Shrinking together and pulling apart: the Austrian gas grid by 2040 under declining natural gas demand and increasing domestic renewable gas generation

Sebastian Zwickl-Bernhard[a,b,*], Aria Rodgarkia-Dara[c], Christoph Gatzen[c], Marcus Otti[a], Antonia Golab[a], Hans Auer[a,b]

[a] *Energy Economics Group (EEG), Technische Universität Wien, Gusshausstrasse 25-29/E370-3, 1040 Wien, Austria*
[b] *Industrial Economics and Technology Management, Norwegian University of Science and Technology, Gløshaugen, Alfred Getz vei 3, Trondheim, 7491, Norway*
[c] *Frontier Economics Limited, 71 High Holborn, London WC1V 6DA, United Kingdom*

Abstract

Keywords:

---

*Corresponding author
Email address: `zwickl@eeg.tuwien.ac.at` (Sebastian Zwickl-Bernhard)

1. Introduction

For decades in Europe, the optimal method of distributing natural gas to end customers, regardless of their varying demand scales (ranging from large industrial facilities to individual households), has been consistently been through the utilization of pipelines and comprehensive gas grids [1]. There are two main reasons for this. Firstly, natural gas has been a cheap energy source due to its unlimited availability in Europe through imports, mainly from neighbouring regions [2]. And secondly, the transport of natural gas through pipelines has been technically efficient and economically cheap over both short and long distances [3]. Particularly the latter reason allowed for large quantities of natural gas used to provide various energy services throughout the territory. Both reasons mentioned were mainly responsible also for the fact that gas customers were only charged low costs for using the gas grid (historically mainly for withdrawals of natural gas, not or less for injections). This paper aims, among other things, to analyze how these gas grid costs for end customers could develop in the course of decarbonizing energy systems.

In the context of piped natural gas supply, Austria has a long tradition. In fact, Austria was one of the first Western European countries connected to natural gas pipelines. The "Trans Austria Gas Pipeline" (TAG) started operation in 1968 and connected Austria with Slovakia [4]. The gas came from Russia. The consequences of this long history of natural gas in Austria are reflected on the one hand in a high dependence on natural gas for the provision of energy services [5] and on the other hand in a well-developed gas grid in the country [6]. However, natural gas grids face an uncertain future, as does the Austrian gas grid. European and national decarbonization policies are pushing the use of natural gas towards renewable energy alternatives in all energy sectors and services. The consequence is a massive reduction in demand for natural gas expected for the future in Europe [7]. It is therefore unclear to what extent gas grids will still be needed and whether they can be operated economically. With reference to the first paragraph, both reasons for efficient gas grids are called into question when considering the decline in demand for natural gas, carbon pricing and the general shift towards electrification of energy services. The main objective of this paper is to contribute to this discussion by quantifying the scope and size of the Austrian gas grid, laying in the geographical center of the European gas grid, until 2040 under different decarbonization scenarios. In particular, the goal it to answer the following three research questions:

- How does Austria's gas grid develop by 2040 under different decarbonization scenarios of the Austrian and European energy system, ranging from electrification of most of energy services to importing large amounts of renewable methane?
- Given the ageing nature of gas grids and pipelines, what is the need for replacement investment in the Austrian gas grid by 2040, especially in view of the expected increase in renewable gas generation (e.g., biomethane and synthetic gas) and its gas grid injection?
- How does Austria's gas grid change by 2040 in terms of grid costs for the end customer in comparison to the status quo?

The proposed analysis of the Austrian gas grid is not only a detailed regional case study, but also provides relevant insights for other countries with the expectation of a high potential for domestic renewable gas generation in the future, such as Germany, Italy, and France (see in [8]). The relevance of this case study must also be considered from a European perspective. The Austrian gas grid has historically been an important hub for the transmission and distribution of imported natural gas through Europe and provides ample storage capacities (see in [9]). Therefore, changes in the Austrian gas grid might also impact the gas grid of neighboring countries and vice versa.

A mixed-integer linear optimization approach is proposed to answer the three research questions. The applied model takes into account the existing natural gas grid (transmission, high-pressure and mid-pressure pipelines) as a starting point and decides whether or not the gas grid supplies the gas demand

5. Synthesis

To the three research questions posed in this paper, the generated results show some expected and some unexpected results. As expected, by looking at the future demand volumes of natural and renewable gas, the Austrian gas grid in a decarbonized energy system will shrink. However, the extent of shrinking varies between the decarbonization scenarios but is generally significantly lower than expected when looking solely at the future demand volumes. The main driver is the integration of decentralized renewable gas generation (biomethane and synthetic gas), and stand-alone supply options (trucking and on-site gas storage) are not competitive with piped supply. Nevertheless, in terms of grid costs, it is primarily the fixed costs of the existing gas grid (rather than the capital costs of the refurbished gas pipelines) that lead to, in some scenarios, a significant increase in average grid costs compared to the status quo (e.g., a fivefold increase in the scenario with high electrification of the energy system). Only in the scenario with continued high use of natural gas (through imports of decarbonized natural gas) do average gas grid costs remain similar to today's gas grids.

Considering the ambitious national climate targets, such as the decarbonization of the gas sector, the findings above, and the overall results, their applicability extends to countries with similarly high aspirations for renewable gas generation. For instance, the results for countries such as Germany, Italy, and France might look similar in Europe. These generalizations are more to be understood as qualitative statements and would require detailed analyses in any case. The specific geographical location of the renewable gas (and demand) in the analysis has proven to be too determining and crucial.

Concerning the study's limitations, two aspects should be mentioned and considered when interpreting the results. First, the results are primarily scenario-driven. For example, natural gas demand and renewable gas generation are determined by the scenarios and then used exogenously in the gas network modeling. The demand and generation volumes are inelastic to gas network costs. Second, based on the gas network costs, an indication of the end customer costs is given. In this context, treating (average) gas network and retail costs is relatively simplistic and could mislead the inattentive reader. Again, the average network costs are used to give a quantitative indication of how network costs for retail customers may develop in the future. As always with this type of analysis, especially when dealing with sensitive data of the existing energy system, such as gas network information, the number of assumptions that have to be made due to lack of information by the researcher and third parties should be taken into account when interpreting the present results.

6. Conclusions

The future of natural gas grids is one of the most pressing issues in realizing energy system decarbonization. This paper contributes to the discussion on this issue by conducting a techno-economic analysis of the Austrian gas grid to 2040 in four different decarbonization scenarios. This case study provides detailed insights into a well-developed gas grid with an expected significant decrease in natural gas demand and a significant increase in decentralized renewable gas generation.

Austria's natural gas grids will shrink in the future; how much depends primarily on the level of integration of renewable gas and not on the level of demand for natural gas. The ability to spatially concentrate natural gas demand (and thus allow for smaller gas grids) is likely much higher than decentralized renewable gas generation. Ultimately, the size of gas grids is answered by the quantities of demand and generation and their spatial location. In the area-wide integration of domestic renewable gases into the gas grid, a significant increase in average grid costs for the end customers has to be expected. The aging of the existing gas grid and related refurbishment investments play a relatively minor role in the gas grid costs, as fixed costs mainly determine them. At the same time, off-grid solutions such as trucking and on-site storage are not competitive with the gas grid (even if the gas grid is very low-utilized).

The final finding on the increase in gas grid costs for large-scale renewable gas injection can be a starting point for further work. The questions that arise are not only who bears the high gas grid costs in such a case and what influence they have on the end customer's decision whether or not it is economical to stick with natural gas as an energy source, but also how synergies between renewable gas generators and natural gas demand can be exploited. That means exploring the spatial interplay of local production and demand, for example, by forming regional renewable gas clusters.