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This dissertation investigates security of European gas supply (*gas-SoS*) giving particular consideration to gas infrastructure, notably gas transport and transit. Gas-SoS is endangered mainly by a disruption to existing supplies. For Europe, gas supply infrastructure acts as a tool to gain, maintain and expand access to new gas sources and consolidate access to existing ones. So the SoS-related (infrastructure) strategy has been assessed in the dissertation theoretically and practically, qualitatively and quantitatively.

The research objective pursued is: *To describe and evaluate gas-SoS for Europe, as well as to specify prospective ways for the SoS enhancement, with a focus on European infrastructure [...].* From this, two research questions have been derived:

- (1) How secure are the European countries in terms of their natural gas supplies?
- (2) How can the gas-SoS in Europe be improved (with emphasis on infrastructure)?

The central discussion of the study is in assessing the level of security risks which single European countries face. Thereupon, the family of SoS-indices *HHI'14* has been developed. The ultimate aim is to apply and test indices. With their application the author hopes to gain insights into the indices adequacy as a policy tool for energy security developments. While the existing literature offers a number of SoS indicators to date, their usefulness has never been tested. For the first time, this dissertation has been testing the predictive success of SoS-indices. It confronted them with the economic losses in the 2009 interruption of Russian gas flows to Europe, and with the EU subsidies under the EEPR programme.

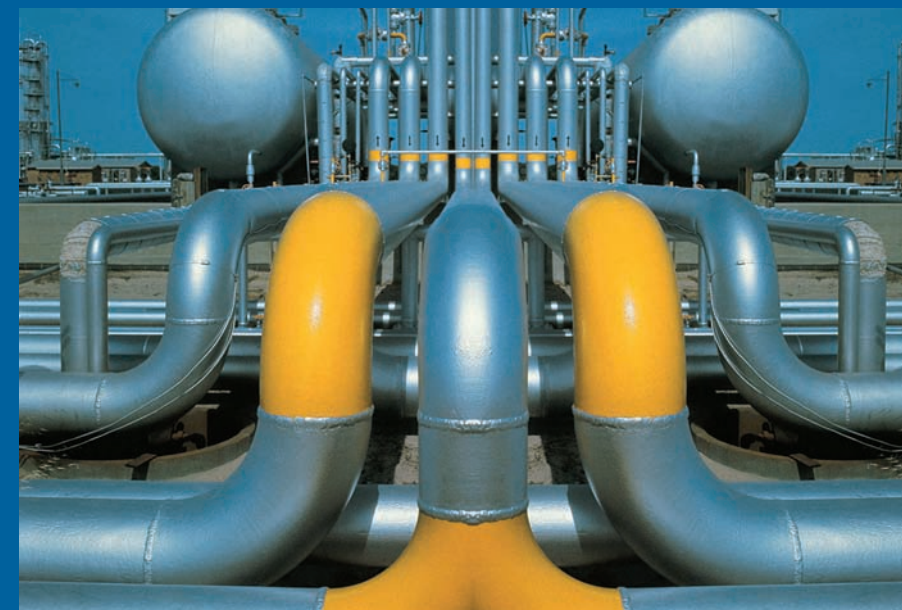
This investigation sets out that SoS-indices are rather important for a quick and coherent overview over the state of energy security for a large and diversified region like Europe. They cannot completely substitute, however, a detailed discussion of the situation in each member state.

..... ISBN 978-3-939290-46-9

Rostyslav Ruban

The European Natural Gas Supply, under Particular Consideration of Gas Transit

Rostyslav Ruban



# The European Natural Gas Supply, under Particular Consideration of Gas Transit

EUROPA-UNIVERSITÄT  
FRANKFURT (ODER)

viademica.verlag berlin 2013

**Edition**  
**Wirtschaftswissenschaften**

Reihe EUV | Band 01

Europa-Universität Viadrina Frankfurt (Oder)  
Faculty of Business Administration and Economics  
Chair of Economic Theory (Microeconomics)

Rostyslav Ruban

**The European Natural Gas Supply,  
under Particular Consideration  
of Gas Transit**

D i s s e r t a t i o n  
in Fulfilment of the Requirements  
for the Degree of "Doktor der Wirtschaftswissenschaften"  
(Dr. rer. pol.)

submitted by: Mag. Rostyslav Ruban  
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submitted on: 4 March 2013  
Ph.D. viva examination: 25 March 2013

**viademica.verlag berlin**

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Ihr Partner für wissenschaftliche Fachliteratur

ISBN 978-3-939290-46-9

Berlin 2013

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Mobilfunk 0171 / 6 95 43 38

## Die Deutsche Bibliothek – CIP-Einheitsaufnahme

RUBAN Rostyslav:

The European Natural Gas Supply, under Particular Consideration  
of Gas Transit · Dissertation in Fulfilment of the Requirements for the  
Degree of "Doktor der Wirtschaftswissenschaften" (Dr. rer. pol.)

Rostyslav Ruban.      Erstaufgabe viademica.verlag berlin.      Berlin 2013  
ISBN 978-3-939290-46-9

..... EDITION Wirtschaftswissenschaften .....

\_\_ Reihe EUV · Europa-Universität Viadrina Frankfurt (Oder) · Band 01 \_\_

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..... ISBN 978-3-939290-46-9

Bezug: Direkt über den Verlag oder über den Buchhandel

Verbindlicher Buchhandelsverkaufspreis: 69,60 € .....

## **Acknowledgements and Dedication**

The present thesis was produced during my post-graduate studies at the European University Viadrina Frankfurt (Oder), being a holder of research grants by the German Academic Exchange Service/DAAD, the Federal Ministry of Education and Research/BMBF (“Europa Fellows 2”), and by the German gas supply company E.ON Ruhrgas. It was accepted as dissertation in March 2013 by the Faculty of Business Administration and Economics.

The thesis was created in a most warm and inspiring atmosphere, and I owe special and deepest thanks to my supervisor – Professor Dr. Friedel Bolle. He constantly found time to discuss and teach all that a Ph.D. candidate should know. The scientific and human assistance of Professor Bolle has substantially contributed to my professional and personal development. His willing support concerning formalities has made my research stay in Germany easier. Not least of all, it was Professor Bolle who enabled my doctorate in Frankfurt (Oder) and has taken over the first report.

I am also very grateful to Professor Dr. Reimund Schwarze, who has kindly agreed to take over the coreport.

When a Ph.D. candidate has a best friend as I have in my twin brother Andrey, even difficult days end in laughter and hours of telephone calls. Thank you for the best personal support and energy whenever I needed it!

I dedicate this thesis to my wonderful parents Alexandra and Gennadiy, who have never given up encouraging me with their endless love and so much more. A very special acknowledgement to them for the understanding and everyday advice, which they have brought from the beloved home country, Ukraine, into my time-consuming work on the following energy-economic research project.

Full responsibility for errors or omissions rests with the author alone.

Frankfurt (Oder), March 2013

Mag. Rostyslav Ruban

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# Chapter 1

## Introduction

**Research Background** COM [2008:3] points out: “Europe’s energy networks are the arteries on which we all depend for the energy to fuel our homes, businesses and leisure. The EU’s energy policy sets out clear goals and objectives<sup>1</sup> for sustainable, competitive and secure energy. [...], the EU will not achieve its ambitions unless its energy networks change considerably, and fast”.

European gas demand declined in 2009 upon the economic crisis. Capros et al. [2010] expect it to decline further in the coming decades. At the same time, European gas production is predicted to decline even more, causing increasing gas import dependency. To offset this trend, new gas supplies from sources outside the EU will be necessary, and therefore significant investment is in order to facilitate that the gas reaches the European customer. In this respect, many EU countries have announced and started to implement gas infrastructure projects, with financial support occasionally granted under the EEPR. In parallel, the European gas market is undergoing a change driven by EU directives, aimed inter alia at integrating national markets into a single European gas market. This change precipitates the need for greater interregional gas flows. Seeing that the regional gas markets, primarily in Central/South-East Europe (CSEE), began their development in relative isolation, they have to become more inter-linked. It is in this environment that we began examining the issue of *gas supply security* (SoS), and viewing it specifically in connection with the enlarged Europe. The impulse of the present dissertation was given by the situation of particular vulnerabilities of the individual national markets to disturbances in the gas supply. This is against the background where the EU Commission has established a Union-wide framework for the SoS in terms of common infrastructure and supply standards, including fixing a mandatory “protected customers” category.

High costs are involved in gas supply disruptions. It was mainly due to the recent gas disputes between Russia and Ukraine, which in January 2009 resulted in serious gas shortages notably in CSEE, that the SoS notion has been put at the top of the European agenda. This has led to a drive on the part of many CSEE countries to promote containment of their dependencies on Russian gas. So, they are in strong support of gas flows that increase diversification away from Russia, particularly from the Caspian/Middle East.

Given the above (and other) gas market changes, systematic analysis is required to fully understand the gas supply security and its application to the most vulnerable part of Europe by far – CSEE. Providing this analysis is the aim of this dissertation. In this study, we will develop a stylised approach to assess the SoS category in both theoretical and practical terms, both qualitatively and quantitatively. While the existing literature offers quite a number of SoS-related composite indicators, their use-

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1. The so-called “20-20-20” targets: 20% reduction in greenhouse gas emissions, 20% share of renewable energy in EU final energy consumption, and 20% improvement in energy efficiency by 2020.



fulness has never been tested. In this investigation we will, for the first time, test the predictive power of SoS-indices – by confronting them with the economic losses in the 2009 interruption of Russian gas flows to Europe and with the EU subsidies for its member states within the EEPR.

**Research Objective and Research Questions** With regard to the above-mentioned situation, this study pursues the following research objective: *To describe and evaluate Europe’s gas supply security, as well as to specify prospective lines for the SoS enhancement, with a focus on European infrastructure projects, in accordance with individual countries’ need/priority.*

In order to meet this objective, the research questions are qualified as:

- (1) How secure are the European countries in terms of their natural gas supplies?
- (2) How can the gas-SoS in Europe be improved (with emphasis on infrastructure)?

**Overview of the Study** The study is organised into three conceptual parts. Among them, Chapters 3 and 4 aim to answer the two research questions above. The approach of the present work gives particular consideration to gas transport and transit.

The Introductory Chapter 1 first describes the background that our research is embedded in. It presents the problem and provides the reader with the chapter summary.

Chapter 2 is an overview of the gas industry. While contributing to the SoS discussion later on, Section 2.1 refers to gas user types and their differing consumption profiles throughout a year. Section 2.2 provides gas supply chain fundamentals. Section 2.3 describes the European gas sector and, countrywise, its gas transmission and storage facilities (or more precisely, “entry points” for gas). Here it becomes clear that the national gas markets strongly differ in their key market data and their infrastructure characteristics. Section 2.4 ends by addressing the nature of conflicts among country-actors of gas transportation.

The theoretical underpinnings of the SoS notion are outlined in Sections 3.1, 3.2 and 3.5 of Chapter 3. While Section 3.1 develops the conceptual framework and Section 3.5 provides the graphic interpretation along with the “costs of security” idea, Section 3.2 discusses the legal environment for SoS in the EU. A detailed review of the tools of gas supply security management follows in Section 3.4. The tools are discussed regarding gas market-relevant cases. From here, it becomes possible to evaluate the SoS. Section 3.6 suggests an evaluation framework and stepwise quantifies a set of parameters serving the comparability of the SoS situations in individual markets. This, on the one hand, reflects the country-specific gas market and infrastructure characteristics (partly shown in Chapter 2) and, on the other hand, discusses the first research question qualitatively and quantitatively. The evaluation is preceded by “protected customers” issues (Section 3.3), and followed by the empirical observations of SoS incidents from the past (Section 3.7), with a focus on Russia.

The largely descriptive Chapter 4 aims to approach the second research question of the study. It shifts focus to CSEE, after Subsection 3.5.3 gave us the intuition and Section 3.6 confirmed numerically that the CSEE region generally enjoys lower SoS than the EU-15. Section 4.2 is an in-depth explanation regarding the CMEA background for CSEE vulnerabilities in the energy field. We address it as a major challenge for the enlarged EU. The consequences of that background, which have im-

peded to effectively respond to the January 2009 gas crisis, are explored in Section 4.3. For this real emergency situation, the SoS tools introduced in Section 3.4 are discussed. The central result of Chapter 4 is reported in Section 4.4 with its various insights into the sustainable development patterns of the CSEE gas supply, based on the restrictions by capacity saturation (Subsection 4.4.1), network gaps/bottlenecks, and the import dependency projections (Section 4.1). A focus throughout Section 4.4 is on CSEE gas infrastructure projects, in accordance with countries' needs. Those needs are indirectly expressed in the EEPR financial envelope, dealt with in Subsection 4.4.2. The ultimate aim of the infrastructure projects' (and of the January 2009 gas crisis) analysis is to provide and apply security-of-supply (SoS) indices developed in Chapter 3. While the academic literature offers a wide range of SoS-related metrics, their usefulness has never been tested. Subsections 4.3.3 and 4.4.4 will, for the first time, test the predictive power of such composite indicators – by confronting them with the economic losses in the 2009 interruption of Russian gas flows and with the EU subsidies under the EEPR program. In Subsection 4.4.5, an adjustment is made compared with Section 3.6, which did not involve the EEPR influence on country SoS scores. Section 4.5 closes with an expose of European networking initiatives enabling a higher level of cooperation/integration between the TSOs, ultimately destined to bring the gas networks together.

The Conclusions in Chapter 5 summarise the findings of this study, and finally recommend considering further research.

# Chapter 5

## Conclusions and Discussion

This dissertation investigates security of European gas supply with a focus on infrastructure, in particular gas transport/transit. Gas-SoS is endangered mainly by a disruption to existing supplies. For Europe, gas supply infrastructure acts as an option in gaining, maintaining and expanding access to new gas sources and consolidating access to existing ones. As emphasized already in the Introduction, the EU will not be able to meet its energy goals without new and improved networks. So the SoS-related (infrastructure) strategy has been assessed in the dissertation by theoretical and practical approaches, qualitatively and quantitatively. This chapter provides conclusions of the accomplished study and deals with recommendations for further research.

**Summary and Conclusions** The research objective has been posed as: *To describe and evaluate Europe's gas-SoS, as well as to specify prospective lines for the SoS enhancement, with a focus on European infrastructure projects, in accordance with individual countries' need/priority.* From this objective, two research questions have been derived and addressed in Chapters 3 and 4. This analysis could not be carried out without describing the European gas industry itself. Therefore [Chapter 2](#) has highlighted the role of energy/natural gas in the economic process and the gas usage peculiarities per consumer group, as well as it has accentuated the differences in the national markets' characteristics and, of course, in their gas supply infrastructures, etc. The main results of Chapter 2 are:

- a strong correlation between economic growth and energy consumption in the EU-15 ( $r = 0.95, p = <0.0001$ );
- ever-increasing peak demand loads for natural gas in the residential sector which can imply dangers for SoS;
- permanently declining gas reserves and gas production all over Europe, while import dependence increases. (Upon that, most of the local pipelines supplying the increased imports pass through various states with different objectives.);
- actors of the multi-country vertical gas supply chain which are inclined to conflict, undermining gas supply reliability.

These basic facts have provided necessary insights into why gas economics, transportation, and security of supply have assumed importance and turned into the focus of this study. This enabled to proceed to research questions directly.

[Chapter 3](#) addressed the first research question – that is, “*How (in-)secure are the European countries in terms of their gas supplies*”. It states that factors determining the degree to which a country can cope with gas supply interruptions include the supply infrastructure set-up, the structure of gas use, and the SoS tools in place to mitigate security risks. Pursuing this research question, Chapter 3 contributed to analysing the countries gas consumption make-up and it traced the use of different SoS tools in European markets. As a result, Section 3.3 displayed how vulnerable the residential sector turned out to be – which offered an explanation of why the common “protected

customer” standard has been established for households (OJL [2010]). On the other hand, Section 3.4 laid out how dependent upon certain SoS instruments individual countries were. In Section 3.5, we argue that the quantity of imported gas is a security problem and it imposes a cost on society, being prompted by society’s expectations that gas will continue flowing. On the back of it, however, we have conclusively illustrated that, while enjoying some of the lowest gas prices in the EU, the CSEE region had relatively little (unlike EU-15) “manoeuvre space” for increased costs due to SoS considerations. (In contrast, it is just high pricing which can help markets attract the necessary diversified supplies and, thus, to enhance SoS.) Finally, because some believed that Russia’s disputes with transit countries Ukraine and Belarus lately were the biggest threat of supply disruptions (to Europe), Section 3.8 presented the track record of Russia’s 20-year experience of “gas wars” with former Soviet republics. Such a detailed narrative is essential as these facts are currently accompanied with speculative discussions of Russia’s ability and readiness to use gas supply disruptions as a political weapon even against its EU customers.

The central discussion addressing the first research question is in Section 3.6. A pure characterization of country-specific SoS situations (even combined with some kind of collation) enabled better understanding of the discrepancies of individual SoS conditions. Such a description is valuable in itself. But for the real intercomparison among countries, quantification is needed. Based on a carefully designed set of parameters and on sophisticated measurement techniques, Section 3.6 has therefore assessed the level of security risks which single European countries face. The research question has led us to thinking about *SoS-indices* in principle, to constructing new SoS-indices, and to comparing them with the existing ones. We have developed the composite indicator *HHI’14* and calculated it according to three different statistical methods – in search of the best method. The research question has also led us to measuring the “*N-1*” infrastructure standard proposed by the EU (OJL [2010]). The EU Commission itself did not calculate country values – it only communicated what it approximately meant by “N-1”.

This study is not the first attempt to put figures on the SoS. The added value of our approach, however, involved a more advanced underpinning. And as compared with simply introducing the SoS-management tools (Section 3.4), the value lies also in the all-inclusive evaluation of gas market-relevant cases. Benefits are the explicit SoS indication and the country ranging possibility – while the pure discussion of SoS tools is more of conceptual nature. The presented approach has contributed to pursuing quantitatively the research objective of this dissertation. Summarising the course of Section 3.6, the following outcomes become available:

- small European nations suffer from lower SoS than large ones;
- the CSEE region suffers from lower SoS than the EU-15;
- SoS is crucially influenced by diversity of country-specific factors.

Our focus on exploring the applicability/usages of the SoS-indices developed in Section 3.6 (*HHI’14s*) and of those adopted (“N-1” plus several composites stemming from other authors) appears to be even more significant and novel. With their application we hope to gain insights into the indices adequacy as a policy tool for present and future energy security developments. While the existing literature offers quite a number of energy security indicators to date, their usefulness has never been tested.

Within Chapter 4, in closing of the January 2009 gas crisis analysis (Section 4.3) and of the infrastructure projects analysis (Section 4.4), we have – for the first time – been testing the explanatory power of SoS-indices. We confronted them with two measurable phenomena: (a) with the economic losses in the 2009 interruption of Russian gas flows to Europe; and (b) with the EU subsidies under the EEPR programme.

The clarification of “how secure the countries were” led to the second research question. Chapter 4 thus aims to address “*How the SoS in Europe can be improved (with emphasis on infrastructure)*”. Upon that, the study’s focus has been shifted to CSEE – based on the relatively bad local SoS scores (as judged by quantifications in Section 3.6). A profound analysis in the case of CSEE could not be carried out without investigation of the background of gas supply vulnerabilities. CMEA “baggage”, restricting the energy-political discretion of the region, has been explained in Section 4.2. Our analysis covered the inherited distortions like excessive seasonality of gas demand, lack of supply diversity, and inefficiency of infrastructure. It concluded that the unidirectional and non-integrated networks architecture has turned into a major obstacle to the CSEE goal of overcoming the single-source dependency (on Russia). Overcoming of that dependency is considered necessary on the understanding that a prolonged disruption of the gas inflows from Russia would have had a catastrophic impact on the region. In January 2009, the degree of CMEA-caused vulnerabilities became painfully evident in CSEE. They proved to be an impediment to dealing with the supply cut. In terms of this real emergency situation, Section 4.3 has thus explored implications of the CMEA inheritance for the enlarged EU and discussed the practical use of the SoS tools presented in Section 3.4. As was to be proved, we confirmed that mainly the inadequacies in gas transport (in terms of capacities, bi-directional capabilities, networks isolation) constrained flows towards CSEE throughout the duration of the gas cut, rather than an overall shortage of substitute gas.

As previously mentioned, factors determining the ability to cope with supply disruptions also comprise the gas supply infrastructure set-up. This is why, following up on this topic that was introduced in Subsection 2.3.3, Section 4.4 committed to an in-depth discussion of advanced infrastructural issues. There needs to be flexibility, redundancy, and alternative options in the system if gas disruptions are to be managed. Our examination of the infrastructure utilization (Subsection 4.4.1) has detected, however, that Europe’s gas transmission, production and storage capacity was totally or nearly totally exhausted in the extreme cold winter days. Infrastructure concerns were mainly related to CSEE. Still, bottlenecks and missing pipeline links *within* Europe were jeopardising decisions concerning capital outlay *outside* Europe. COM [2010b: 11] instructs that “every European region should implement infrastructure allowing physical access to at least two different sources”. This suggested that a common European strategy was needed. It is where the *EEPR* emerged as a financial mean to facilitate necessary investments – being addressed in Subsection 4.4.2. In line with COM [2008] etc., Subsection 4.4.3 has subsequently examined the priority corridors anticipated to strengthen the European GTS. With relevance to CSEE and emphasis on the *EEPR* projects, it dealt with making the two-way gas flows possible, making up for lacking cross-country links (in terms of the shaping *Baltic Gas Ring*, *North-South gas corridor* in CSEE, and the *SEE Gas Ring*), with infrastructure initiatives providing new gas to CSEE (in the form of LNG and pipeline gas), as well as with the increased

storage. Against this background, critical requirements have been addressed such as:

- ensuring that some vital projects are not dismissed as ineffective. (The key here is introducing reliability with respect to the completion of associated projects.);
- avoiding of the multiplicity of infrastructures. (The project development thus requires a more balanced approach.);
- incentives: e.g., for suppliers it is access to a larger pool of demand, whereas for consumers it is increased diversity of supply, new trading opportunities<sup>225</sup> or (with respect to LNG) enabling market integration wherever no direct pipelines exist.

In Subsection 4.4.5, we eventually set out that the SoS-index development (Section 3.6) has contributed to pursuing the *second* research question on a par with the *first* one. HHI'14 and "N-1" are capable of communicating both "the level of (in-)security" and "required measures to be taken in order to improve the SoS scores". What is meant here is the measurable impact of the EEPR on EU's security. It can be calculated – on the understanding that the centralised Community financing made the relevant projects extremely credible for implementing. So Subsection 4.4.5 has estimated how the country scores have changed, in terms of both indices, in response to the EEPR. In trying to reply to the second research question, we have finally (in Section 4.5) reported on a highly promising project NETS (abbreviated for the "New Europe Transmission System") and a forward-looking European Transmission System Operator (ETSO) idea, aimed to unify gas grids – in, respectively, CSEE and EU – by replacing national TSOs and creating a common TSO. SoS will benefit from a progressive unification of gas networks. However, progress is slow. For the time being, notably the German gas market has taken steps towards complete integration. Results from the other declared initiatives remain to be seen.

**Discussion and Further Research** This section evaluates the major, quantitative, findings of the dissertation. It ultimately outlines approaches to future research, based on this study's limitations.

This investigation integrates a number of characteristics of gas-consuming and -supplying countries into indices which promise to describe/evaluate a country's SoS situation best. It may be an important step for improving the understanding of the multifaceted concept of SoS. We pursued the idea to check (for policy decisions) the *usefulness* of differently defined SoS-indices. This has been achieved by testing their predictive success – which has never been done before. Our major findings are presented in Subsections 4.3.3 and 4.4.4. They add up to the following:

- With respect to HHI'14 (more precisely HHI'14<sub>2</sub> and HHI'14<sub>5</sub>), we weakly supported the hypothesis that European nations with "good" SoS scores have coped better with the January 2009 gas crisis than those with "bad" scores. This result is based, however, on a small sample of countries for which economic losses have been estimated. Figures of reduced industrial production as the consequence of the 2009 gas crisis did not show significant relation to any of the HHI'14s. In terms of "N-1", no significant relation could be found.
- Our conjecture that the EU nations with "worse" SoS scores might have enjoyed stronger EEPR subsidies could neither be supported (for both classes of indices).

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225. CSEE countries that are buying natural gas for oil-linked formula price are losing out in the market situations, when traded spot prices are lower.

As we have discovered a correlation of some of those indices with the amount of losses in a gas crisis, this puts in doubt whether the EEPF funding is well-founded.

- On the other hand, investment in infrastructure, made after the gas cut of January 2009, resulted that many EU member states now meet the common SoS standard expressed in terms of “N-1”.

Based on our findings we have concluded that the HHI’14 index of ours together with one more other index (i.e., REES, suggested by Le Coq & Paltseva [2009]) somewhat favoured the ability to explain/predict measurable SoS-relevant phenomena like supply problems and economic losses. But this clearly was insufficiently to firmly recommend their adoption by policymaking.

Some other energy policy recommendations could be:

- In January 2009, enlarged Europe paid the price for its poorly interconnected gas infrastructure. This lesson has been learned and it should be kept in mind in the years to come where gas is expected to substitute more and more other fossil fuels and, in some countries, also nuclear energy resources;
- Some believe that Russia intends to strengthen its influence in Europe by promoting politically motivated infrastructure projects. This might encourage diversification away from Russia – notably for CSEE;
- A constructive dialogue EU–Russia is strongly needed in order to grant transit via Russia to Turkmenistan, Kazakhstan, and Uzbekistan.

Despite the important findings of this investigation, it had its limitations. Occasionally we had measuring problems or were not able to collect the data we really wanted. Therefore further work on aspects not covered in the research, and on shortcomings we ran across when trying to quantify specified indices and consequences of crises, is worthwhile. A few viable areas of future study could be:

- A modified “N-1” method. The current N-1 calculation is sensitive to large infrastructures (pipes, storages, etc.) not necessarily destined for one country. Herefrom it appears not quite correct, e.g., that each preceding transit country in a multiple-country pipeline chain has assigned all its entry capacity to itself by the N-1 design fixed in OJL [2010]. So an adjusted common approach – at least at research level – needs to be developed for the N-1 calculation.
- While our analysis of measuring SoS has provided interesting insights, a few improvements are possible. First, our current SoS-index is static, while policy reform is a dynamic process. Further work should thus look at HHI’14 changing in time (in the manner of, say, Sovacool & Brown [2010]<sup>226</sup>). Second, some arbitrariness present in HHI’14 may be inherent but should be discussed. For instance, why using the “share in TPEC” and not “share in value of TPEC” as weight of a component-parameter? Or why using an adjustment factor for “gas substitutability” on a [1, 2] scale and for “offshore risks” on a [1, 4] scale? – instead of, say, on a [1, 10] scale? Third, the analysis could benefit from the inclusion of some, but not too many, additional factors. For example, we have assumed that domestic production is free from supply risk. Still, disruptions in domestic supply (due to strikes or infrastructure-related breakdowns) should also be addressed. The credible SoS-index should additionally approach diversity in terms of “*independent*” sources and

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226. Based on their SoS-index, Sovacool & Brown [2010] have assessed the relative energy (gas and oil) security performance of 22 OECD nations from 1970 to 2007.

transport routes. In this context, Jansen & Seebregts [2010] indicate: “The *Nord Stream* gas pipeline certainly has value for improving energy [...] security in the EU. Yet, the *Nabucco* project would add more”. Finally, one may criticize our concept of using two families of SoS-indices (HHI’14 and “N-1”) like “one index instead of two would make comparisons easier and more readily communicable”. Although we had good reasons for using two indices, extra efforts might make sense towards that goal too.

- Our focus in this paper has mainly been gas-consuming Europe. Its extension by incorporating an analysis of incentives and behaviour of gas-exporting and transit nations could be desirable – specifically as regards the Middle East/Caspian gas stockroom. One idea might be a game-theoretic analysis involving existent and potential gas suppliers and shippers to Europe – based on the experiences of, e.g., Chollet et al. [2001]. In the light of continuous efforts of CSEE to diversify away from Russian gas, it might also be intriguing to try quantitatively access the judgement like: “It is not clear – given the number of borders which [Middle East/Caspian gas supplies] will need to cross and the potential for problems within and between countries along the route – whether such pipeline routes can be considered more reliable than existing and new supplies from and through Russia which they are intended to displace” (Stern [2006:15]).
- Finally, one should think about other SoS tools. One measure not discussed in this study is a stronger integration of the gas-producing and gas-consuming states. Bolle & Ruban [2007] have investigated gas supply disruptions in vertical structures. They have shown that SoS will be improved should the producers invest (and, in the case of Gazprom, be allowed to invest) in the European downstream market as gas traders. Therefore, the incorporation of vertical integration into a complex SoS analysis might be worth including in future research endeavours.



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