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Estimation of natural-gas consumption in Poland based on the logistic-curve interpretation

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Abstract

This paper describes the possible scenario of the development of the gas sector in Poland. An adaptation of the Hubbert model is implemented to the Polish situation based upon the Starzman modification. The model presented describes hypothetical natural-gas demand, based on average trend of the economy development during recent decades; the model considers natural production/demand maxima of energy carriers. The prognosis is loaded with an error resulting from the use of average data related to yearly increases of the national gross product. The adapted model expresses good compatibility with the natural-gas demand for the period 1995–2000. However, the error of prognosis may reach 20%. The simple structure of the model enables the possibility of yearly updating, and eventual correction of the natural-gas demand. In cases of untypical changes of the economy growth rate (long stagnation, extreme long and accelerated development), the prognosis error may increase.

Keywords: Natural-gas demand; Economy; Hubert model; Energy demand

1. Introduction

Because of the time dependencies of economic and political factors, estimation of the natural-gas consumption is complex. Development of the domestic economy, which depends on European and Worldwide economy, makes the estimation more difficult. Recent decades have shown that estimations of the consumption, made on the basis on current economic conditions, are not fully reliable. Estimations from the Energy Information Administration (EIA) suggest a worldwide yearly increase

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from 2.2%/year to 3.3%/year. However, it is doubtful that this trend will be stable: in the East European countries, the consumption of natural gas will grow very fast. The demand depends both on economic (for example, domestic welfare level, higher profitability of coal energy, limited credits granted to commercial entities, etc.) and non-economic (lack of the active macroeconomic policy, danger of unstable energy-policy, passive state ecological policy) factors. We can expect to reach the gas consumption level per capita similar to the present consumption in UE and USA. In the model presented below, the current consumption characteristics and macroeconomic prognosis have been especially neglected. It was assumed, that the worldwide fluctuations resulting in the alternate recession and economic development periods will be partially offset, so enabling the development of a long-term prognosis, which is resistant to short and medium-term gas-consumption fluctuations.

The model is based on the assumption that there is a maximum demand related to the historic cycle of extraction of mineral resources [1,2]. This in turn is directly related with the worldwide availability of the raw materials, their rate of depletion, as well as with availability of the new energy carriers (hydrogen, fuel-cell electricity, geothermal energy).

2. Description of the model

The presented model of the natural-gas consumption in Poland in the period 2002–2050 has been predicted on the basis of studies published by Hubbert [1,2] and Startzman [3–5]. Originally the model was developed for the prognosis of crude-oil extraction, but later it was adapted for the prognosis of the natural-gas consumption.

The adaptation is based on the assumption that the extraction/production curves are qualitatively equivalent to the gas-consumption curves.

The recent studies of Startzman [4–6] proved the necessity of modifying the consumption/production model, to become a multi-cyclic model.

Total demand/production is expressed by the equation [7]:

$$Q = \frac{Q_\infty}{1 + \mathrm{e}^{-a(t-t_{\max})}} \tag{1}$$

Yearly consumption is determined by the first derivative of the equation, substituting $Q_\infty = 4\frac{q_{\max}}{a}$:

$$q(t) = 4q_{\max}\left\{\frac{e^{-a(t-t_{\max})}}{\left[1 + \mathrm{e}^{-a(t-t_{\max})}\right]^2}\right\} \tag{2}$$

The above equation is equivalent to the equation developed by Laherrere [7]

$$q(t) = \frac{2q_{\max}}{1 + \cosh[a(t - t_{\max})]} \tag{3}$$

The logistic Eq. (1) comprises three parameters: Q_∞, a, and $t_{\max}$. In order to determine the parameters of Eqs. (2) and (3), the Gauss–Newton algorithm was used. The

appropriate derivatives of Eq. (3) are:

$$\frac{\partial q}{\partial q_{\max}} = \frac{2}{1 + \cosh[a(t - t_{\max})]} \tag{4}$$

$$\frac{\partial q}{\partial a} = \frac{-2q_{\max} \cdot \sinh[a(t - t_{\max})](t - t_{\max})}{1 + \cosh[a(t - t_{\max})]} \tag{5}$$

$$\frac{\partial q}{\partial t_{\max}} = \frac{2q_{\max} \sinh[a(t - t_{\max})]a}{[1 + \cosh[a(t - t_{\max})]]^2} \tag{6}$$

3. Polish gas-consumption model

The data from the period 1970–2001 used in the model construction are compared in Fig. 1. Based on the Startzman (1997–2000) studies, the model adaptation is limited to the second cycle, which is representative of the current stage of development of the Polish economy. Limitation of the prognosis, being based on the data 1994–2000, is because of the economic transformations occurring in Poland during the period 1989–1993 [8].

The smoothed data shown in Fig. 2 have been used for the prognosis. The gas consumptions in Poland in the period 1970–2000, both in the real and smoothed mode are shown in Fig. 3.

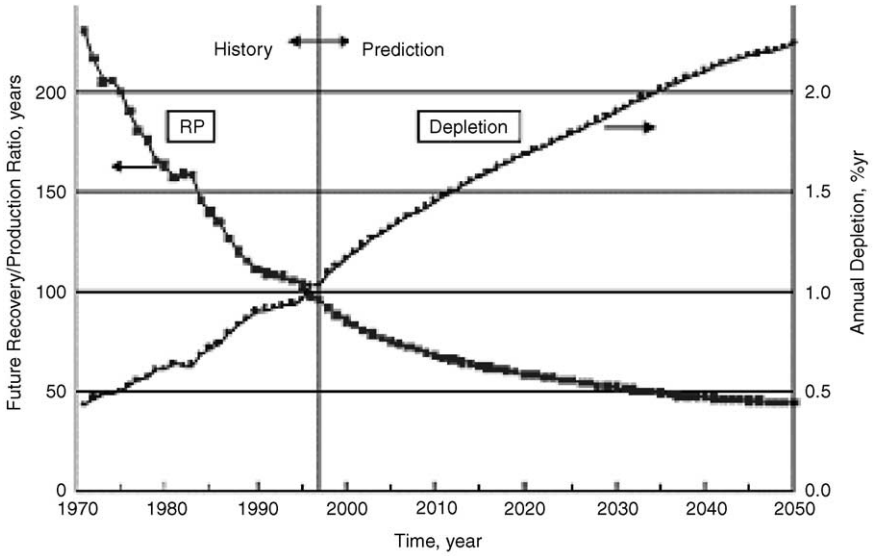

Fig. 1. Historical and predicted trends of the depletion of the worldwide natural-gas resources [5].

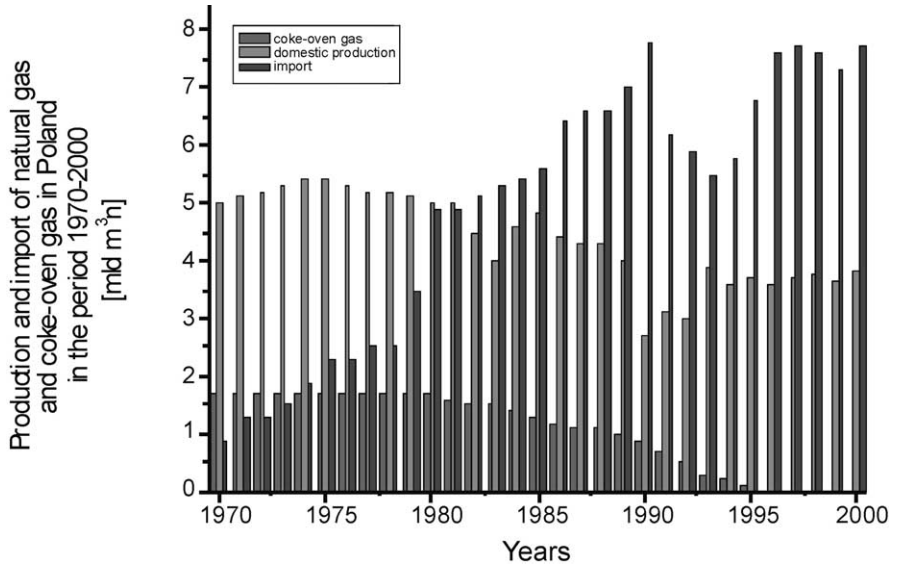

Fig. 2. Production and import of natural gas and coke-oven gas in Poland in the period 1970–2000.

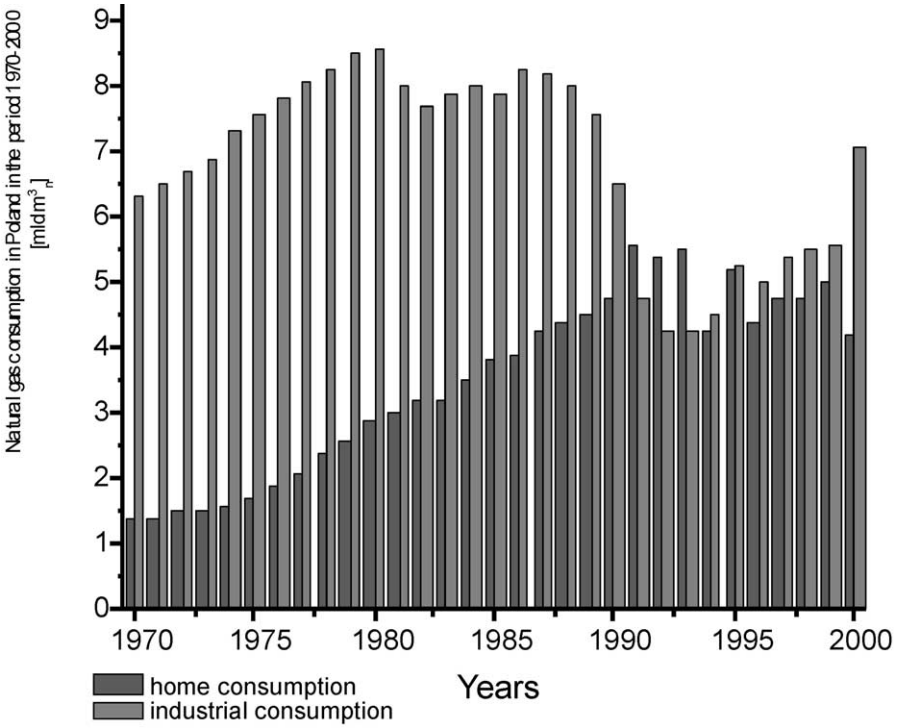

Fig. 3. Natural-gas consumption in Poland in the period 1970–2000.

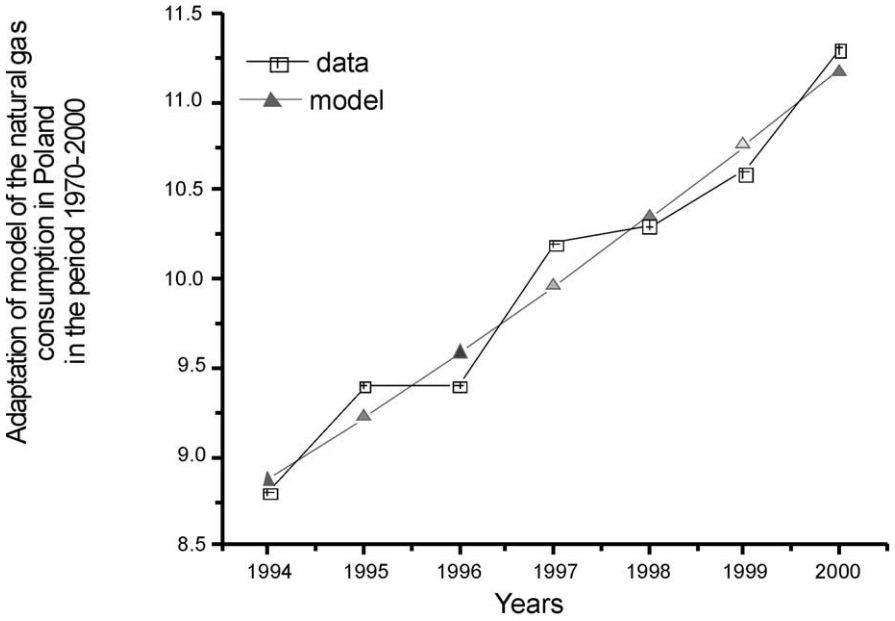

Fig. 4. Adaptation of model of the natural-gas consumption in Poland.

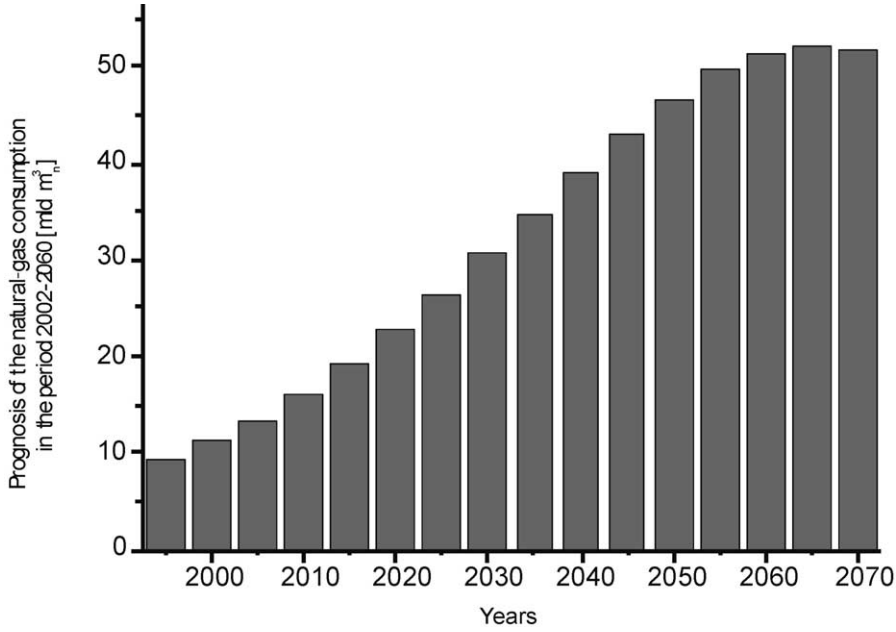

Fig. 5. Prognosis of the natural-gas consumption in the period 2002–2060.

Graphical adaptation of the model to the data shown in Fig. 2 is presented in Fig. 4. Finally, the prognosis of natural-gas consumption in Poland in the period 2002–2070, as based on Hubbert's model, is presented in Figs. 5 and 6. Adaptation of the model to the data of the period 1994–2000 is shown in Table 1.

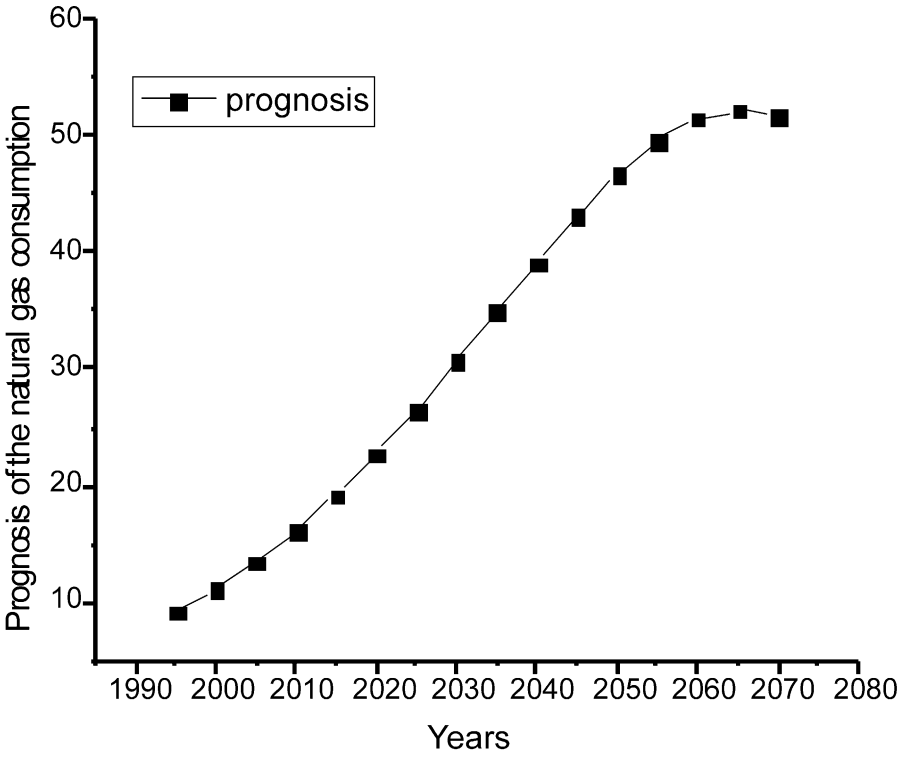

Fig. 6. Prognosis of the natural-gas consumption in the period 2002–2060.

Table 1
Adaptation for the model of the natural-gas consumptions in Poland during the period 1994–2000

Time	Data (mld[a] m_n^3)	Model (β m_n^{3b})
1994	8.8	8.87
1995	9.4	9.22
1996	9.4	9.58
1997	10.2	9.96
1998	10.3	10.35
1999	10.6	10.75
2000	11.3	11.17

[a] mld is equivalent billion (U.S.) or 10^9.
[b] m_n^3 is measured at 0°C and 1 atm.

4. Conclusions

- The adapted model expresses good compatibility with the natural-gas demand of the period 1995–2000.
- The model presented describes the hypothetical natural-gas demand, based on average trend of the economy development during recent decades: the model considers natural production/demand maxima of energy carriers, according to Hubbert's law.
- The model is sensitive to the input data. Averaging of the data of the period 1994–2000, before introducing it to the model, makes the prognosis more reliable.
- The prognosis is loaded with an error resulting from the averaging of the data. The error reaches 20%.
- In cases of untypical changes of the economy growth rate (long stagnation, extreme long and accelerated development), the prognosis error may reach 30%.
- The simple structure of the model enables the possibility of yearly updating, and subsequent eventual correction of the natural-gas demand.

References

[1] Hubbert MK. Nuclear energy and fossil fuels. Drill and Prod Practice, 1956. p. 17.
[2] Hubbert MK. Energy resources [Publ. 1000-D]. Natl. Acad. of Science/Natl. Research Council; 1962.
[3] Al-Jarri AS, Startzman RA. World supply and demand of petroleum liquids [SPE 38782]. 1997.
[4] Al-Fattah SM, Startzman RA. Forecasting world natural gas supply [JPT 2000]. 2000. p. 62–72.
[5] Al-Fattah SM, Startzman RA. Forecasting world natural gas supply [SPE 59798]. 2000.
[6] Al-Fattah SM, Startzman RA. Analysis of worldwide natural gas production [SPE 59798]. 1999.
[7] Laherrere JH, Sornette D. Stretched exponential distributions in nature and the economy. European Physical Journal 1998; Jan:525.
[8] Official statistical data. Rocznik Statystyczny 1970–2000. Unpublished data of PGNIG.