HOW DEPENDENT ARE EUROPEAN ELECTRICITY SYSTEMS AND ECONOMIES ON NATURAL GAS?

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Overview

As a result of the war in Ukraine, the countries of the European Union (EU) have imposed a large number of sanctions on Russia. In the energy sector, a coal embargo was decided at the beginning of April, but explicitly not for imports of pipeline-bound natural gas, which would be difficult to replace in the short term, due to concerns about massive economic damage. While a large part of natural gas is used for heat supply and processing industry, electricity generation still represents a substantial share of the total natural gas demand with 31.7 % in the EU [1]. Against this background, our manuscript aims to answer the arising question how resilient the European power supply is against restrictions in the availability of natural gas.

For this, we have chosen 2025 as target year for our investigations. Based on a probabilistic analysis of the expected interruptions in electricity supply and an economic analysis of the associated economic costs, we examined different scenarios for the European gas supply.

Methods

Our methodology to map the effects of reductions in natural gas-fired power generation on electricity consumption consists of three steps. We first translate possible developments into scenarios for the EU-28 (excluding Malta and Cyprus, including Norway) in the year 2025. We analyze a reference case without reduction and different reduction scenarios, e.g. if 30% or 40% less natural gas is used uniformly in each European country compared to the reference case. Using these scenarios, the second step is a probabilistic simulation and evaluation of the security of supply in the electricity sector using simulation models developed at RWTH Aachen University, taking into account weather- and outage-related uncertainties[2]. The aim of the method is to minimize the resulting demand shortfall in the entire area under consideration. The key figure Expected Energy not Served (EEnS) indicates the amount of energy that cannot be supplied in a year in deviation from the expected demand. For our simulations, we use the data set from the European Resource Adequacy Assessment (ERAA) 2021 [3].

In the third step, we evaluate the economic implications of possible deviations in electricity supply as a result of restrictions on natural gas-fired power generation using a techno-economic simulation model also developed at RWTH Aachen University. This is based on economic and energy input-output data [4–6]. In our simulations, we examine the Value of Lost Load (VoLL), which indicates the consumption-weighted average loss of economic welfare for consumers in euros per unit of energy not supplied. Due to the heterogeneous structure of the different electricity consumers, we differentiate between 15 consumer groups. Possible non-deliveries of electricity due to natural gas restrictions are allocated by the model by minimizing the cumulative VoLL, i.e. the lost consumer surplus, in each individual country at each hour over the entire year under investigation. Thus, on the demand side, we proceed analogously to a merit-order model. The amount of energy that cannot be supplied per consumer group is limited in our model by the hourly energy demand in this sector. For the individual consumer groups, we use published data sources [7] as well as synthetic load profiles available at RWTH Aachen [8]. The simulation models and the input parameters will be explained in more detail in the full-length manuscript.

Results

The model results show that if the amount of gas available for electricity generation is reduced by 30% compared to the reference scenario, consumers in Europe have to forego planned electricity deliveries in a moderate amount of 1.6 TWh on average and associated with relatively moderate economic costs of around €1.4 billion for the affected consumers. This increases significantly with a reduction of the gas volume available for electricity generation by 40% compared to the reference scenario. Consumers in Europe have to forego planned electricity deliveries in a expected average amount of 37.8 TWh which is associated with economic costs of around EUR 77.8 billion. The non-delivery volume is distributed among Belgium , Germany, Denmark, France, Greece, Ireland, Italy, Luxembourg, Latvia, the Netherlands and the United Kingdom. Figure 1 shows the regional distribution of the analyzed parameters in the 40% reduction scenario compared to the reference case without gas quantity restriction. With shares in the total European costs of just under 57.7 % and over 37.8 % respectively, it is evident that Ireland

and Italy in particular would bear the consequences of such an allocation of gas reductions in Europe. In this scenario, these countries account for expected electricity deliveries of 7.5 TWh and 26.6 TWh, respectively, and costs that amount to up to 12.0% of Ireland's and 1.8% of Italy's gross domestic product (GDP), respectively.

The causes of the high economic costs in Ireland are twofold: First, as an island nation in the European interconnected grid, the country has limited access to cross-border load balancing resulting in high expected absolute load shortfalls, and second, there are comparatively few economic sectors in Ireland with low flexibility costs, resulting in increased power cuts in the high-cost commercial sector.

Further analysis, including how a welfare-oriented natural gas allocation could be designed and what consequences this has on security of supply and economic costs, will follow in the full manuscript. In addition, we analyze what effect the postponement of planned coal-fired power plant shutdowns can have.

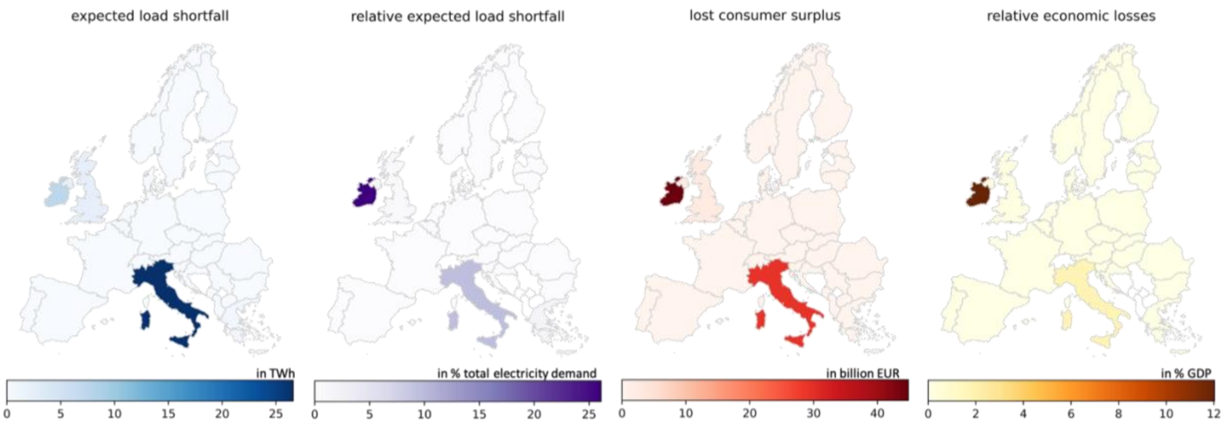

Figure 1: Regional distribution of the determined parameters in the 40 % reduction scenario

Conclusions

We have studied the impact of different gas supply scenarios in Europe on the expected power supply interruptions and the associated economic impact. Based on our model results we draw the following conclusions:

- The example of Ireland shows the **relevance of European load balancing**. In order to absorb national congestion as efficiently as possible, it is therefore advisable to increase the expansion of cross-border interconnection capacities.
- A **solidarity-coordinated distribution** of all natural gas available for power generation in Europe is likely to be an effective means of preventing the current limited cross-border electrical interconnection capacity from leading to increased national congestion and very high value-added losses in individual countries.
- **Coordination** of **gas consumption** between the power sector and other sectors, particularly in the heat and industrial sectors, could increase the amount of gas available for power generation in the event of supply shortages, thereby supporting security of electricity supply.

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