Cost Curves for Gas Supply Security: The Case of Bulgaria

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Abstract

We evaluate the cost-effectiveness of various policy options and infrastructure investment proposals to improve the security of gas supply in Bulgaria, one of the most gas insecure countries in the European Union. We do this by computing 'security of supply cost curve' for different gas supply disruption scenarios. The curves show the cumulative amount of security of supply on the horizontal axis and the unit cost of security on the vertical axis. Measures should be implemented by order or rising unit cost until the public authorities' preferred level of security is achieved. Our results show that a cost-effective gas supply security policy for Bulgaria would concentrate on two measures: (1) allowing reverse-flow transactions on the transit pipelines to Greece and Turkey to access the LNG terminals in these countries in case of disruption in Russian gas supplies and, (2) ensuring effective dual-fuel capability for Bulgaria's heat generation plants. The infrastructure options actually considered by the Bulgarian authorities and gas industry (expanding the withdrawal rate of the Chiren underground gas storage and building a new gas interconnector pipeline with Greece) appear to be much more costly.

Keywords Natural Gas, Security of Supply, Energy Policy, Bulgaria, EU

JEL Classification L38; Q48; L5; L95; L98

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1 Introduction

Over the past few years, the question of energy security has moved to the top of the European political agenda. Concerns about the economic and political implications of Europe's 'dependence' on Russian gas have been reinforced by the crises of January 2006 and 2009. In the latter case Russian gas supplies to Europe via Ukraine have been completely disrupted for two weeks.

Noël (2008) has shown that although Russian gas now covers less than 40% of European imports against more than 80% in 1980, and represents only 6.5% of total primary energy supply in the European Union, supply diversity is concentrated in large energy markets of Western Europe. Smaller economies amongst the newer EU member states in Central and Eastern Europe are heavily dependent on Russian gas. Bulgaria is one of these countries (see Table 1).

Table 1. Dependence on Russian gas in Eastern Europe

		Annual consumption (bcm) [A]	Russian gas imports (bcm) [B]	Dependence on Russian gas [C]
Romania	[1]	15.61	4.48	29%
Poland	[2]	13.7	6.20	45%
Turkey	[3]	35.1	23.15	66%
Greece	[4]	4.03	2.89	72%
Czech Republic	[5]	8.9	6.43	72%
Ukraine	[6]	64.65	52.02	80%
Serbia	[7]	2.4	2.2	92%
Bulgaria	[8]	3.34	3.095	93%
Slovakia	[9]	5.87	5.80	99%
FYRO Macedonia	[10]	0.105	0.105	100%

Notes and Sources:
[1]: refers to 2008; Romanian Energy Regulatory Authority (ANRE).
[2],[3],[4],[5],[9]: refers to 2007, BP Statistical Review of World Energy 2008.
[6]: refers to 2006; IEA, 2007.
[7]: refers to 2007; Energy Regulators Regional Association (ERRA).
[8]: refers to 2008; State Energy and Water Regulatory Commission (SEWRC).
[10]: refers to 2007; Macedonian Gas Association, Sept. 2008.
[C]: [C]=[B]/[A].

Bulgaria's authorities were first alerted to the vulnerability of the country in January 2006 when Russian gas stopped flowing for about a day. When, in January 2009, the Ukrainian gas transit corridor was totally disrupted for two weeks, Bulgaria was one of the worst affected countries amongst EU member states.[2] After the crisis there has been a renewed interest from Bulgarian authorities to invest in energy infrastructure and especially in 'gas supply security'. This paper attempts to evaluate the cost-effectiveness of various policy options and infrastructure investment proposals. We do this by computing, for different gas supply disruption scenarios, what Lapuerta (2007) refers to as a gas 'security of supply cost curve'.

[2] Outside the EU, countries like Croatia, Macedonia and Serbia were also significantly impacted.

2 Defining gas supply security

For the purpose of this article and following Findlater and Noël (2010, p. 237), we will refer to security of gas supply as 'the ability of a country's energy supply system to meet final contracted energy demand in the event of a gas supply disruption'. Being able to source alternative gas to make up for disrupted volumes obviously contributes to gas supply security. However this definition does not require all missing gas to be replaced by alternative gas. Shifting to alternative fuels such as oil products for heat or electricity generation is considered here as an option to increase the security of gas supply. So would be interruptible gas supply contracts for industrial customers.

It should be noted that import dependence in itself is not a good indicator of security of supply. A country that is self-sufficient in gas can still be unsecure if the energy supply system is unable to serve final energy demand in the event of a major gas infrastructure breakdown. Reciprocally, a highly 'dependent' country can be very secure. Finland (to take just one example) is actually even more import dependent than Bulgaria (on Russian gas) yet much more secure, because most gas consumption is switchable to oil in case of gas supply disruption (Noël, 2010b).

Using the definition above, we now turn to assessing Bulgaria's gas supply security situation.

3 Assessing Bulgaria's gas supply security

A country's gas supply security situation – that is, the degree to which it can cope with gas supply disruptions – is determined by several factors including the gas supply infrastructure set-up, the structure of gas consumption and, critically, the policies in place to deal with gas supply security risks.

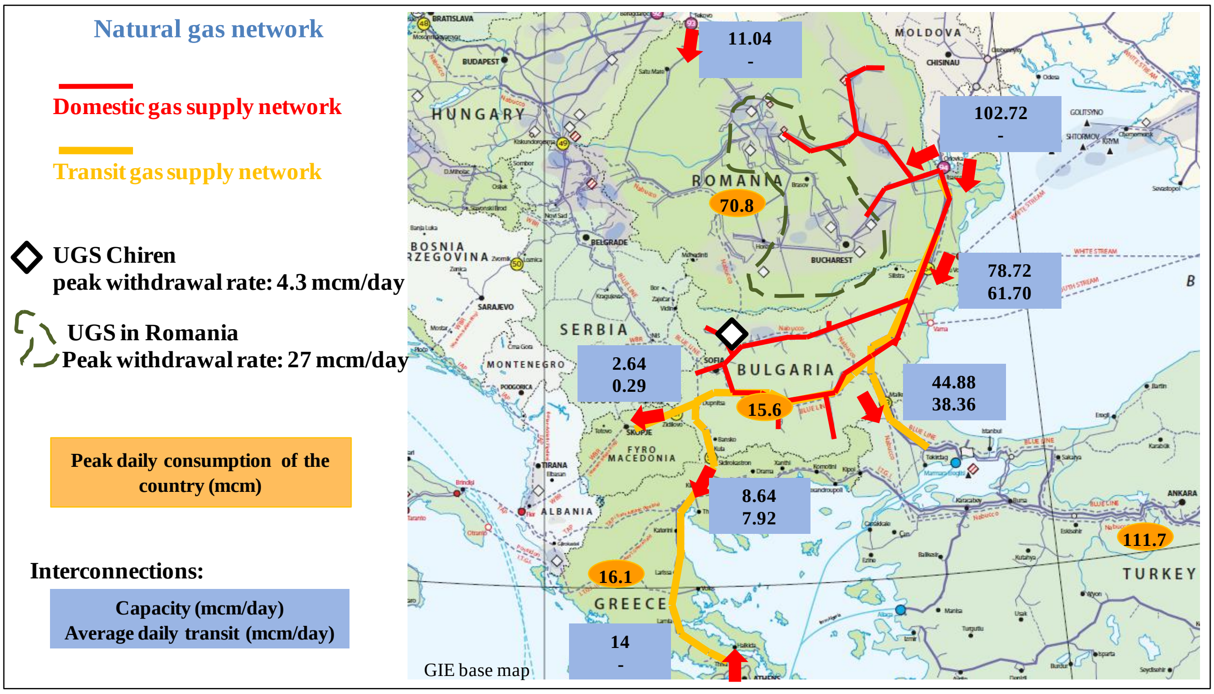
Neumann (2007) and Le Coq (2009) have tried to use quantifiable indicators to measure the security of energy supply situation in EU Member States. The variables involved are the political stability of exporting countries and import dependency of the importing country. Le Coq (2009) also includes variables linked to energy transit and to an indirect measure of economic impact.

Such indicators might help assess the level of risk a country faces but do not reflect the energy system's ability to address them. For instance, no consideration is given to the physical and contractual ability to source alternative gas or other energy sources. Similarly, policies in place to mitigate the risks, including emergency plans, are ignored. This is why, like Findlater and Noël (2010) did for the Baltic States, we opt for a qualitative assessment of the security of supply situation of Bulgaria.

3.1 Gas supply set-up, consumption structure and associated risks

The Bulgarian gas supply network is composed of two different pipeline systems. One is a domestic supply pipeline while the other is a separate transit pipeline that brings gas to Turkey, FYROM (Macedonia) and Greece. These two pipelines are branches of a single upstream pipeline system carrying Russian gas through Ukraine, Moldova and Romania. Because Russia is the single gas supplier of this corridor, a so-called 'N-1 situation', corresponding to the loss of the largest supplier, simply means a total disruption of gas exports to Bulgaria. Potential causes of such disruptions include political and commercial disputes – such as the recurrent Ukrainian-Russian one – but also technical failures[3].

Figure 1. Overview of the natural gas network in Bulgaria



Sources: cf. calculations and sources cited in the text.

Bulgaria consumes around 3.34 bcm of natural gas each year. More than 3 bcm are imported from Russia. Bulgaria currently possesses only one Underground Gas Storage (UGS) facility, in Chiren, located in the north-east of the country. This facility has a peak withdrawal capacity of 4.3 mcm/day (Tzvetkova, 2009a).

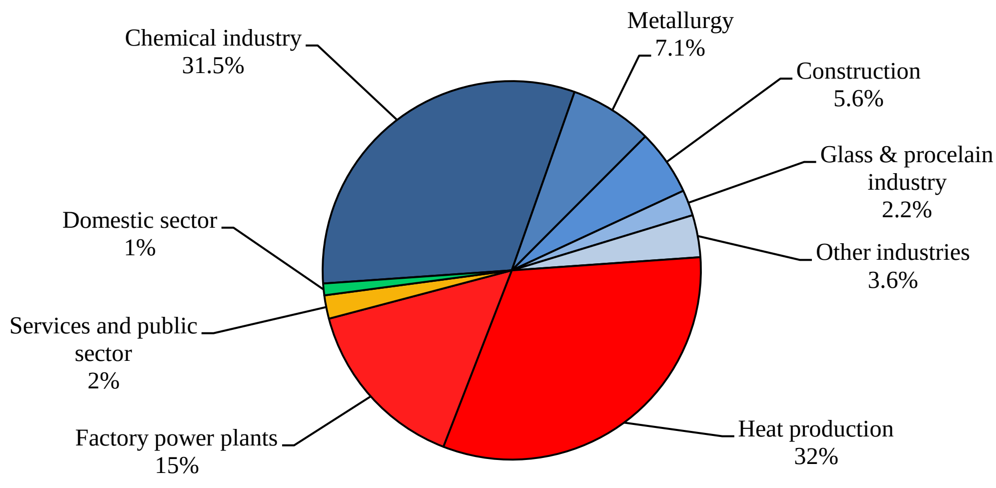
The breakdown of the natural gas consumption in Bulgaria is presented in Figure 2. Heat generation accounts for 32% of the total and industry, 50%. Moreover, around 50% of the total heat consumed is generated from gas (cf. Figure 3). Consequently, a large scale gas supply disruption would put at risk a major share of heat generation and would threaten normal industry operations.

The picture is very different for electricity generation, which would withstand a gas supply disruption well. Only 5.7% of Bulgarian electricity is generated by gas-fired power plants (cf. Figure 4). Moreover, there is excess generation capacity both in Bulgaria and in its neighbouring countries, and there is excess transmission capacity between these trading partners (Silve, 2009). As a result, electricity supply would not be affected by a gas supply disruption.

To summarize, Bulgaria faces a risk of disruption of its only natural gas supply import route. This would have major consequences on heat generation during the winter season and would affect industrial operations. This is typically what has been observed during the gas crisis in January 2009.[4]

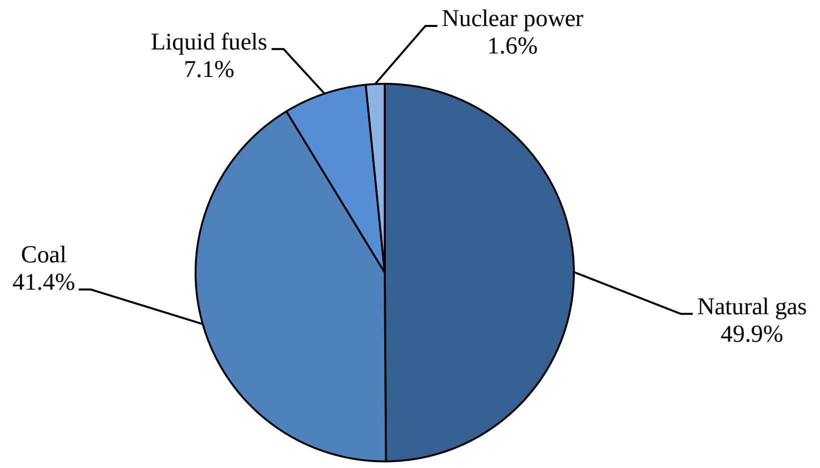
[3] In April 2009, a pipeline blast in Moldova also led to a supply disruption in the Balkans, with a 70% gas supply drop in Bulgaria. (Reuters, *Blast reduces Russian gas supplies to Balkans*, in *Reuters*. 2009).
[4] For a detailed description of the gas crisis of January 2009 and of its impact on Bulgaria, see Silve (2009), pp. 7-14.

Figure 2. Structure of gas consumption by sector, Bulgaria (2007)



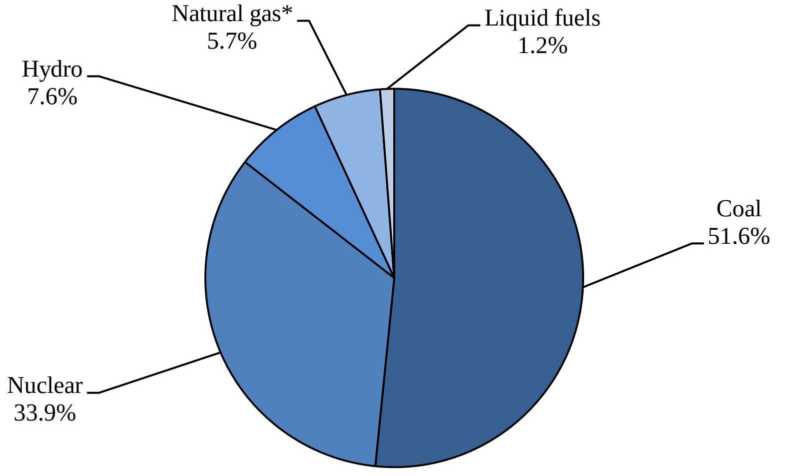
Source: Bulletin on the state and development of the energy in the republique of Bulgaria , SEWRC, August 2008.

Figure 3. Structure of heat generation by fuel type, Bulgaria (2007)



Source: Bulletin on the state and development of the energy in the republique of Bulgaria , SEWRC, August 2008.

Figure 4. Electricity generation mix, Bulgaria (2007)



Notes and sources: SEWRC, December 2008; * cogeneration

3.2 Bulgaria is unable to cope with gas supply disruptions

Bulgaria was unable to cope with the gas supply disruption of January 2009 and was forced to witness a significant impact on its population and economy. Despite the warning of January 2006, when gas supplies from Russia through Ukraine had been briefly interrupted, the Bulgarian authorities had not started to look seriously at developing new infrastructure, diversifying supply sources and designing appropriate emergency procedures.

During the crisis almost 50% of contracted gas consumption could not be served by the system. As Russian imports were completely shut down on 6th January, consumption had to abruptly adjust through rationing, dropping from about 13 mcm/d to about 6 mcm/d (Kardejak, 2009, slide 51).

The sum of withdrawal from storage and indigenous production – the latter being negligible – amounts to between a quarter and a third of peak winter consumption, depending on temperatures and economic activity. Both sources are drawn upon at close to maximum rate during cold winter months, leaving little possibility to compensate for disrupted imports. Moreover, Bulgaria has virtually no ability to source alternative imports in the event of Russian gas supplies being cut off.

Bulgaria seems to have a limited ability to switch some of its gas consumption to alternative fuels during a supply interruption. Gas-fired district heating plants are supposed to maintain two weeks' worth of heavy fuel oil on site but their ability to effectively shift fuels was called into question by the crisis of January 2009. In Sofia, it took close to a week for the district heating company to shift to heavy fuel oil.

Some industrial customers could in theory sign interruptible supply contracts. This would allow for a reallocation of some gas volumes from the industry toward consumers usually regarded as non-interruptible (for instance heat generation for domestic use). There does not seem to be such contracts in place in Bulgaria and there is no indication that Bulgargaz ever proposed interruptible contracts to its industrial customers.

The crisis of January 2009 exposed the lack of emergency preparedness. For instance, the Minister of Economy and Energy issued an order on January 6th to restrict natural gas consumption in the entire territory. However, it took 2 days for the order to come into effect (Tzetkova, 2009b). A quicker and more organised response, including a better management of the rationing of industrial customers, could have helped preserve enough gas for a few days of residential heating consumption for instance.

Short-term transactions with neighbouring countries could also have alleviated the crisis in Bulgaria but there are contractual and infrastructure barriers to overcome. In particular, destination clauses or defective regulation of transit pipelines make such transactions all but impossible in the region. Additionally, there are some physical barriers to better regional co-operation, such as the lack of reverse-flow capacity. Only at the very end of the crisis did some gas companies inject natural gas in the Bulgaria-Greece pipeline from the Greek LNG terminal at Revythoussa. They did not actually reverse the flow but by injecting gas they allowed Bulgaria to pump into gas 'stored' into the transit pipeline, the so-called linepack. Greece was thus able to provide 2.5 mcm of natural gas per day to Bulgaria (Kovacevic, 2009).

Since 2006 some other Central and Eastern European countries have taken measures to build security-enhancing gas infrastructure. For example, Hungary built a strategic gas storage facility[5]; Romania and Hungary signed a Joint Development Agreement in July 2008 launching an interconnection project between the national gas transmission systems of the two countries (Transgaz, 2009).

The crisis certainly revived the political and industrial interest for gas supply security and the authorities are considering several infrastructure projects to improve the situation.

4 Existing proposals to improve gas supply security

An expansion of the Chiren UGS facility has been planned and is expected to be completed in 2011. According to official figures, the maximum daily withdrawal rate will be increased to reach 10 to 12 mcm per day, for an investment cost estimated at € 250 million (Tzvetkova, 2009).

Additionally, a second UGS facility is currently under consideration. A depleted natural gas field located in Galata, in the Black Sea, would be converted into a new storage facility. Its working volume should increase progressively from 250 to 800 mcm (Tzvetkova, 2009)., but no estimate of its maximum peak withdrawal rate has been released so far.

Another project consists in building a new pipeline connecting Greece and Bulgaria, separate from the existing transit pipeline carrying Russian gas. The project, initially studied by the Ministry of Economy and Energy of Bulgaria, has in July 2009 received the backing of the Italian utility Edison SpA – the main backer of the ITGI pipeline[6] –, which announced its intention to build it in a joint-venture with the Bulgarian Energy Holding and the Greek gas company Depa.

Finally, there is renewed interest for the Romania-Bulgaria interconnection project that has been under consideration for a few years (Transgaz, 2009). In February 2009, Bulgartransgaz and SNTGN Transgaz SA – the Bulgarian and Romanian gas transmission system operators, respectively – have signed a protocol stating that they would issue, within 6 months, a pre-feasibility study analysing the current data related to the two gas transmission systems and the interest expressed by potential users in the capacity of the future interconnection. Based on the outcome of this study, the two parties are expected to conclude a Joint Development Agreement (Transgaz, 2009). The length of this connection is estimated to be only around 15 km, of which between 7 and 13 would be located on the Bulgarian territory. Its construction will probably take around 2 years, for a total investment cost that we have estimated at € 23.9 million.[7]

These projects signal a renewed interest for investing in Bulgarian gas supply security improvements. However, to make rational decisions, public authorities need to know how these options compare in terms of additional supply security per unit of investment. In the next sections we provide such an assessment.

[5] Which was not yet completed in January 2009.

[6] The Interconnector Turkey Greece Italy (ITGI) is a pipeline project destined to import Azeri gas to Europe via Turkey.

[7] See appendix 9.2.5 for cost calculations.

5 The gas supply security cost curve: methodology

The security of supply cost curve is drawn by ranking policy options and measures by order of rising unit cost. The horizontal axis of the graph shows the cumulative amount of security of supply (or insured gas consumption) while the vertical axis shows the cost per unit of security of supply. The curve allows policy makers to choose a cost-effective policy-mix to attain their preferred level of gas supply security.

5.1 Drawing the curve

The horizontal axis shows the cumulative level of gas supply security. The metric to quantify security of gas supply follows directly from our definition. A unit of gas supply security is a million cubic meter (mcm) of peak daily gas consumption that is insured against supply disruption, either by allowing it to be replaced by alternative gas or substituted by alternative energy.

The vertical axis shows the cost per unit of gas supply security provided. This is obtained by dividing the total cost of implementing a given policy measure by the volume of gas consumption it would insure. For example, if the total cost of implementing a policy of dual-fuel capability for power plants was € 100 million and power plants consumed 1 mcm/d at peak gas consumption time, the unit cost of that policy measure would be € 100 million per mcm/d of peak gas consumption insured.

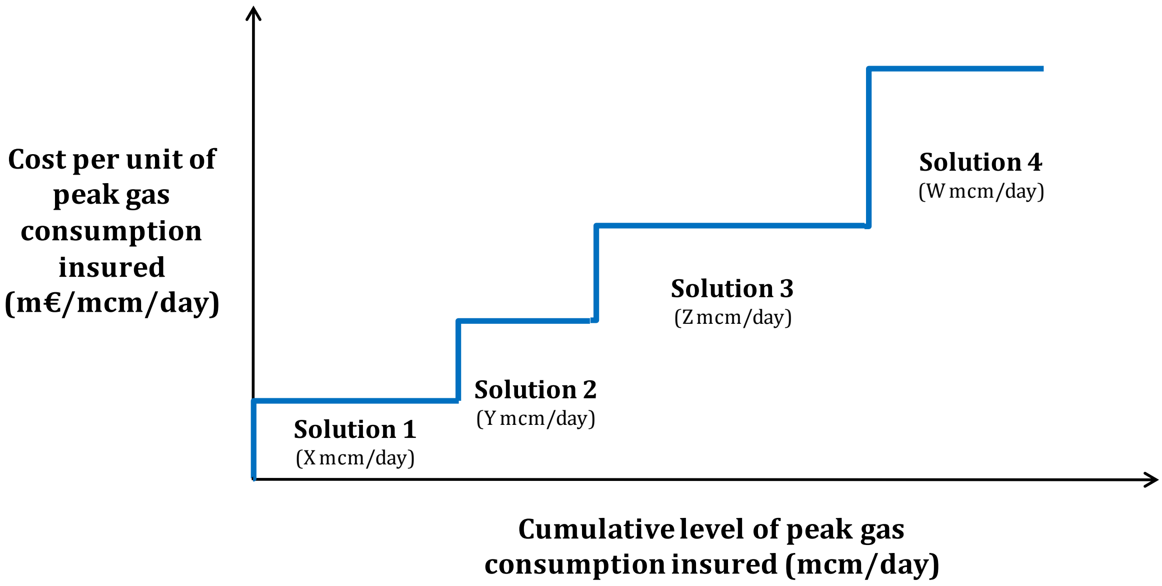
The total cost of the policy options is the net present value (NPV), over the lifetime of the infrastructure or equipment, of the sum of the investment cost (CAPEX) and operating costs (OPEX). We use an infrastructure lifetime of 20 years and a cost of capital of 10%[8].The OPEX breaks down into two components. The fixed operating costs, such as maintenance of pipelines and compressors, would be incurred during the entire life of the infrastructure irrespective of gas supply interruptions. Other operating costs, such as the extra cost of running heating generation plants on fuel oil instead of natural gas, would be incurred only during periods of gas supply disruption.

Given the second component of the OPEX, the overall cost of each option will be sensitive to the occurrence of gas crises over the coming decades. We use three scenarios for the occurrence of 15 day disruptions[9]: once a year (scenario 1); once every three years (scenario 2); once every ten years (scenario 3). We calculate the cost of security measures and draw the associated curve for each scenario.

[8] These figures could be modified and sensitivity analysis could be carried out.

[9] 15 days is an arbitrary number but corresponds roughly to the gas crisis of January 2009 where gas supply to Bulgaria totally cut off for 14 days.

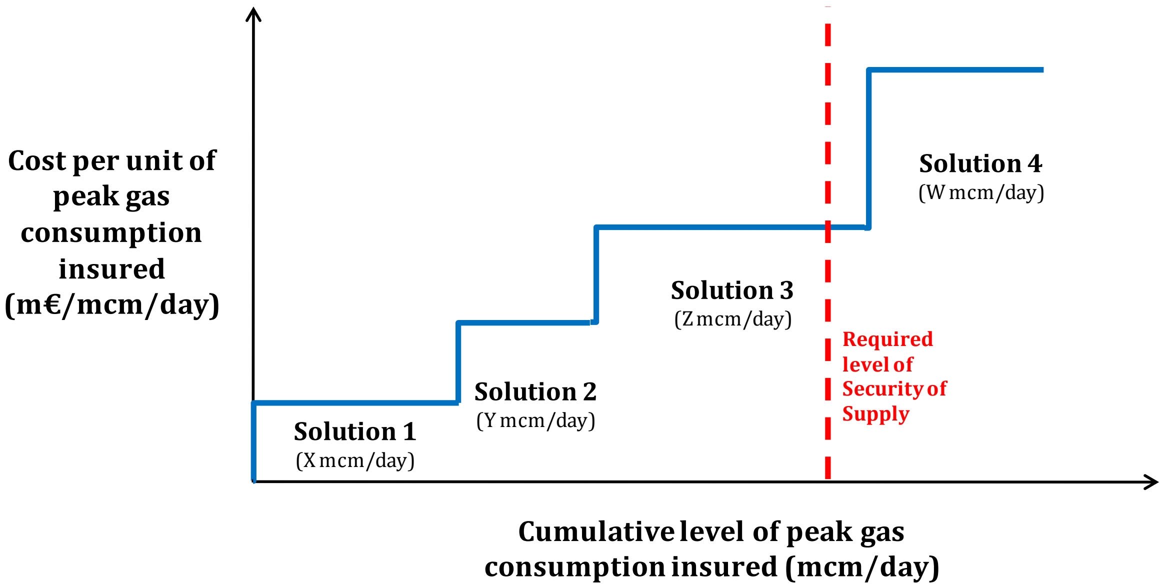
Figure 5. 'Security of supply' cost curve concept



5.2 Using the curve as a policy tool

The security of supply cost curve can help choose where money should be spent once it has been decided that the country is under-insured against gas supply disruptions and needs to buy more security. Policy options should be implemented by order of rising unit cost, starting with the cheapest and moving up until the required level of gas supply security is reached. Figure 6 shows the chosen level of security as a vertical dotted line. The cost effective policy mix here would consist in implementing solutions 1, 2 and 3.

Figure 6. 'Security of supply' cost curve concept



The cost curve alone cannot help policy makers choose the appropriate level of supply security for the country (that is, where to put the vertical dotted line). The government may want to insure the gas consumption of some specific categories of customers, the interruption of which would be particularly costly economically or politically. Such is the approach chosen by the European Commission in its Proposal for Regulation on the Security of Gas Supply, which asks governments to define categories of 'protected customers' including at least the residential sector (European Commission, 2009)[10]. Alternatively, the government may try to determine the economically optimal amount of supply security, which would suppose to know the demand curve for gas security. The latter can be revealed by assessing the willingness to pay for each additional unit of gas security provided (as illustrated by Hough (2005) and attempted for Greece by Damigos *et al.* (2009)); or by calculating the marginal damage function, i.e. the value of the damage incurred for each unit of gas not delivered (as illustrated in Hirschhausen *et al*. (2008)).

In this paper we do as if the Bulgarian authorities wanted to secure the entire peak gas consumption, shown as a vertical dotted line on the graphs in the following section.[11]

[10] The European Commission, Council and Parliament found an agreement on the Regulation in June 2010 but the final version of the text is not publicly available at the time of writing. For a critique of the Regulation at various stages of the negotiation see Noël and Findlater (2009) and Noël (2010).

[11] It has proved impossible to get an official figure for Bulgaria's peak daily gas consumption, either from the Bulgarian or European authorities. We have estimated it as follows. In Romania, Turkey and Greece (three neighbouring countries) the peak daily consumption represented respectively 166%, 116% and 146% of the annual average daily consumption. Retaining the most conservative figure (166%) the peak daily consumption in Bulgaria is estimated to be 15.6 mcm/day.

6 Results: security of supply cost curves for Bulgaria

6.1 The measures considered

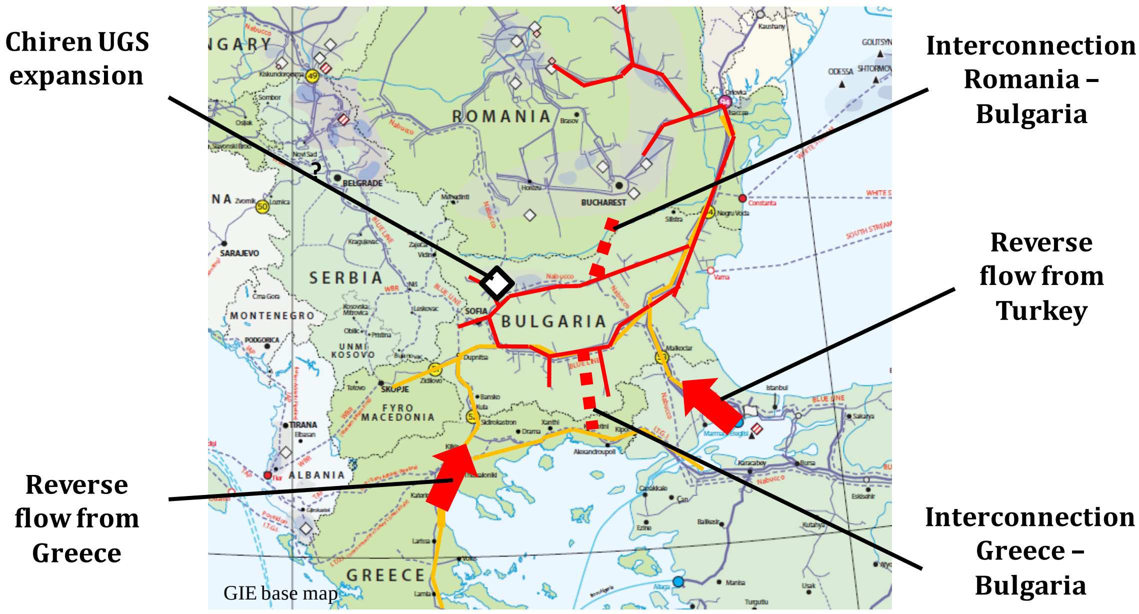
For each of the options listed below, we have estimated the total net present cost of implementation and the volumes of gas they would insure on a peak day.[12]

- Reverse flow from Greece in the existing transit pipeline
- Reverse flow from Turkey in the existing transit pipeline
- Chiren UGS expansion
- Diesel back-up for gas-fired heat generation
- Diesel back-up for gas-fired electricity generation
- New gas interconnection between Romania and Bulgaria
- New gas interconnection between Greece and Bulgaria

We also include into the curves two existing options – indigenous gas production and the use of the underground gas storage (UGS) at Chiren.

The figure below shows some of the options in their geographical context.

Figure 7. Policy options to improve gas security of supply

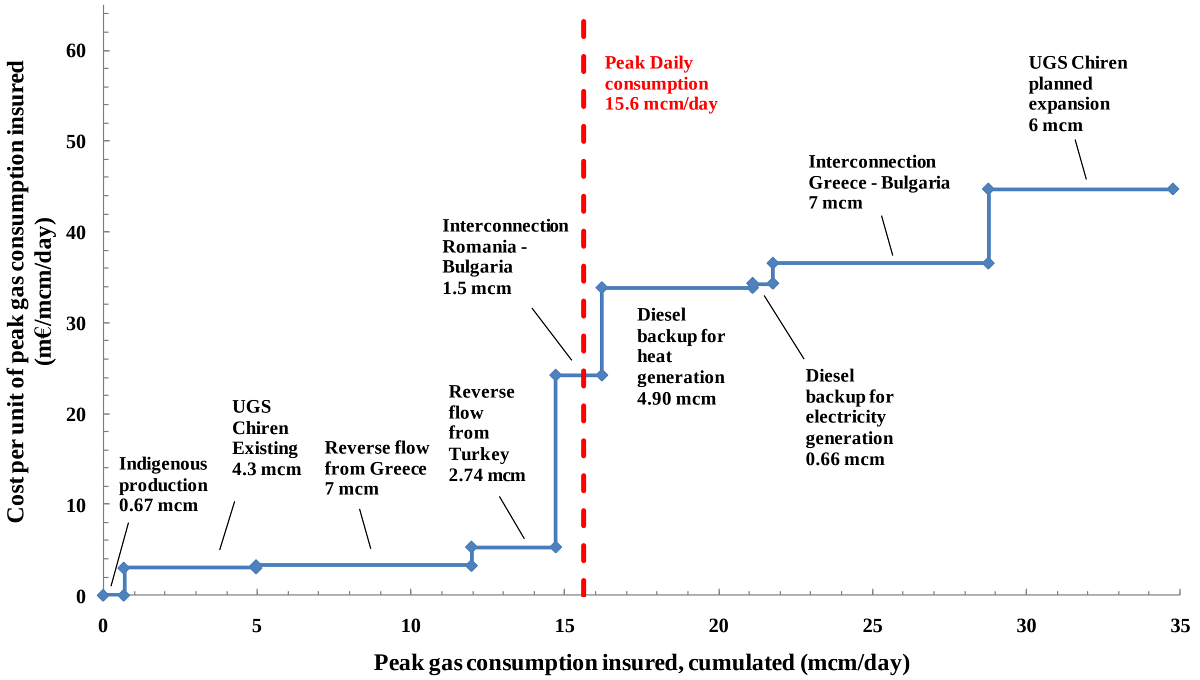


6.2 Cost curve for disruption scenario 1

In scenario 1 we assume a 15-day total disruption of Russian imports every year. The security of gas supply cost curve is shown in Figure 8.

[12] Details on the calculations are provided in appendices 9.1 and 9.2.

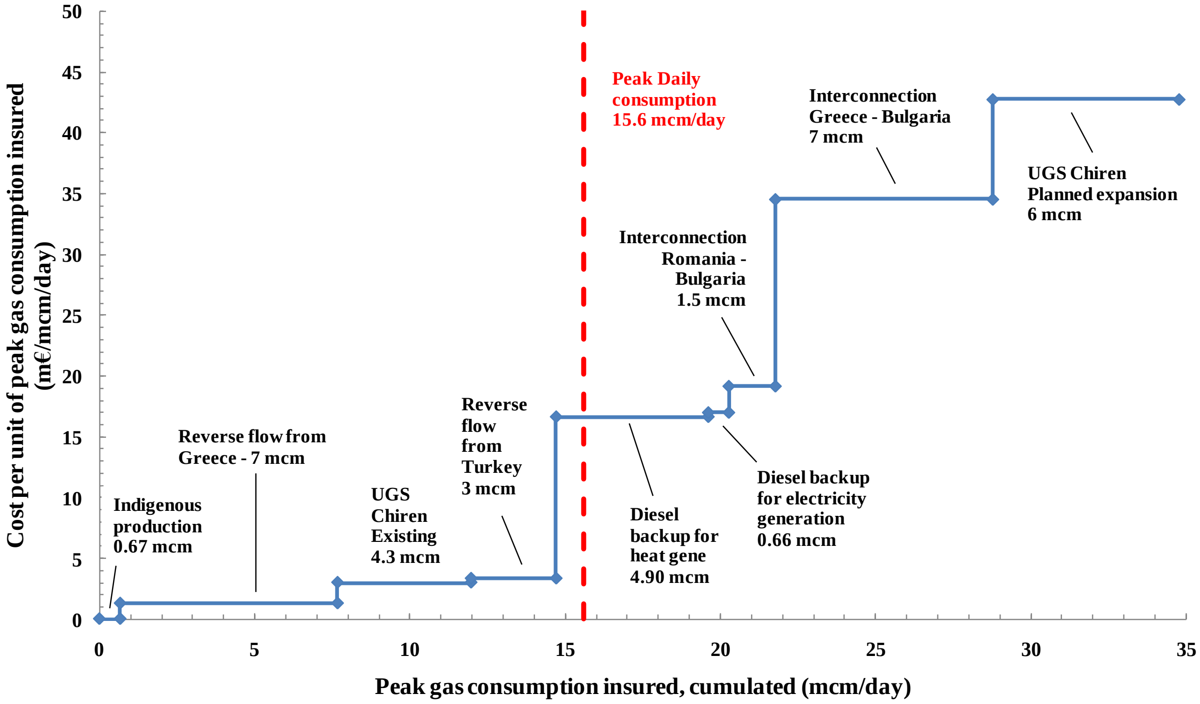
Figure 8. Security of supply cost curve in scenario 1



6.3 Cost curve for disruption scenario 2

In scenario 2 we assume a 15-day total disruption of Russian imports every 3 years. The security of gas supply cost curve is shown in Figure 9.

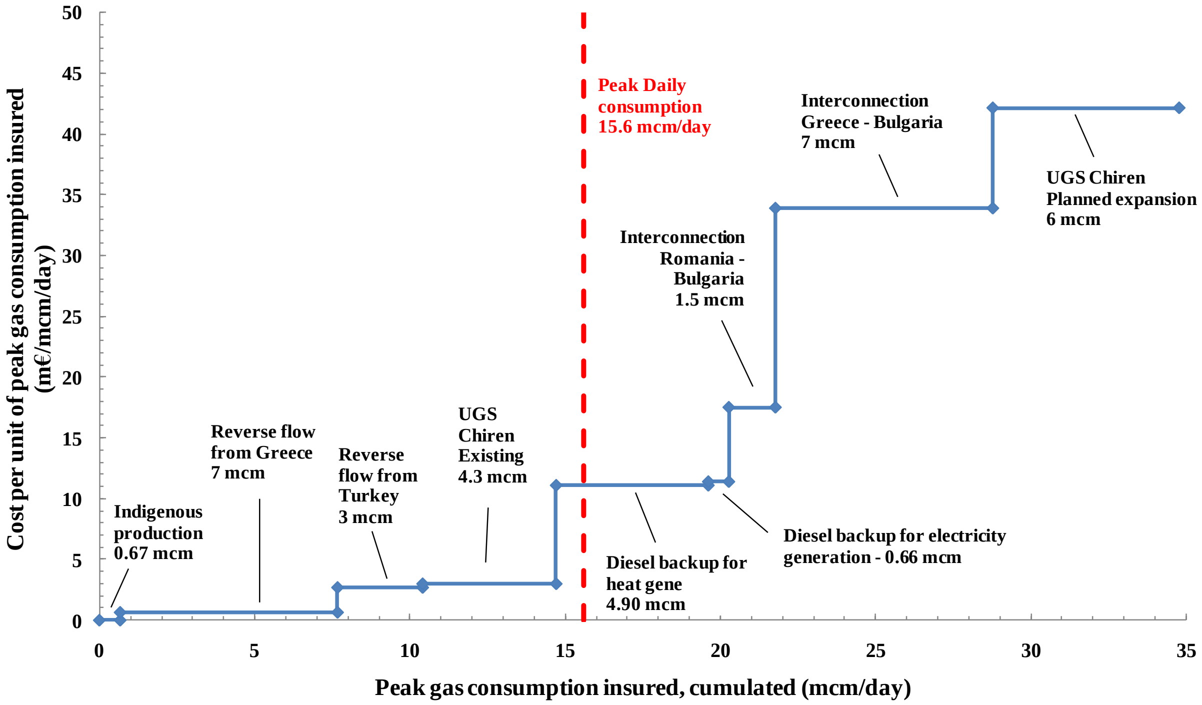
Figure 9. Security of supply cost curve in scenario 2



6.4 Cost curve for disruption scenario 3

In scenario 3 we assume a 15 day-total disruption of Russian imports every 10 years. The security of gas supply cost curve is shown in Figure 10.

Figure 10. Security of supply cost curve in scenario 3



7 Policy recommendations and discussion

7.1 Recommendations

Increasing Bulgaria's gas supply security is necessary and will not be free. As a matter of principle and, in the current economic and financial context, of feasibility, public authorities should ensure that it is done in the cheapest possible manner. The security of supply cost curves show that to move Bulgaria from its current level of gas supply security to 'full security' – i.e. 100% of peak gas consumption insured against a total disruption of Russian gas imports – at least cost, the following three policy measures should be implemented:

- Equipping the existing transit pipelines to Greece and Turkey so that gas can be shipped into Bulgaria;
- Installing dual-fuel equipment (and effective fuel-switching capability) for heat generating plants;
- Build the new interconnection pipeline with Romania.

In scenarios 2 and 3 the interconnection with Romania is not needed to effectively cope with a disruption in Russian supplies, even if peak gas consumption were to increase substantially in the years to come. In scenario 1, certainly the least realistic of the three with one disruption every year over twenty years, the interconnector is part of the cost-effective mix. However, even a relatively small increase in peak demand would require the next measure to be implemented, namely back-up diesel for heat generation.

Given that the latter secures nearly 5 mcm/d against 1.5 mcm/d for the interconnector; that dual-fuel, unlike building a new pipeline, can be implemented gradually as peak consumption rises; that, unlike the interconnector, it generates security close to the consumers and without relying on international co-operation; given, finally, that our cost calculations for dual-fuel are based on light fuel oil (diesel) and the cost would be lowered significantly by using cheaper (though more polluting) heavy fuel oil[13] – for all these reasons it would not be too much of a distortion to simplify the recommendations and advise the Bulgarian authorities to concentrate on:

- Enabling the transit pipelines to Greece and Turkey to be used in both directions, and
- Ensuring that heat generating plants can promptly switch to petroleum products in case of emergency.

On the contrary, it is striking that the one policy measure that the Bulgarian authorities seem most keen to implement, namely increasing the withdrawal rate of the UGS facility at Chiren, appears to be the most expensive amongst the options we have analysed, in all three scenarios. Its cost per unit of security provided, compared to reversing the transit pipeline to Greece, ranges from 14 times more expensive in scenario 1 to 65 times more expensive in scenario 3 (perhaps the most likely scenario of the three). Even if we have underestimated the cost of reverse flow by 50% and overestimated the cost of improving Chiren's withdrawal rate by 100% the latter would still be 16 times more expensive than the former in scenario 3. If still feasible, the Bulgarian authorities should revisit the decision to expand Chiren.

Similarly, one of the key lessons drawn from the crisis of January 2009 by the European Union is that new pipeline interconnections are a requisite for effective crisis management. The European Commission has set aside funds, as part of its 'economic recovery package', to subsidise cross-border gas pipeline projects, including €45 million for the Greece-Bulgaria interconnector (European Commission, 2010). However our calculations show that, for exactly the same benefits, there is a very important cost difference between allowing the existing transit pipeline to operate in both directions and building a brand new one. Authorities should keep in mind that the cost will be borne eventually by Bulgarian (and potentially Greek) gas consumers.

7.2 Discussion

Explaining why the Bulgarian authorities tend to favour relatively expensive gas security measures and overlook the cost-effective ones is the topic for another paper. However we would like to briefly mention four issues that could be elements of an explanation.

First, the Bulgarian gas industry is organised as a de-facto monopoly, with Bulgargaz part of the 100% government-owned Bulgarian Energy Holding. Accordingly, the company is very well

[13] The existing Bulgarian legislation, like the Romanian, Estonian or Lithuanian ones, mandates that district heating generating companies store heavy fuel oil, not light fuel oil (diesel). Furthermore, because Bulgaria's district heating relies on boilers (not turbines) we probably overestimate the capital cost of dual fuel for heat. There is no reason to assume that the oil product market would not work in times of gas supply emergency but if one does so, longer periods of on-site storage can be mandated, at a cost that rises exponentially with the number of days mandated (because of the opportunity cost of capital on the value of the stored products).

placed to influence policy and regulatory choices in a way that preserves its dominant position. In this respect, expanding underground storage capacity and withdrawal rate is much safer than creating the possibility for competitors to bring non-Russian gas, including spot-priced gas, to Bulgaria. It applies to building new interconnectors as well as reversing the flow of the existing transit pipelines to access the Greek and Turkish LNG terminals, as well as gas from Azerbaijan.

Secondly, opening the transit pipelines to Greece and Turkey to third-party trading faces considerable political and legal challenges. This is because these pipelines are not part of Bulgaria's regulated high-pressure network and are exempt from EU rules. They are governed by intergovernmental agreements pre-dating EU accession that Russia is probably unwilling to re-open. It would require a co-ordinated diplomatic effort from (at least) Greece, Turkey, Bulgaria and Romania to try and change the legal regime governing these pipelines. Therefore, there is a hidden political cost attached to this otherwise very attractive gas security policy option.

Thirdly, legitimate questions can be asked regarding the effective availability of gas in neighbouring countries if the region faces a total disruption of Russian gas through the Ukrainian corridor. Romania, Turkey and Greece would all be impacted. In principle contracts should be honoured even in times of crisis and Bulgaria could mandate suppliers to sign option contracts that would guarantee delivery. However there could be serious political pressure to retain whatever gas is available inside the 'exporting' country, irrespective of commercial contracts.[14] The safest option is probably Greece, which will soon have ample spare import and transmission capacity allowing greater confidence that potential contracts with Bulgaria would be honoured even in times of Russian supply disruption.

More work is needed to explore the political feasibility and political economy of gas supply security policy choices. Revealing the relative costs of various policy options was a necessary first step.

[14] After the crisis of January 2009 Slovakia passed a new law giving its government the right to prevent the 'export' of gas stored in the country in times of emergency. This is one of the reasons why the European Commission included in its proposed Regulation on gas supply security (European Commission, 2009) language meant to preserve the functioning of the market and the execution of contracts in times of gas supply emergency.

Appendices

8 Estimates of natural gas capacities available from neighbouring countries

8.1 Greece

8.1.1 Consumption in Greece

Between the 6th of January and the 22nd of January, the Russian gas supply due to be delivered to Greece through Ukraine and Bulgaria was null (RAE, 2009a). The maximum consumption of Greece during this period was 12 mcm/day, while the maximum volume expected from Russia every day was at most equal to 8 mcm (RAE, 2009a). If the period 2004-2007 is taken as a reference, the peak in daily gas consumption would equal 16.1 mcm/day, and this is the figure we have kept for our analysis.

8.1.2 Capacity of the Revithoussa LNG terminal

During the crisis, Greece easily met its domestic daily gas demand thanks to increased deliveries at its LNG terminal in Revythoussa (RAE, 2009a). Since unloading and regasification capacity upgrades, completed in June 2007, the daily gasification capacity of the LNG terminal has approximately been equal to 14 mcm/day (RAE, 2009a).

Additional upgrade, with the construction of additional storage space, is to be completed by 2013 (RAE, 2009b). This will allow Greece to maximise the quantity of gas delivered through its LNG terminal to the Greek market as well as to the European and Balkan markets thanks to future interconnections. It will not only reinforce the capability of dealing with emergency situations and demand peak, but could also, thanks to further increases in gas volumes capacity, attract additional LNG suppliers.

8.1.3 Import capacity through the ITGI pipeline

On top of its LNG capacity, Greece possesses import capacities from Turkey, through the Turkey-Greece connection completed in 2007. We have estimated at 9 mcm/day the maximum daily import capacity. Additional developments on this supply route are expected to further increase the transit capacity. The Interconnection Turkey Greece Italy (ITGI) pipeline, whose completion is due in 2011, will come in parallel to the Greek-Turkish pipeline and is aiming at transmitting gas from Turkey to Italy (Greek Embassy, 2007). According to RAE, the project's planning includes an onshore section of 600km of length, from Komotini to Thesprotai's coastline, and an offshore section from Thesprotia's coastline to Italy's Otranto of 200km of length (RAE, 2009b). The total investment cost was estimated at € 900 million, from which € 100 million are expected to be received from European Energy Funds (Geropoulo, 2009). The possible supply sources are the areas of the Caspian and the Middle East. Pipeline's sponsors, Edison SpA and DEPA S.A., have already submitted requests for reserving a transmission capacity through the onshore section of the Greek-Italian pipeline of 8 bcm of natural gas per year, giving an idea of the minimal daily transit capacity that can be expected thanks to this pipeline: 21.9 mcm/day (RAE, 2009b). This project will transform Greece into a real natural gas transit hub.

8.1.4 Conclusion on the available gas capacity

Adding up the import capacities listed above shows that in the event of a gas supply cut from Russia, between 7 and 29 mcm/day of natural gas could be provided to Bulgaria via a Greece-Bulgaria interconnection. The upper range is even more likely as Italy, down the line of the ITGI pipeline, was able to cope entirely with the decreases in imports from Russia during the crisis, thanks mostly to its UGS capacities. Even if reverse flow capacity is limited by the capacity of the existing pipeline – 8.64 mcm/day (cf. Figure 1), it still makes sense to invest in adequate equipment to be able to reverse the flow and/or to invest in new pipelines.

8.2 Turkey

A detailed analysis of the gas available from Turkey in the event of a crisis has not been carried out. However, current talks with Azerbaijan could result in Bulgaria securing import contracts of 1 bcm of natural gas per year (i.e. 2.74 mcm per day), if a new pipeline is built (Cedigaz, 2009). Before any pipeline is built, Azerbaijan could be seen as having the ability, in the event of a Russian gas disruption, to supply Bulgaria with 2.74 mcm of natural gas per day through the Turkish pipeline (provided that the flow is reversed). Gas could also be provided by the LNG terminal located at Marmara Ereglisi.

8.3 Romania

Romania consumes 15.61 bcm of natural gas per year. Although it also imports gas from Russia, 71% of its domestic consumption is covered by indigenous production. The natural gas transmission system in Romania has a total capacity of 58 bcm/year while the capacity used only equals 27 bcm/year (Transgaz, 2009). This means that a considerable amount of capacity could be used for transit purposes. Yet, the fundamental question is to know whether Romania will have extra gas to provide to Bulgaria in the event of a gas supply interruption from Russia.

The peak daily consumption in Romania is around 70 mcm/day. Unlike its southern neighbour, it possesses a much larger UGS capacity, with an aggregated peak withdrawal rate of around 26 mcm/day (cf. Table 2), which could be complemented by an average daily indigenous production of 30.5 mcm/day. It will not be sufficient to cover the Romanian domestic peak consumption. However, if Romania is able to import gas from Western Europe or to increase its domestic production, it could potentially be able in the future to transfer some gas to Bulgaria in the event of a Russian gas supply disruption.

Table 2. Underground Gas Storage in Bulgaria and Romania – Peak Withdrawal Capacity

	Location		Total capacity (mcm)		Peak withdrawal capacity (mcm/day)
Bulgaria	Chiren	[1]	350	[3]	4.3
Romania	all UGS except Balanceanca	[2]	2,694	[4]	26

Notes and Sources:

[1], [2]: GIE, June 2008.

[3]: Ministry of Economy and Energy of Bulgaria, 2009.

[4]: Transgaz, 2009.

9 Cost calculations

9.1 Summary

Table 3. Comparison of options in scenario 1 (one crisis every year)

Option		Remarks	Capacity (mcm/day)	PV (investment + operating costs) (m€/mcm/day)	Limitations
Indigenous production	-	-	0.67	-	-
UGS	Chiren	Existing	4.30	3.00	81 days of storage
Reverse flow	from Greece	-	7.00	3.26	-
Reverse flow	from Turkey	-	2.74	5.31	-
Interconnections	Romania - Bulgaria	-	1.50	24.21	-
Heat generation	Switch to diesel	-	4.90	33.82	-
Electricity generation	Switch to diesel	-	0.66	34.30	-
Interconnections	Greece - Bulgaria	Low estimate	7.00	36.51	-
UGS	Chiren	Planned expansion	6.00	44.66	34 days of storage

Note: Present value calculated for a 20 year period with a rate of return of 10%.

Table 4. Comparison of options in scenario 2 (one crisis every 3 years)

Option		Remarks	Capacity (mcm/day)	PV (investment + operating costs) (m€/mcm/day)	Limitations
Indigenous production	-	-	0.67	-	-
Reverse flow	from Greece	-	7.00	1.28	-
UGS	Chiren	Existing	4.30	3.00	81 days of storage
Reverse flow	from Turkey	-	2.74	3.33	-
Heat generation	Switch to diesel	-	4.90	16.63	-
Electricity generation	Switch to diesel	-	0.66	16.98	-
Interconnections	Romania - Bulgaria	-	1.50	19.15	-
Interconnections	Greece - Bulgaria	-	7.00	34.53	-
UGS	Chiren	Planned expansion	6.00	42.76	34 days of storage

Note: Present value calculated for a 20 year period with a rate of return of 10%.

Table 5. Comparison of options in scenario 3 (one crisis every 10 years)

Option		Remarks	Capacity (mcm/day)	PV (investment + operating costs) (m€/mcm/day)	Limitations
Indigenous production	-	-	0.67	-	-
Reverse flow	from Greece	-	7.00	0.65	-
Reverse flow	from Turkey	-	2.74	2.69	-
UGS	Chiren	Existing	4.30	3.00	81 days of storage
Heat generation	Switch to diesel	-	4.90	11.10	-
Electricity generation	Switch to diesel	-	0.66	11.40	-
Interconnections	Romania - Bulgaria	-	1.50	17.52	-
Interconnections	Greece - Bulgaria	-	7.00	33.90	-
UGS	Chiren	Planned expansion	6.00	42.15	34 days of storage

Note: Present value calculated for a 20 year period with a rate of return of 10%.

9.2 Detailed calculations

9.2.1 UGS

Existing capacity

Table 6. Table 1. UGS (existing)

Withdrawal capacity		[A]	**4.30**	mcm/day
	Security required for:		15	days
	Active working volume required		64.50	mcm
Operating cost		[B]		
	OPEX per mcm		21,000	€/mcm
	Total yearly OPEX		**1.35**	m€

Notes and sources:
[A]: Ministry of Economy and Energy of Bulgaria, 2009.
[B]: Calculations based on industry data.

Extension

Table 7. UGS (extension)

Withdrawal capacity		[A]	**6.00**	mcm/day
	Security required for:		15	days
	Active working volume required		90.00	mcm
Investment cost		[B]	**250.00**	m€
Operating cost		[C]		
	OPEX per mcm		21,000	€/mcm
	Total yearly OPEX		**1.89**	m€

Notes and sources:
[A], [B]: Ministry of Economy and Energy of Bulgaria, 2009.
[C]: Calculations based on industry data.

9.2.2 Electricity generation

Not producing the electricity

Electricity generation consumes 7.2% of the total gas consumed in Bulgaria, i.e. around 0.241 bcm/year or a daily average of 0.66 mcm/day. 5.7% of the electricity is generated from this gas, i.e. 2,228.69 GWh per year or an average of 6,106 MWh per day. If Bulgaria decides to lower its electricity exports as a result of a decrease in its domestic electricity generation, the cost of stopping electricity generation from gas would be equal to the loss of profits on exports. To calculate these losses accurately, we should consider the price of imported gas and compare it to the price of exported electricity. Because they were not available, these export prices have been approximated by the prices for very large industrial customers (cf. Table 8).

Table 8. Price of gas and electricity in Bulgaria

2nd semester	2008		Industrial price
Electricity	(€/kWh)	[A]	0.0435
Gas	(€/kWh)	[B]	0.0241
	(m€/mcm)	[C]	0.223

Notes and sources:
Eurostat. [A]: for consumption > 150 000 MWh.
[B]: price for annual consumption between 10^5 GJ and 10^6 GJ. [C]: [C] = [B] / 0.10814.
Energy equivalence: 1 MWh = 3.6 GJ = 108.14 cm of natural gas (assume efficiency of 100%).

During a gas supply disruption, the losses are deduced as follow:

i.e.:

To sum up, with this option, 0.66 mcm of natural gas could be freed up per day for a cost of around €118,000 per day.

However, Bulgaria might want to maintain its electricity generation level constant even in the event of a gas crisis. It would notably be the case if utility companies do not have interruptible contracts with their customers. It could also be argued that stopping electricity generation and reducing exports by the same amount can only be a short term solution, because the excess capacity would have to be replaced over time given the advanced age of many power stations. In that case, Bulgaria should consider diesel back-up for its electricity generating plants.

Maintaining dual-fuel capability

Diesel back-up is a relatively standard option in several countries including Spain, the UAE, Singapore and the UK. Some gas-fired power plants in Bulgaria are already supposed to be equipped with dual fuel capability but we do not know the extent to which this measure is currently enforced. Consequently, the cost of maintaining dual fuel capability has been calculated assuming that none of the gas-fired power plants were currently able to switch to diesel.

Based on data provided by the industry and on our own calculations, investment and operating costs for maintaining dual fuel capability have been estimated, along with operating costs for running power plants on heating fuel oil during gas supply interruptions. Investments costs notably include costs of fuel oil storage tanks, water injection systems, oil circulation systems and have been estimated at € 5 million for a 400 MW power plant. The cost of 5 days of back-up fuel stored on-site has also been added. In the event of a disruption lasting more than 5 days, the fuel tanks would have to be refilled. Operating costs reflect the additional maintenance costs incurred when running on heating fuel oil as well as the difference between the cost of contracted Russian gas and the cost of heating fuel oil.

We acknowledge that the high volatility of prices of oil and gas prevents operating costs to be forecasted precisely and limits the robustness of our estimates. Our estimates are summarized in Table 9.

Table 9. Dual fuel capability for electricity generation

Peak gas consumption for electricity generation			**0.66**	mcm/day
Investment		[A]	**3.50**	m€
	Power of the installation		254.42	MW
	Capital cost		5.50	m€/400 MW
Operating cost for a 15-day disruption		[B]		
	Cost of light fuel oil for industry		11,900	€/TJ
	Cost of natural gas for industry		6,240	€/TJ
	Extra expenditure on fuel		**1.88**	m€
Price of oil kept in storage (5 days of consumption)			**1.32**	m€
Cost of the option (NPV of CF)				
	Scenario 1		**34.30**	m€/(mcm/day)
	Scenario 2		**16.98**	m€/(mcm/day)
	Scenario 3		**11.40**	m€/(mcm/day)

Notes and sources:
[A]: Authors' calculations based on industry data.
[B]: Eurostat and European Commission data.

Lifetime: 20 years.
Cost calculation for a 20-year long period.
Rate-of-return: 10%.

9.2.3 Heat generation

Heat generation uses 32% of the natural gas within Bulgaria, i.e. 1.077 bcm/year. The share of heat generated from gas equals 49.9%. Households account for 28% of the total heat consumption, while the rest is mainly consumed by ‘industrial and economic users’ (67%) (SEWRC, 2008).

District heating is more efficient and more economically viable than electricity heating in cold European countries. Moreover, as more than half of the electricity in Bulgaria is generated by coal-fired power plants, gas-fired district heating plants could also be considered as more environmentally friendly.

Some companies in the heating sector have been able to switch to other fuel sources such as distillate during the crisis. On January the 6th, the heating utilities stopped operations and started the procedures to switch to diesel (Tzvetkova, 2009b). However, it has also been reported that several district heating plants have been forced to shut down, resulting in many households having their heat supply cut off. As we did not know the proportion of plants possessing dual fuel capabilities, we have presupposed in our analysis that no district heating plant was currently able to switch to diesel.

Heat consumption by industrial consumers could be considered as ‘interruptible’, in the sense that it could be cut without having any other impact than a financial one. However, according to our definition of gas supply security, this demand should be covered in the event of a gas supply disruption.

To estimate the peak daily consumption of natural gas for domestic and industrial heating, we have used the same hypothesis as the one used to estimate the peak daily consumption of natural gas in Bulgaria. As previously mentioned[15], peak consumption in neighbouring countries is at most 166% of the average daily consumption. Therefore, the upper estimate for the gas consumed on a daily basis for heat generation would be 4.90 mcm[16].

Dual fuel capability for domestic and industrial heating

One option is to have dual fuel capability for gas-fired district heating plants. Switching to diesel could reduce the consumption of natural gas by 4.90 mcm per day. To estimate the cost of the solution we have used similar calculations as in the case of electricity generation. Our estimates are summarized in Table 10.

Table 10. Dual fuel capability for heat generation

Peak gas consumption for heat generation			**4.90**	mcm/day
Investment		[A]	**24.65**	m€
	Power of the installation		1,793	MW
	Capital cost		5.5	m€/400 MW
Operating cost for a 15-day disruption		[B]		
	Cost of light fuel oil for industry		11,900	€/TJ
	Cost of natural gas for industry		6,240	€/TJ
	Extra expenditure on fuel		**13.9**	m€
Price of oil kept in storage (5 days of consumption)			**9.8**	m€
Cost of the option (NPV)				
	Scenario 1		**33.82**	m€/(mcm/day)
	Scenario 2		**16.63**	m€/(mcm/day)
	Scenario 3		**11.10**	m€/(mcm/day)

Notes and sources:
[A]: Authors' calculations based on industry data.
[B]: Eurostat and European Commission data.

Lifetime: 20 years.
Cost calculation for a 20-year long period.
Rate-of-return: 10%.

9.2.4 Reverse flow

The attempt by Greece and a major gas company at the end of the gas dispute of January 2009 to reverse the flow has shown that this could be technically feasible. The gas company prepared to make deliveries to Bulgaria of gas coming from the LNG terminal of Revythoussa. However, the Bulgarian government being reluctant to pay for this delivery, administrative limitations prevented this solution to be implemented earlier during the crisis[17]. Without technically reversing the flow, the gas company injected gas in the pipeline in the south of Greece, which allowed Bulgaria to extract gas from the linepack of the transit pipeline.

[15] Cf. note 11 p10.
[16] 1.66*(1,077/365) ≈ 4.90.
[17] Source: industrial contacts.

Greece-Bulgaria

Capacity

Investing in infrastructures to be able to reverse the gas flow, or investing in exchange capabilities with Greece makes sense if Greece is not only able to make up for its own consumption during a gas crisis, but could also deliver extra capacity to neighbouring countries. In the event of a crisis, we have estimated that Greece could supply at least 7 mcm per day of gas to Bulgaria (cf. Appendix 8).

Estimate of cost

The cost to reverse the flow in a pipeline is estimated at around € 1 million per compression station[18]. The pipeline delivering gas to Greece via Bulgaria does not currently have any compression station (RAE, 2009b). However, the installation of a compressor unit in the main pipeline (at Nea Mesimvria, near Thessaloniki) is planned for 2010. Assuming that this single compression will be sufficient to reverse the flow from Greece to Bulgaria and that LNG terminal capacity will not be a constraint, reversing the flow could provide 7 mcm/day of natural gas for an investment cost of € 1 million. During the crisis of January 2009, the spot price for LNG was around USD 9 per MMBTU in the Mediterranean area[19]. Based on this price and on the price of contracted gas in Bulgaria, the operating cost induced by the purchase of LNG instead of Russian gas has been estimated at around € 21,900 /mcm. The costs of implementing this solution have been summarised in Table 11.

Table 11. Reverse flow in the Bulgaria – Greece pipeline

Capacity		[A]	**7.00**	mcm/day
Number of compressors		[B]	**1.00**	
Investment per compression station		[C]	**1.00**	m€
Total investment			1.00	m€
Additional operating cost for a 15-day disruption		[D]		
	Cost of contracted Russian gas		226,014	€/mcm
	Cost of LNG		247,876	€/mcm
	Extra expenditure on fuel		**2.30**	m€
Cost of the option (NPV of CF)				
	Scenario 1		**3.26**	m€/(mcm/day)
	Scenario 2		**1.28**	m€/(mcm/day)
	Scenario 3		**0.65**	m€/(mcm/day)

Notes and sources:
[A]: Based on estimated available gas (cf. estimates in the text).
[B]: Botas, 2008; Ministry of Economy and Energy of Bulgaria, 2009.
[C]: Industry sources.
[D]: Eurostat and European Commission data.
Lifetime: 20 years.
Cost calculation for a 20-year period.
Rate-of-return: 10%.

Bulgaria-Turkey

Capacity

We have estimated that in the event of a crisis, Turkey could provide at least 2.74 mcm of natural gas per day to Bulgaria (cf. Appendix 8)

[18] Source: industrial contacts.
[19] *Spot Netback Indications.* ICIS Heren Global LNG.

Estimate of cost

Gas could also be provided by Azerbaijan or by the LNG terminal located at Marmara Ereglisi, and the study of the operating costs of the solution has been based on the spot price of LNG. 6 compression stations of the Bulgarian-Turkish pipeline should be upgraded to be able to reverse the flow. This would allow the supply of 2.74 mcm of natural gas per day for an investment cost of € 6 million. The operating costs would be around € 0.90 million for a 15-day gas disruption. These figures are presented in Table 12.

Table 12. Reverse flow in the Bulgaria – Turkey pipeline

Capacity		[A]	**2.74**	mcm/day
Number of compressors		[B]	**6.00**	
Investment per compression station		[C]	**1.00**	m€
Total investment			6.00	m€
Additional operating cost for a 15-day disruption		[D]		
	Cost of contracted Russian gas		226,014	€/mcm
	Cost of LNG		247,876	€/mcm
	Extra expenditure on fuel		**0.90**	m€
Cost of the option (NPV)				
	Scenario 1		**5.31**	m€/(mcm/day)
	Scenario 2		**3.33**	m€/(mcm/day)
	Scenario 3		**2.69**	m€/(mcm/day)

Notes and sources:
[A]: Based on estimated available gas (cf. estimates in the text).
[B]: RAE.
[C]: Industry sources.
[D]: Eurostat and European Commission data.

Lifetime: 20 years.
Cost calculation for a 20-year period.
Rate-of-return: 10%.

9.2.5 Interconnections

Greece-Bulgaria

As presented in section 4, one of the possible projects is to build a connecting pipeline between the ITGI pipeline in Greece, and the main delivering gas pipeline in Bulgaria. Based on industry data, we have estimated the investment cost at around € 230 million. The operating costs, including the maintenance cost of pipelines and compressors would be about € 0.37 million per year, to which € 2.30 million would be added in the event of a 15-day disruption. This last figure reflects the difference between the price of contracted gas and the spot price of LNG that would be injected in the pipeline in the event of a Russian gas disruption. The construction is expected to be completed within 2.5 years (Tzvetkova, 2009a). These figures are summarised in Table 13.

Table 13. Interconnection Greece – Bulgaria

Capacity		[A]	**7.00**	mcm/day
Lenght		[B]	**120.00**	km
Investment (pipeline + compressor)		[C]	**230.28**	m€
OPEX		[D]	**0.37**	m€/year
Additional operating cost for a 15-day disruption		[E]		
	Cost of Russian gas		226,014	€/mcm
	Cost of LNG		247,876	€/mcm
	Extra expenditure on fuel		**2.30**	m€
Cost of the option (NPV)				
	Scenario 1		**36.51**	m€/(mcm/day)
	Scenario 2		**34.53**	m€/(mcm/day)
	Scenario 3		**33.90**	m€/(mcm/day)

Notes and sources:
[A]: Based on estimated available gas (cf. estimates in the text).
[B]: Ministry of Economy and Energy of Bulgaria, 2009.
[C], [D]: Authors' estimate based on industry sources, 2009.
[E]: Eurostat and European Commission data.

Lifetime: 20 years.
Cost calculation for a 20-year period.
Rate-of-return: 10%.

Turkey-Bulgaria

As for Greece, reversing the flow or building a new connection could be two options. In the case of a new connection, the best option is probably to connect the IGTI pipeline to the Bulgarian domestic network, option that has already been detailed in the previous section. As mentioned earlier, if such a connection is created, talks have started to secure the supply of 1 bcm of Azeri gas annually, i.e. 2.74 mcm/day.

Romania-Bulgaria

We have estimated that Romania could secure around 1.5 mcm of natural gas per day for Bulgaria in the event of a gas crisis (cf. Appendix 8). The construction of the pipeline that has been announced by Edison, would have a total investment cost of around € 23.9 million according to our estimates. Operating costs during a disruption depend on the price of gas on the spot market during this period. This price is difficult to predict. In our calculations, we have arbitrarily assumed that the price of gas on the spot market would be 30% higher than the price of contracted gas. Our estimates for an interconnection Romania-Bulgaria are summarised in Table 14.

Table 14. Interconnection Romania – Bulgaria

Capacity	[A]	**1.50**	mcm/day
Lenght	[B]	**15.00**	km
Investment (pipeline + compressor)	[C]	**23.91**	m€
OPEX	[D]	**0.046**	m€/year
Additional operating cost for a 15-day disruption	[E]		
Cost of Russian gas		226,014	€/mcm
Cost of gas delivered from Western Europe		281,894	€/mcm
Extra expenditure on fuel		**1.26**	m€
Cost of the option (NPV)			
Scenario 1		**24.21**	m€/(mcm/day)
Scenario 2		**19.15**	m€/(mcm/day)
Scenario 3		**17.52**	m€/(mcm/day)

Notes and sources:

[A]: Based on estimated pipeline capacity, Ministry of Economy and Energy of Bulgaria.
[B]: Ministry of Economy and Energy of Bulgaria, 2009.
[C], [D]: Authors' estimate based on industry sources, 2009.
[E]: Eurostat and European Commission data.

Lifetime: 20 years.
Cost calculation for a 20-year period.
Rate-of-return: 10%.

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