Towards EUGas-26: the European Gas Assessment model for EU Directive 2008/14/EC and EU Regulation No 994/2010

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Abstract

Questions concerning security of supply and identification of critical components of the European gas market have gained more and more attention since the adoption of the Council Directive 2004/67/EC. Due to the importance of gas in the European energy mix, the European Union (EU) needs tools and know-how to address, support, and assess the development of a well-functioning internal gas market, of its infrastructure, and diversification of supply. The "European Gas Assessment" (EUGas) project is an ongoing effort to develop an integrated hydraulic country scale project of national gas transmission systems (NGTS) to support Directive 2008/114/EC on "the identification and designation of European Critical Infrastructure (ECI)" and Regulation 994/2010 on "measure to safeguard security of gas supply". EUGas can identify key ECIs and conduct a risk analysis based on major threat scenarios. It can evaluate vulnerabilities of assets and potential impacts of disruptions. It can support the definition of infrastructure and supply standards, and the establishment of "Operator Security Plan", "Preventive Action Plan", "Emergency Plan", or "Risk Assessment", particularly in light of a "regional cooperation". EUGas is a country level model of NGTSs built using a combination of commercially available software to provide a technical insight into the operation of such complex systems. Composed of approximately 5.000 nodes and 6.500 pipelines, it covers, up to now, 20 Member States (i.e., Finland, Sweden, Denmark, The Netherlands, Germany, Poland, Latvia, Estonia, Lithuania, Czech Republic, Slovakia, Hungary, Austria, Romania, Bulgaria, Greece, France, Belgium, Luxemburg and Portugal). EUGas provides a detailed one-time steady state pressure and flow analysis of the integrated system, and it uses a Geographic Information System (GIS) data processing component and a hydraulic network solving engine. The paper presents a short description of the architecture of EUGas, and of the solutions identified to cope with the challenging problems in scaling up at the EU level. A GIS module, based on ESRI ArcGIS Desktop©, performs all necessary data pre-processing in order to have a topologically correct network. A Scenario creation module provides tools to manage demand/supply data and create scenarios to be tested in the network. A Hydraulic solver module, based on GL Noble Denton SynerGee Gas©, solves the steady state condition of a gas grid under different load and environmental conditions. Examples are provided to show EUGAs capabilities. Open issues are reported in the conclusions mostly in light of covering all Member States with EUGas-26. In particular, a strategic steps are the validation in collaboration with Transmission System Operators of the details of the facilities of the infrastructure, the access to information concerning demand in the framework of REMIT, and the identification of strategies and legal constraints in coping and managing a possible crisis at the national or regional level.

Keywords: hydraulic modelling, risk assessment, natural gas transmission system.

1. Introduction

As energy has come to be a vital part of Europe's economy and of modern lifestyles, we have come to expect secure energy supplies: uninterrupted access to energy sources at an affordable price (Gracceva and Zeniewski, 2014). Since the adoption of Council Directive 98/30/EC concerning common rules for the internal market in natural gas, and with the Treaty of Lisbon (in 2007), energy policies of the European Union (EU) have had a security of supply "pillar". Major steps have been undertaken to create electricity and gas markets, increase competition, diversify sources and supplies, to cut consumption and emissions (COM, 2014). These policies not only aim to increase competitiveness and keep affordable prices as well as move towards a more sustainable energy system, but –the EU being a major energy importer- they are equally important for energy security. Thus, with the EU's 2020 energy and climate policies, energy efficiency, renewables polices and the planned 2030 policies, a range of measures exist to also address security of supply concerns.

Questions concerning security of supply and identification of critical components of the European gas market have gained more and more attention since the adoption of the Council Directive 2004/67/EC concerning measures to safeguard security of natural gas supply. The reference legal framework put in place at the European level to address such issues is set by Directive 2008/114/EC on “the identification and designation of European Critical Infrastructure (ECI)” and Regulation 994/2010 on “measure to safeguard security of gas supply”. Furthermore as a result of Regulation No 713/2009 the creation of the “Agency for the Cooperation of Energy Regulator” and of the “European Network of Transmission System Operators for Gas” (both in 2009) pushed forward to provide means to achieve the challenging objectives set by the planned 2030 policies. Anyway due to the importance of natural gas in the European energy mix, the EU needs tools and further know-how to address, support, and assess the development of a well-functioning internal gas market, of its infrastructure and diversification of supply.

Among a variety of tools numerical modelling is one way to quantitatively analyse gas markets, next to theoretical modelling and economic studies (Bo, 2012). Several overall models have been developed by public or private research Institutes or Agencies, like NATGAS by CPB Netherlanads Bureau for Economic Policy Analysis, GASMOD by Deutsches Institut für Wirtschaftsforschung, GASTALE by the energy Resource Centre of the Netherlands, and TIGER by Energiewirtschaftliches Institut of the University of Cologne (Bo, 2012). ENTSOG has developed a specific model of the European gas grid to fulfil its institutional obligation. The model relies on entry/exit zones and cross border Capacity. Its outputs can be easily used by stakeholders and Transmission System Operators’ customers (TSO) for internal evaluations. All these models are mainly developed to describe the behaviours of a competitive natural gas market to analyses the effects of liberalisation or investment in infrastructures within the EU. They are primarily developed using linear programming techniques and provide a quite simplified and generalised decryption (mostly for the infrastructure part).

The “European Gas Assessment” (EUGas) project is an ongoing effort to develop an integrated hydraulic country scale model of national gas transmission systems (NGTS) to support Directive 2008/114/EC and Regulation 994/2010. EUGas can identify key ECIs and conduct a risk analysis based on major threat scenarios. It can evaluate vulnerabilities of assets and potential impacts of disruptions. It can support the definition of infrastructure and supply standards, and the establishment of “Operator Security Plan”, “Preventive Action Plan”, “Emergency Plan”, or “Risk Assessment”, particularly in light of a “regional cooperation” foreseen by Regulation 994/2010.

The poster presents a short introduction of the development of EUGas along with two examples of applications.

2. The EUGas project

The “European Gas Assessment” (EUGas) project aims at developing an integrated environment for the analysis of country level hydraulic models of NGTSs built using a combination of commercially available software to provide a technical insight into the operation of such complex systems. Composed of approximately 5.000 nodes and 6.500 pipelines, it covers up to now 20 Member States (i.e., Finland, Sweden, Denmark, The Netherlands, Germany, Poland, Latvia, Estonia, Lithuania, Czech Republic, Slovakia, Hungary, Austria, Romania, Bulgaria, Greece, France, Belgium, Luxemburg and Portugal; Figure

1). EUGas models the main components of the national high pressure transmission system of a Member State (MS) by spatially locating pipelines (with a 3D description), LNG facilities, Underground Storage Facilities, Compressor Stations, off-take points, main production sites and cross-border points. EUGas provides a detailed one-time steady state pressure and flow hydraulic analysis of the integrated system under a user defined scenario (like average winter, daily peak winter demand or crisis) of demand/supply, with focus on three types of flow category (i.e., domestic and district heating, industrial, and power production flows) liked to Regulation 994/2010.

The development of EUGas is carried out by the integration of three different modules (Figure 2): a Geographic Information System (GIS) module, a scenario creation module and a hydraulic solver module. All three modules can exchange data in a way to ensure "feature consistency" (i.e., through a rigid set of rules for naming elements each component of a model is unambiguously identified and such label is the same in each module) and "topology consistency" (i.e., the geometrical relationships among entities is enforced and maintained in the GIS and hydraulic module by a shared set of rules) (Zaccarelli et al. 2012, 2013).

The first module, implemented by ArcGIS Desktop version 10.1©(ESRI, 2012), performs all necessary data pre-processing in order to have a topologically correct network composed of nodes (i.e., entry and exit points of gas) and branch lines. A standardised spatial geodatabase is compiled to collect a 3D description of the grid, and manage the information concerning the features of a pipeline (e.g., diameter, length, TSO owner, from to node, year of construction, etc.), of a compressor station (e.g., total power, number and type of unit, compressor ratio, suction/discharge pressure, etc.), gas storage (e.g., capacity, withdrawal rate, etc.), LNG and production sites (e.g., injection rate and pressure), and cross-border points (e.g., capacity). The geodatabase has a dedicated toolbox for data checking and auxiliary information for population, industrial and economic indicators, gas fired power plants, and administrative units (i.e., NUTS 3 level polygons for all MSs). Maps can be easily compiled to summarise results and performing further analysis.

The scenario creation module is a database composed of spreadsheets for each MS, where data concerning the demand/supply are stored, managed and processed based on specific rules for gas allocation to nodes. Such rules can be changed in a way to describe some reference scenarios like average winter conditions, peak demand conditions or crisis. Some predefined charts and pivot tables are available to check data consistency and balance.

The last module is the hydraulic numerical solver engine based on SynerGee Gas© version 4.7.1 (GL Noble Denton, 2013). The module creates an explicit 3D hydraulic model and solves the steady state condition of the gas network under different load and environmental conditions (passed by the scenario creation module). A dedicated warehouse has been created to collect all reference objects (e.g., pipelines with defined properties, standard regulators, a standardised compressor facility) to facilitated the model creation. The underline engine provides advanced facilities for editing and charting of flows and pressures by flow category type.

EUGas is still undergoing an active development because the urgent need to cover all EU-26 national natural gas transmission systems. It is expected to complete the spatial coverage of all MSs by the end of 2014, and to have final platform ready by mid-2015. As up to now it is possible to identify four major phases of development (Figure 3; Pride 2008a, b; Zaccarelli et al. 2012):

Phase 1: the project focused on identifying the main features of the hydraulic module relevant to the application of Directive 2008/114/EC and Regulation 994/2010. The research assessed (i) problems of data collection and demand/supply allocation, (ii) evaluated a first procedure for data checking, and (iii) focused on modelling conditions and constraints for reaching a steady state solution. In this phase only the hydraulic module was available, and the network topology was built within SynerGee Gas directly by the user. This phase was carried out as a pilot study linked to a workshop “European Critical Gas Infrastructure modelling. A one-day workshop at the JRC. September 2007”. Data on infrastructure was provided by the involved TSOs.

Phase 2: the project focused on a tight integration between the hydraulic network module and the new GIS module, and started to develop a simplified strategy for data down-scaling from the national to the node level. The use of the GIS module opened to the possibility of exploiting commercial spatial databases (like PLATTS or IHS) describing transit and transmission gas networks, along with the major network facilities to derive a simplify network topology with “virtual exit points” and “virtual production points”. No request to national TSOs was made for details concerning network topology, pipeline technical properties, or facilities features. Demand/Supply gas data were acquired by public available sources, namely from the “Gas Infrastructure Europe” web site (GIE), and processed to get estimates for exits points. Regarding gas infrastructure (e.g., gas pipelines, gas compressor stations, gas storages) in some cases real and in others virtual production and off-take points were considered. Application of virtual production points was needed especially in cases where many gas fields were scattered within a country. Furthermore application of virtual off-take points in some cases was needed, because of simplification of the gas model. In cases where technical data for gas compressor stations and gas storages was not available some assumptions had to be done.

Phase 3: the project took advantage of the extension to new countries and the enforcement of Chapter 3 of Annex I of Regulation (EC) No 715/2009 prompted for solutions for new problems: i) how to cope with low quality geographic data; ii) how to balance the complexity of the network with a detailed description of the facilities along a pipeline; iii) how to process and link multi-temporal demand/supply gas data at the node level to the network. Identification of the most reliable spatial data is a key moment in building a consistent picture of the national and European gas transmission network. Resilience and reliability analysis under different disruption or crisis events requires a sound geographic description to ensure dependable results, meaningful scenarios and trustworthy forecasts on dynamics. Georeferenced raster base maps, acquired by the TSOs web pages, were used to build from scratch or to correct and adjust the project’s commercially vector datasets. A complex network topology was addressed by coupling the detailed description from the base map with a procedure to simplify and aggregate pipelines and nodes to reach a balance in abstracting the relevant features of the grid. Finally, during this phase the availability of demand/supply data at the node level for multiple years prompted for the definition of specific solution for (i) data handling and storing, (ii) conversion among different unit of measures, and (iii) aggregation for the definition of a demand/supply reference set of values for a particular condition (e.g., average winter or daily peak demand).

Phase 4: the project focused on two major aspects to provide a sound base for the last step of extension of the model to cover all remaining MSs with a NNGTS. A standardized version of a reference geodatabase has been developed to enforce consistency and repeatability of the GIS modelling and gas grid data collection. The template provides to the modeller a flexible framework to build a topologically consistent network, while leveraging all operations and setting for attributes definition, value checking (i.e., avoidance of misspelled text values through domains), and coordinate systems coherence. The availability of tools for topology checking and features naming ensures an increased productivity and a substantial reduction of error. Once a country model is developed starting from the template, the maintenance workflow is easier, as well as its updating and integration with other country models.

A better definition and standardization of the down-scaling and allocation procedure of demand/supply data to the node level is provided, by creating a dedicated module the "scenario creation" module. The procedure tries to cover all cases encountered during phase 3 and 4 in order to clarify how flows for different types of nodes are calculated or can be updated. It moves form the most simple case of available values for the maximum daily peak flow (at the node o at the country level), to the overall calculation of flows under high stress condition based on apportionments from surrogates. Any future extension of the EUGas model or its update will follow one of the identified strategies of the procedure.

Finally, it has been recognised the need of a tight collaboration with TSOs and MS's Competent Authorities (as identified by Regulation 994/2010) and thus not only for data exchange, but also for validation and use of EUGas's country level models. It is important to underline that EUGas is not meant for capacity calculation or one-to-one description of a national grid. Its level of simplification of a grid translates, along with the approach for supply/demand (i.e., only for some countries it is possible to map off-takes with actual flows provided by the TSO), in errors when compared with results provided by models developed by TSOs. As a benchmark EUGas uses capacities published by ENTSOG for cross-border points.

4. Examples of applications

Figure 4 provides two examples of application of EUGas: a "Supply Trace" analysis of natural gas supply for the region of Romania, Bulgaria and Greece, and an assessment of the impact of grid simplification (i.e., deletion of the medium pressure grid) in modelling the national grid of Denmark. A detailed description of this last example is provided by Rodriguez-Gomez et al. of the proceedings of this Conference.

5. Conclusions

EUGas is an ongoing project developed by the Institute for Energy and Transport - Directorate-General Joint Research – to provide to other DG and the European Commission a tool to strengthen and assess the application and impact of Directive 2008/114/EC and Regulation 994/2010. It couples a detailed description of MSs' natural gas high pressure grid with scenario building, graphical output and hydraulic numerical solutions. It could be used for a variety of applications, though its primarily context is risk assessment and crisis assessment.

EUGas has been developed by using the best knowledge and information publicly available through what TSOs and Competent Authorities have published, or private companies sell on the market. But still a consistent validation of the basic information concerning national infrastructure and topology is one the major issue. Though a more extensive application of Regulation (EC) No 715/2009 (i.e., Chapter 3 of Annex I) has substantially improved the amount and quality of the available information, TSOs are reluctant, for a variety of reasons, to disclose general technical details on their network. EUGas has strongly benefited from a close collaboration with the following TSOs: DESFA, Gasum, Energinet.dk, REN - Gasodutos, Enagás, Fluxys, Snam Rete Gas, and Gasunie Transport Services B.V.

Furthermore, the approach used by EUGas to allocate demand/supply could take advantage of the application of Regulation (EU) No 1227/2011 on Wholesale Energy Market Integrity and Transparency (REMIT). As it stands now, only for some Member States (e.g., Greece, Romania, Hungary) it is possible to associate to off-take points estimates based on a statistical analysis of time series of flows values. For other Member states a general approach of allocation is applied based on profiling the amount and types of users in administrative units. With a full and extensive application of REMIT a far better description of flows can be achieved.

Finally, an open issue within EUGas is the clear definition of a portfolio of possible strategies for coping with crisis scenarios. As a further step in the last part of the development of the project, it is expected to be able to create for each Member State a clear set of rules to be used in simulation concerning measures for safeguard protected costumers, cutting of groups of users, managing fuel switching in gas fired power plants, and apply market and non-market based security of supply actions.

Disclaimer note

DG-JRC does not endorse any commercial software mentioned in the paper. The opinions express by the Authors in this document are theirs alone and do not necessarily represent those of the DG-JRC, nor of other EU Institutions.

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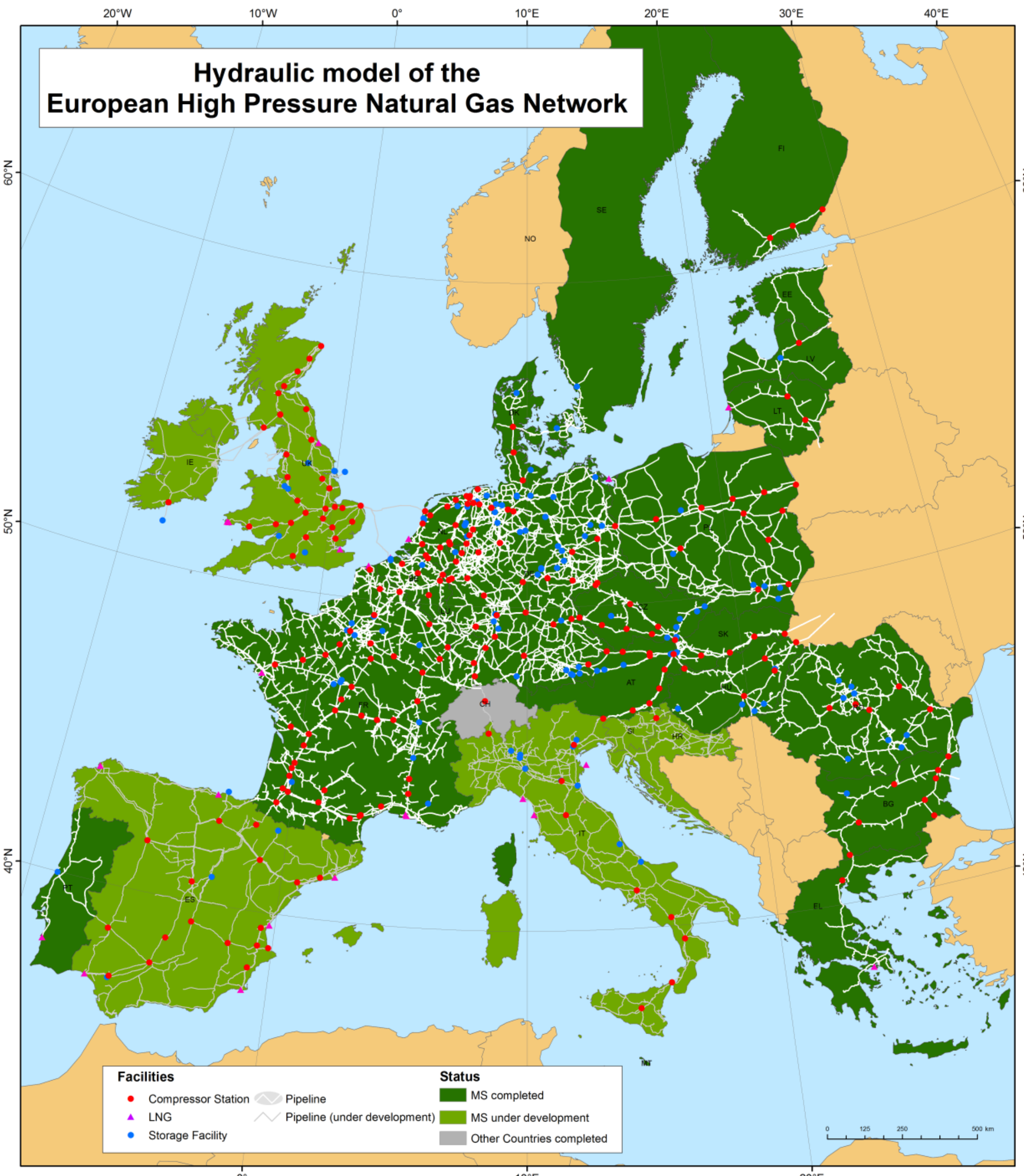

Figure 1. High pressure natural gas network and facilities for the hydraulic model of national grids of Member States developed (dark green) and under development (light green) in the EUGas project. Production sites, off-take nodes and cross-border points are not shown.

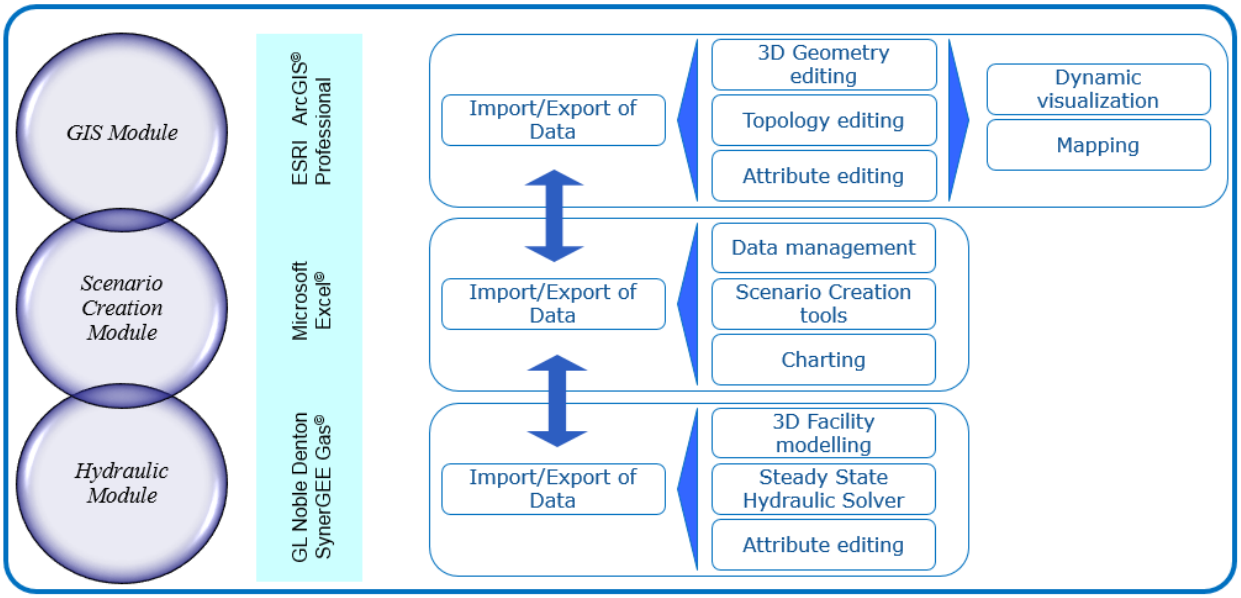

Figure 2. Modular structure and main functionalities of the EUGas integrated environment.

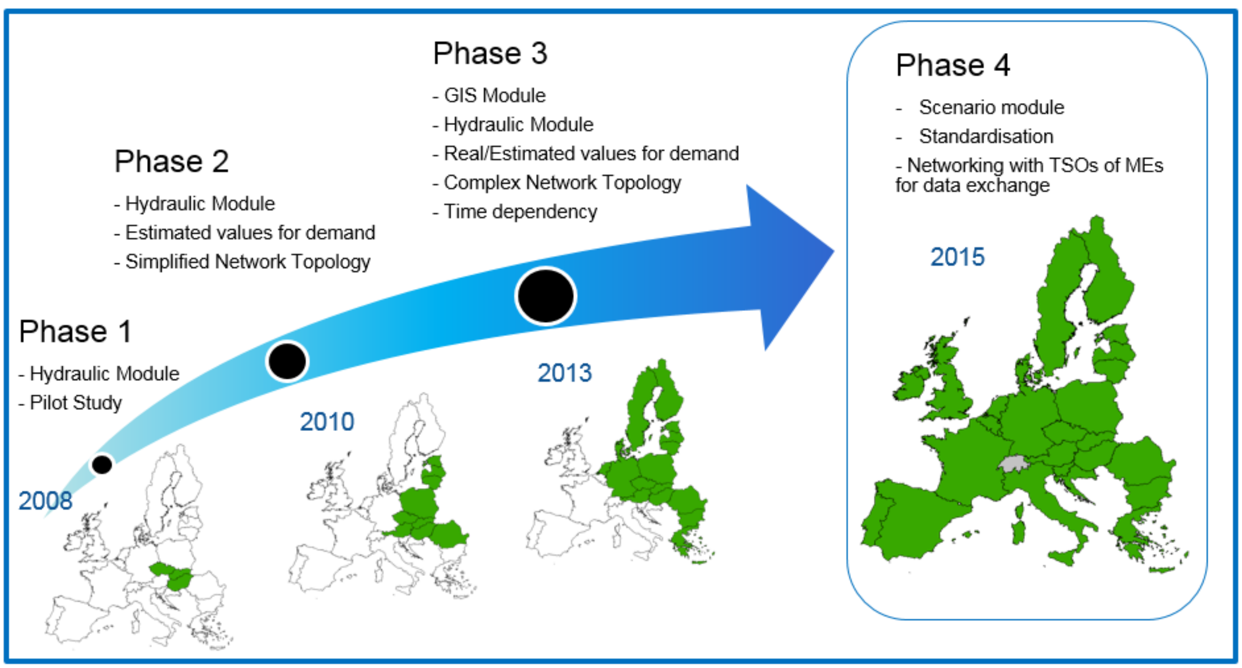

Figure 3. Phases of the development of the EUGas integrated environment since 2008.

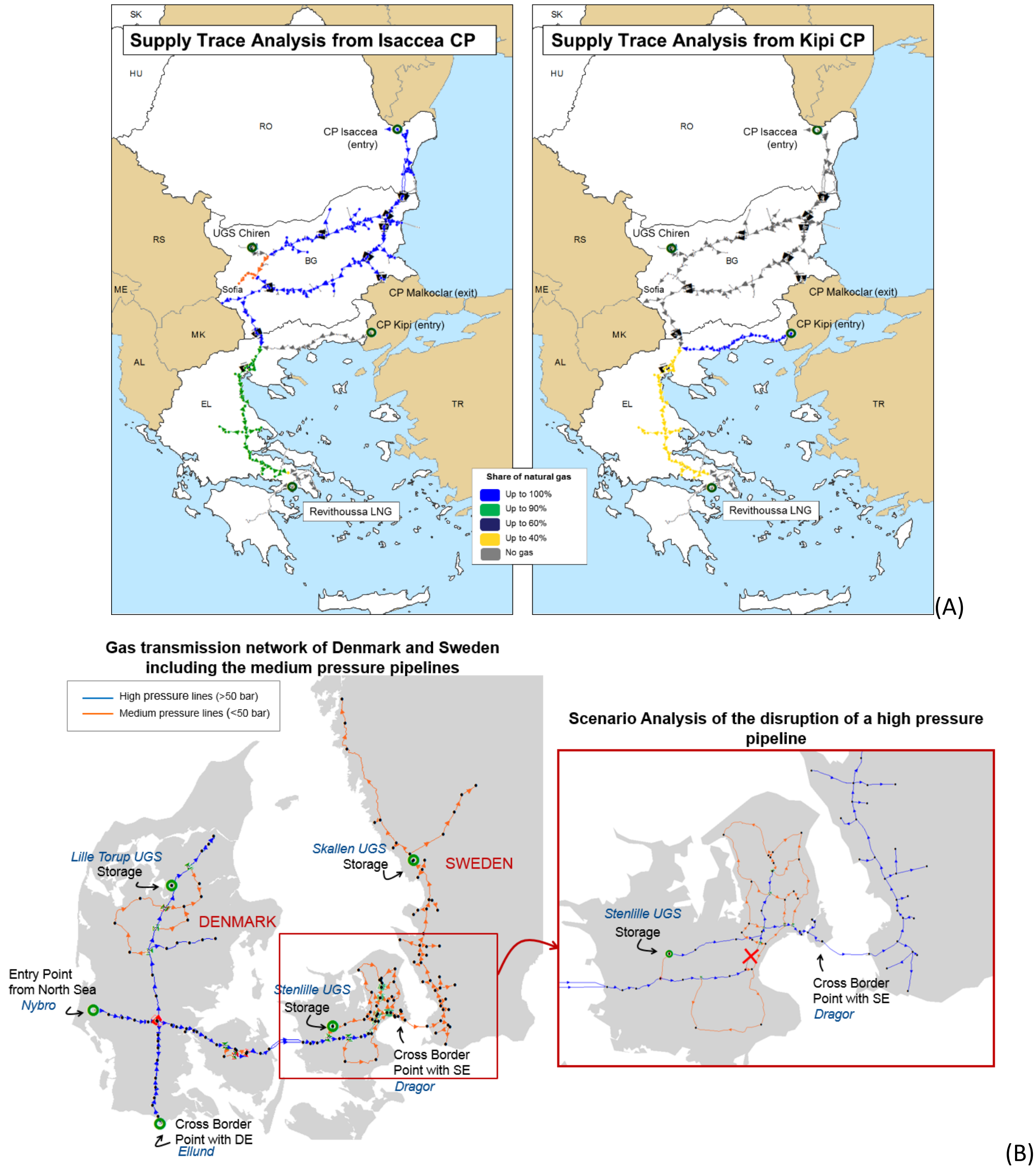

Figure 4. Examples of application of the EUGas model: (A) "Supply Trace" analysis of natural gas supply for the region of Romania, Bulgaria and Greece in EUGas. The analysis shows the share of natural gas in each pipeline associated to a specific supply node in an "average winter" scenario: supply from Ukraine at the Isaccea cross-border point (CP; on the left) and from Turkey at the Kipi cross-border point (on the right). It is clear how the regions of Attica and Peloponnese depend on the supply from the LNG facility of Revithoussa. (B) Assessment of the effects a disruption of a pipeline in a highly populated when the medium pressure lines (in orange) and high pressure lines (in blue) are considered together in the hydraulic mode. By the higher connectivity provided by the medium pressure lines the system is able to meet the basic needs of gas of Copenhagen and partially of Sweden.