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Evaluation of natural gas supply options for south east and central Europe. Part 1: Indicator definitions and single indicator analysis

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Abstract

The need for diversification of energy sources is an immanent goal in long term energy strategy. In particular, this is of great importance for the natural gas supply. In this respect, evaluation and assessment of potential natural gas resources and their relation to consumers is of great importance. The natural gas supply in Europe is one of the main issues of European energy strategy to be followed in the future. In particular, the natural gas supply in the southeast countries is important.

This paper provides a framework for understanding how much natural gas is available for use in south east and central Europe as well as the links to the recent supply of natural gas and its transport. The analysis is focused on evaluation of the potential routes for natural gas supply to the south east and central European countries. The potential options included in this analysis are the Yamal Route; Nabucco Route; West Balkan Route; LNG NEUM Route and Gas by Wire Route. In this analysis, attention is focused on the following indicators for assessment of potential options: environmental indicator; NG cost indicator; NG transport and royalty indicator; investment indicator; and NG demand indicator. The first part of this paper is devoted to the definition of the indicators and to single indicator analysis.

Keywords: South east Europe; Natural gas routes; Indicators; Single criterion evaluation

1. Introduction

The natural gas supply in Europe is one of the main issues of energy strategy to be followed in the future. Natural gas, as a cleaner burning source of fossil fuel than oil or coal, is now commonly believed to offer part of the solution to climate change and to problems associated with poor air quality. Once considered largely a waste product of oil production, natural gas is currently experiencing a huge increase in demand around the world. As a plentiful, economically viable and less polluting fuel, natural gas makes sense for developing economies looking for new sources for power generation. There is an abundance of natural gas in the world, but it is a non-renewable resource, the formation of which takes thousands and possibly millions of years. Therefore, as the use of this fossil fuel is increasing, it is important to understand the availability of its supply. This paper will provide a framework for understanding how much natural gas is in the ground available for our use and its links to the major natural gas consumers as well as links to the available natural gas transport means. As natural gas is essentially irreplaceable (at least with current technology), it is important to know how much natural gas is left in the ground for us to use. Discoveries of new resources are geographically not evenly distributed. In order to meet the needs of

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modern society, natural gas transport is essential in making it available at different locations. Besides the need to discover new resources, there is a need for its transport to places where it is needed.

2. Natural gas resources

As natural gas is essentially irreplaceable, it is important to know how much natural gas is left in the ground for us to use. However, this becomes complicated by the fact that no one really knows exactly how much natural gas exists until it is extracted. Measuring natural gas in the ground is not an easy task and involves a great deal of inference and estimation. With new technologies, these estimates are becoming more and more reliable; however, they are still subject to revision. A common misconception about natural gas is that it will run out, and quickly. However, this could not be further from the truth. Many people believe that energy price spikes, such as were seen in the 1970s, and more recently in the winter of 2000, indicate that we are running out of natural gas. Recent shortages of natural gas in south east Europe due to the dispute between Russia and the Ukraine have opened a need for diversification of the natural gas supply to this region. Lack of natural gas resources did not cause the aforementioned periods of high prices and gas shortage. Rather, there were other forces at work in the marketplace. In fact, it is estimated that there is still a vast amount of natural gas in the ground. In order to understand its importance, it is useful to present some estimated natural gas resources [1–3]:

Russia	1700 Tcft
Iran	970 Tcft
Qatar	910 Tcft

The misconception of natural gas availability is related to the distance between gas resources and gas consumption locations. This draws attention to potential availability of means and routes for gas transport. Presently, known natural gas reserves available for gas supply to Europe are in four main locations: the Russian basin, North Sea basin, Mediterranean basin and Middle East basin. Also, there are three modes of gas transport, depending on the gas volume and the distance between the gas source wellheads and the final gas terminals for gas distribution within a country. As shown in Fig. 1, there are transport means by gas pipeline, LNG terminal and DC or AC power by wire [4].

Europe is one of the main natural gas consumers and is planning to base its future energy strategy on natural gas. Fig. 2 shows the forecast of natural gas consumption for years 2000, 2010 and 2030 [4].

As can be noticed, the main future natural gas consumers, besides residential consumers, will be power plants.

Presently, the natural gas supply for south east and central Europe is obtained mainly from the Russian basin and is strongly dependent on the single market option. The gas market in these countries is still at an early stage of development. In evaluation of the present state of the natural gas market in south east Europe, in a study entitled "South East Europe Natural Gas Market, Council of European Energy Regulators ASBL, 2005", the following statement is made "Gas market in Austria, Hungary and Italy have high levels of per capita consumption and low expected growth rates, hence they can be regarded as mature markets. Among Non-EU ESCEE countries the only relatively mature gas market is in the region of Romania. On the other hand per capita consumption in Greece and Non-EU ESCEE countries except Romania is in general far smaller which suggests that there is significant room for increase. Greek, Turkish, Serbian, Bulgarian and Croatian gas markets are expected to develop rapidly according to available official forecasts [5]. In the remaining countries of the region gas consumption has either just started recently or is not much developed" [6]. Fig. 3 shows the gas consumption in south east countries [6].

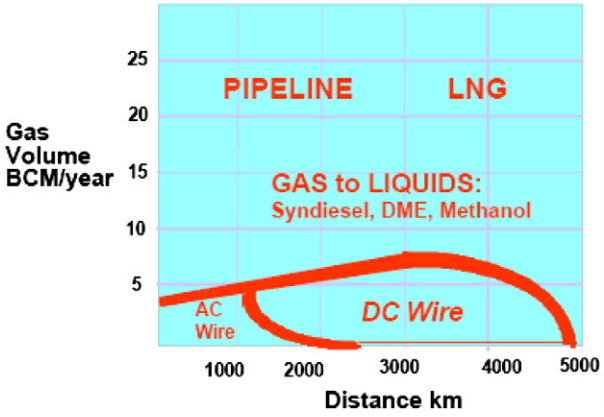

Fig. 1. Natural gas transport.

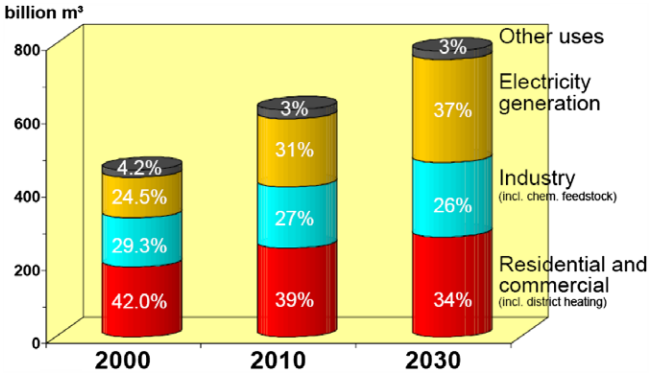

Fig. 2. Forecast of natural gas consumption in Europe.

In the evolution of the natural gas strategy, besides the available resources and market development, gas transport and its diversification will play an important role. For this reason, it is immanent to develop a future natural gas strategy in order to introduce the evaluation of the potential options that are designed to meet the future demand for natural gas.

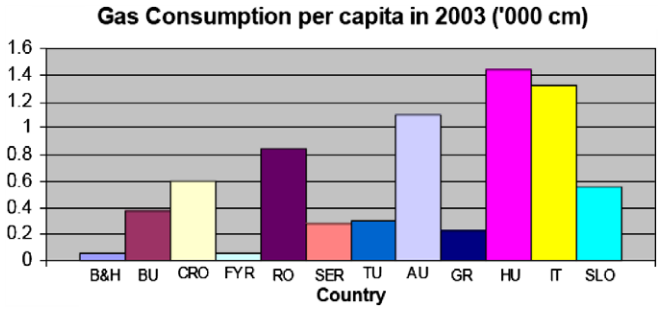

Fig. 3. Natural gas consumption in south east countries.

3. Natural gas transport options for south east Europe

It is known that the natural gas supply in European regions is of paramount importance for future economic development because of the related constraint by the Kyoto protocol. In this evaluation, attention is focused on those potential routes that are of interest for south east and central Europe.

3.1. Yamal-Europe gas pipeline network

The Yamal-Europe transit gas pipeline, with a total length of approximately 4000 km, will connect Western Europe with the rich natural gas deposits of the Yamal peninsula. This is one of the largest development projects at the turn of the century, posing a challenge to designers, engineers and contractors, including numerous Polish and international companies involved in the Polish section of the pipeline.

Russia is the largest natural gas source supplying central and south east Europe through the Yamal pipeline [7]. Geographically, it is situated as the main gas supply through Belorussia and Poland to run parallel to the first Yamal and would have a similar capacity. In this context, Belarus is an important transit country for Russian gas deliveries to Europe, with the country's natural gas transportation monopoly Beltransgaz managing a total of more than 2000 km of natural gas pipelines. The total capacity for the two Yamal lines is foreseen at 65.7 billion cubic metres. Fig. 4 shows the Yamal pipelines for natural gas supply to Europe [8]. A Yamal link, designed to connect the Slovakian infrastructure, is under consideration although, at present, the degree of priority of this project is unclear. The project to increase the capacity of the existing Yamal pipeline through Belorussia to Poland remains an important priority. This project of 1–2 billion Euros would allow for the increase in the export capacity from the existing Gasprom fields and would, thus, contribute

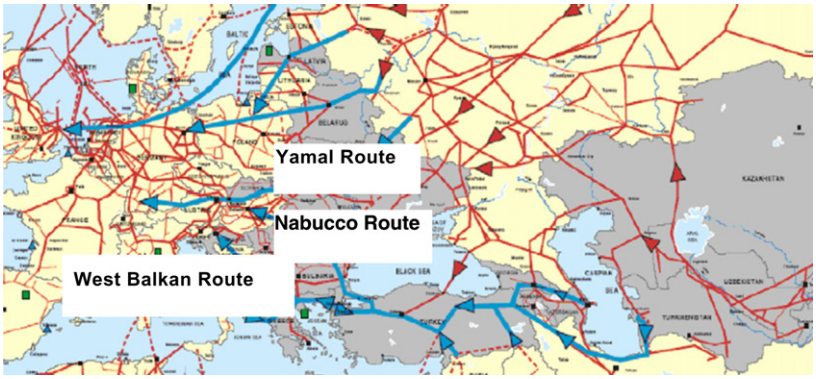

Fig. 4. Yamal, Nabucco and west Balkan pipeline route.

Fig. 5. Nabucco pipeline route.

Fig. 6. West Balkan pipeline route.

directly to the objectives pursued in the context of the EU/Russian energy dialog. The integrated Yamal project will include both the development of the Yamal fields and the creation of a new pipeline for the export of natural gas to Europe (see Figs. 5 and 6).

The natural gas cost from the Yamal fields is estimated to be in excess of 20 Billion Euros. There is little doubt that, in view of the substantial potential for energy savings in Russia, as well as the potential production capacity of various smaller fields being developed by the independent oil company, Russia will be able to increase its export of natural gas to Europe without the full development of the Yamal fields, at least within the foreseen future.

3.2. Nabucco route

The Nabucco route is a natural gas pipeline project for Turkey, Bulgaria, Romania, Hungary and Austria [9]. The extent of detailed planning and, in particular, its development by prospective gas importers makes it look increasingly probable that, during the next few years, we will see the development of at least one of the major pipeline systems for the delivery of Eurasian gas to Europe via Turkey.

The geographic locations of Turkey, Bulgaria, Romania, Hungary and Austria are connected to the major producers/suppliers of natural gas in the Caspian Sea region. The major consumers of energy in Turkey and Europe make south east Europe an important transit route for Russian, Caspian and Middle East natural gas supplies. The total capacity of the Nabucco project is estimated at 20–30 billion cubic metres with a total of 3630 km of pipelines. It will meet the market needs in the North, central and West Balkan regions. Austrians OMV will develop the Nabucco project in partnership with the Turkish state pipeline company, Botas, the Hungarian MOL Transmission PLC, the Bulgarian Bulgas and the Romanian Transgas. Transit countries would use 8–10 Bcm/year so that the delivery to Baumgarten would be around 17–20 Bcm/year [10]. The partners in the project have all agreed to meet at least part of their domestic demand by means of the Nabucco pipeline.

3.3. West Balkan route

South east European countries do not have very developed natural gas markets. Most of the potential use of natural gas in these countries is at the planning stage. The Turkey, Greece, Former Yugoslav Republic of Macedonia, Serbia, Bosnia, Croatia and Hungary West Balkan gas pipeline aims to develop potential diversification of gas supply to south east and central Europe. This pipeline is still at the early stages of development so that there is a deficiency of currently available data. The pipeline is planned to start in Erzurum in Turkey and to end in Baumgarten in Austria. This pipeline is aimed to connect the Turkmenistan, Iran and Iraq [11] gas resources with central and south east Europe. The total capacity of this pipeline is planned to be 15 Bcm. It is estimated that the length of the pipeline (L) will be around 2880 km. The total investment for the pipeline is estimated to be 10 Billion US$. It is of interest to emphasize that this option is connecting most of the countries in the West Balkans where there is a deficiency of natural gas. In particular, most of the electricity in these countries is produced by coal combustion, which significantly contributes to CO_2 pollution problems in this part of Europe.

In particular, it should be mentioned that the shortage of natural gas in this region would affect future economic development. Recently, most of these countries are planning to develop extensive local gas networks and expect to rely on the diversified gas supply [12–15].

3.4. LNG terminal NEUM

The liquefied natural gas (LNG) market is becoming a challenging issue in the potential for natural gas transport [16,17]. It is estimated that the world LNG trade in 2002 was 159 Bcm and will become 410 Bcm by year 2015. This corresponds to an LNG market share of 6% in 2002 and

Fig. 7. Location of LNG terminal in the NEUM port.

10% in 2015. This proves that LNG terminals are promising options for future natural gas supply.

In this respect, this has been selected as a potential option for the natural gas supply to south east Europe. It is anticipated that the liquefied gas will be transported with ships to an LNG terminal to be build in the Port of NEUM where degasification and storage capacity will be built [18]. The natural gas will be transported through Bosnia, Croatia and Hungary to its final destinations. Recently, project 5C for construction of the highway Neum – Sarajevo – Slavonski Brod has been under consideration [19]. It is anticipated that a natural gas pipeline will follow the same geographical route. It will start at the port of NEUM and end in Baumgarten (Austria). Fig. 7 shows the geographical location of the NEUM port. The LNG terminal NEUM will open a new potential route to bring natural gas from Mediterranean countries (Algeria, Tunis and Libya) [20] and the Middle East (Qatar, Oman and Iran) [21] to south east and central Europe. In particular, this route can substantially contribute to the potential diversification of the natural gas market.

Since this option is aimed to supply natural gas to the south east European countries, it is assumed that this route will be developed in two phases corresponding to the future development of natural gas markets in these countries. Each phase will have a capacity of 5 Bcm. The pipeline transport route is estimated to be 600 km.

3.5. Gas by wire option

The Gas by Wire option is designed to introduce the possibility to have natural gas consumed in a combined cycle power plant for electricity production [22,23]. Then, electricity will be transported by high voltage power lines to the destinations of south east and central Europe. The location of the power plant is anticipated to be in Turkey.

In defining this option, some assumptions are made. The gas consumption (G) is 15 Bcm. The lifetime heat consumption per unit electricity production (g) is 1940 cm/kW h The efficiency of the NGCC power plant (η) is 0.56 [24]. Under these conditions, the total power installed (P) will be 5000 MW with a production (W) of 77×10^9 kW h/year. With a length of the transfer line (L) equal to 2500 km, the total energy loss (W) will be about 4%. The investment cost is based on the converter cost (C_{con}) of 60 $/unit and on the transmission line cost (C_{TL}) of 70 $/1000 km [25]. Environmental indicators include the CO_2 production due to energy losses in the transmission lines.

4. Indicators

In the evaluation of natural gas supply systems to the south east European region, the criteria and respective indicators described below are taken into consideration. For each transport option, the capacity is designed to represent the capacity of the pipeline taking into consideration its present and future yearly maximum capacity. The capacity is expressed in m^3/year.

4.1. Environmental indicator

The pollution indicator of atmospheric air (total emissions of polluting substances) is one of the main parameters for the assessment of atmospheric degradation. Carbon dioxide produced from the combustion of natural gas in compressors for power transport and methane leaks are taken as the main indicators for the natural gas pipeline impact on the environment. In the assessment of pollution from gas pipelines, it is considered that there are two kinds of emissions, namely indirect and direct emissions [26,27]. Direct emissions comprise combustion products from gas turbines. Indirect emissions result from the leakage of gas pipelines. From the Gasprom analysis [28], it is taken that

$$G_{CO_2}\ (\text{indirect emissions}) = 0.7 \times G_{tot}$$
$$G_{CH_4}\ (\text{direct emissions}) = 0.3 \times G_{tot}$$

It is anticipated that the ratio between the CO_2 and CH_4 emissions is 1/24 [29], so that the total amount of emissions is

$$G_{GHG} = G_{CO_2} + G_{CH_4} \times 24$$

For the LNG option, it is assumed that CH_4 is released from the degasification terminal and from pipeline leakage.

4.2. Natural gas cost indicator

This indicator introduces the present annual average cost of natural gas [29]. It includes the source cost and the transport cost and is expressed in $/$m^3$. For gas pipeline transport, it is assumed that the total natural gas price comprises production and transportation costs [30]. So, the natural gas production cost (C_{pro}) is taken as the FBO price at the wellhead [31].

For the Yamal pipeline, the production cost is based on the Gasprom gas cost of 2004 [32]. The Nabucco pipeline is fed with Turkmanien gas obtained in Turkey so that its price is defined by a Tukmanien information source [31]. For the Balkan route, the natural gas production cost is Iranian gas delivered to Turkey [32]. For the LNG terminal, the anticipated natural gas cost is obtained from Qatar [33].

4.3. Natural gas transport and royalty cost indicator

The pipeline transport and royalty cost comprise the total cost for natural gas transport from the wellhead to the final terminal of the gas route.

$$C_{\mathrm{TR+RO}} = C_{\mathrm{TR}} + C_{\mathrm{RO}}$$
$$C_{\mathrm{TR}} = L \times c_{\mathrm{tran}}$$

where the length of pipeline (L) is per 1000 km and the transport cost (c_{tran}) is per 1000 km [34].

The royalty cost is defined as a percentage of the total gas cost, which includes natural gas cost and transport cost. In this analysis, it is anticipated that the royalty is 15% [35]. The royalty cost is, therefore:

$$C_{\mathrm{RO}} = (C_{\mathrm{pro}} + C_{\mathrm{TR}})0.15$$

The LNG cost includes the gas production and liquefaction costs as well as the transport cost to the LNG terminal. Transport cost comprises degasification and storage cost as well as pipeline transport cost to the main consumers, so, the LNG cost is given by:

$$C_{\mathrm{LNG}} = C_{\mathrm{ln}\,g} + C_{\mathrm{tran}}$$

with the LNG cost given by:

$$C_{\mathrm{ln}\,g} = C_{\mathrm{prod}} + C_{\mathrm{liq}}$$

where C_{prod} is the gas production cost, C_{liq} is the liquefaction cost and the transport cost (C_{tran}) includes the decompression and pipeline costs, $C_{\mathrm{tran}} = C_{\mathrm{dec}} + C_{\mathrm{pipe}}$.

For the LNG option considered in this evaluation, all costs are based on the cost of the LNG system defined in Ref. [38] multiplied by the ratio of the capacity of the option and the standard capacity for the selected reference.

4.4. Investment cost indicator

The investment cost consists of the total investment in the specific gas route. It includes tubing that corresponds to the respective capacity of the route. It is based on the length of the pipeline and also on the physiology of the ground. For example, an underwater pipeline would cost much more than an onshore pipeline.

The investment cost indicator is derived from data available in the literature [36]. Basic data are taken from estimates for investments of a capacity (Q) of 10 Bcm natural gas pipelines. In the determination of the pipeline cost, it was assumed that for every 100 km, there was one compressor station. A diameter (D) of 48 in. was used for all pipelines.

4.5. Natural gas demand indicator

The natural gas demand indicator is a parameter that defines the need of a region for the respective natural gas route. The value of this parameter is obtained as the quantified merit for the respective route that reflects the demand for gas in the countries through which the gas line is installed.

This indicator is calculated in m^3/capita/year. It is obtained by adding the total natural gas consumption in individual countries and dividing by the total population of the countries where the natural gas route exists. This evaluation uses standard values for natural gas demand for year 2003.

5. Single indicators assessment

The standard procedure in the assessment of different options is based on single parameter analysis. It implies that the rating among options is obtained by specific individual indicators. For evaluation of the potential options of natural gas supply, the results are presented in Table 1.

Single indicator evaluation of the natural gas route options under consideration are presented in Figs. 8–12. It can be noticed that in the single indicator assessment, the following priority among options is obtained:

Table 1
Indicators

	Option	Capacity Bcm/year	Length km	Indicators				
				Environment WGP 10^3t/year	NG Cost Euro/10^3 m^3	Transport cost Euro/10^3 m^3	Investment Euro/m^3/year	NG demand 10^3 m^3/capita/year
1	Yamal gas route	30	4000	9930	90.47	40.5	0.91	1
2	Nabucco Project	20	3600	6400	37	79	0.5	0.65
3	West Balkan gas route	15	3400	3500	37	96.6	0.6	0.31
4	LNG terminal NEUM	10	600 + 1600	2380	47.2	38.95	0.155	0.53
5	Gas by wire	15	5000	3250	37	73.6	0.24	0.437

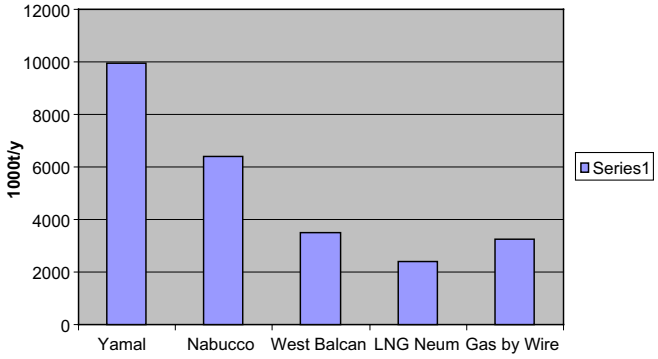

Fig. 8. Environmental indicator.

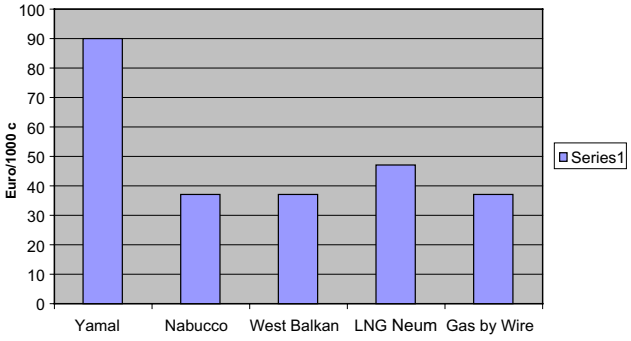

Fig. 9. Natural gas cost indicator.

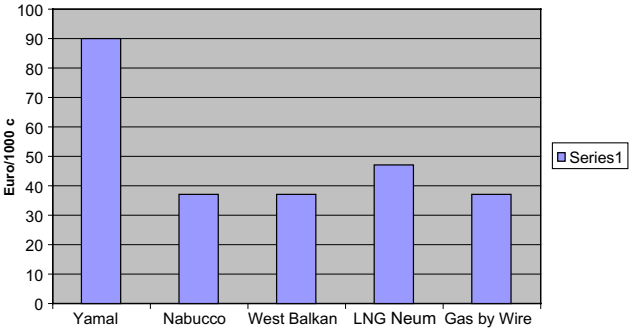

Fig. 10. Gas transport indicator.

Environmental indicator	LNG terminal NEUM option
Natural gas cost indicator	Nabucco gas by wire options
Natural gas transport indicator	West Balkan option
Natural gas investment indicator	LNG terminal NEUM option
Natural gas demand indicator	West Balkan option

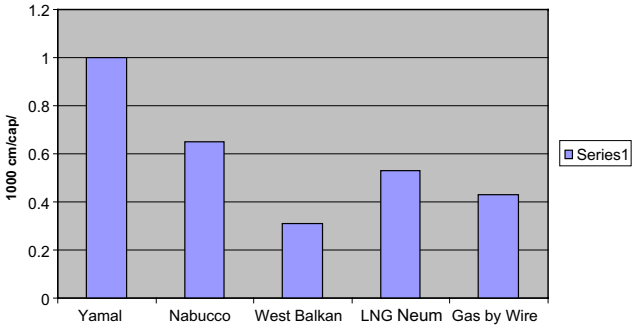

Fig. 11. Investment indicator.

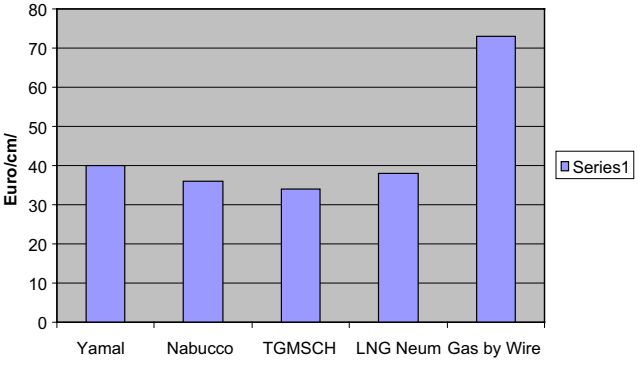

Fig. 12. Natural gas demand indicator.

It is of interest to notice that, depending on the indicator, the obtained result shows different priorities among the options. Between the five options under consideration, four of them have the first place on the priority list depending on the indicator. This proves that any assessment of these options is biased depending on the criterion and the indicator selected. For this reason, there is a need for multi-criteria evaluation of the potential options under consideration. This will verify the interaction among the criteria and their mutual compliance.

6. Conclusions

In conclusion, for the single indicator assessment of potential options, it can be noticed that the priority listing is related to the individual indicator. In the evaluation of potential options, decision making is strongly related to expert assessment and will lead to biased decisions. There are difficulties to obtain reliable data for this kind of evaluation, so it is of great interest to be in a position to validate the quality of the indicator values. In particular, the priority list obtained by a single indicator is reflecting only the merits obtained by the specific indicator. It has no possibility to take into account mutual interaction and the contribution of other indicators without introducing expert selection of indicators or arbitrarily selected weighting coefficients for the individual indicators.

Further cases will be explored in which the weighting coefficients of the indicators are varied in a manner to better discriminate between the five options.

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