/implementation_notes/2010_01_21_third-party_access_to_storage_facilities.pdf
4. Polish Oil and Gas Company (PGNiG S.A.) , www.pgnig.pl
5. Weather Information Service, www.ogimet.com