Exploring the Role of Europe in the global LNG Market Equilibrium until 2040

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Abstract

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1. Introduction

With the Paris Agreement 2015, the world is committed to achieving carbon neutrality by mid-century [1]. Towards carbon neutrality, undisputedly renewable energy resources will play a key role in reducing the use of fossil fuels such as oil and coal [2]. To what extent natural gas, another crucial fossil fuel, plays a role in the future of energy systems and their way to carbon neutrality is still controversial. Some reasons are worth mentioning here why, despite ambitious climate targets being set in some countries and regions, massive demand for natural gas must still be assumed until the mid-century (and possibly even later). Historically, natural gas demand has been highly concentrated geographically near natural gas production as it has been mainly transported through gas pipelines, which limited the transport distance to a few thousand kilometers. As liquified natural gas (LNG) became technically and economically available at scale in ~~recent years~~, the number of countries and regions with access to natural gas through LNG imports via cargo transport has rapidly increased. Particularly, in those countries with high shares of oil and coal in their energy systems, LNG is now seen alongside renewable energy resources as a leading energy carrier to reduce carbon emissions.[1] One example is China [4], but other countries, such as India [5], Nigeria [6], and Ghana [7], could also be mentioned.[2] In developing countries such as those mentioned above, increasing LNG demand not only replaces coal and oil but is expected to enable energy access for citizens [10].

In contrast to developing countries, the situation and expectation for Europe regarding LNG demand is different. Europe's LNG demand is not an issue of enabling energy access to citizens or replacing oil and coal but primarily an

[1] The specific emissions of natural gas (in g/kWh) are in the range of one-third compared to coal (see [3]).

[2] Traditionally, the Asian energy market, particularly the Japanese one, firmly focused on LNG. Other countries, for example, China and South Korea, have shifted to LNG and increased their demand partly significantly in the past decades [8]. Today, as China has become the largest LNG importer worldwide, more than half of China's overall natural gas imports are LNG [9].

issue of energy security. LNG imports to Europe were minor since Europe has been mainly supplied with piped gas in the last decades. The leading supply country for Europe's natural gas demand was Russia. Traditionally, about 40% of Europe's total natural gas imports were Russian piped gas. In some European countries, such as Germany, to name one of them, dependence on Russian piped gas was even more significant. In 2020, more than 65% of natural gas demands were covered by imports from Russia [11]. The geographical proximity between Russia and Europe and the generally low price of Russian piped gas in the past was the main reason why Europe as an LNG market has been unattractive until now. However, this situation has changed fundamentally as a result of the invasion of Ukraine by Russia in February 2022. In response to Russian aggression and the resulting war in Ukraine, Europe has imposed sanctions on Russia. These have led to the collapse of Russian piped gas imports to Europe in 2022 and, consequently, a rethinking of natural gas in Europe. On the one hand, measures were taken to reduce energy and, thus, natural gas demand. On the other hand, Europe had to look for alternatives to replace the lack of imports from Russia. In addition to (limited) increased piped gas imports from Norway and other reactions, the main consequence is that LNG is on Europe's agenda now.

In the short term, LNG is essential for the supply security of Europe's energy systems. That is why Europe was willing to pay high prices in 2022, facing the risk of not being able to meet all the natural gas demands otherwise. In order to bring the procured quantities of LNG to Europe and the countries, new LNG terminals across Europe were also built. For example, Germany, Poland, but also Italy and Greece have already built or are currently in the process to built LNG terminals [12]. In view of the above, it can be expected that LNG will play an important role in Europe's energy supply not only in the crisis mode of 2022, but also in the medium term. Although European countries have attempted to negotiate short-term supply contracts for LNG, the investments made in LNG terminals and related transport infrastructure point

to longer-term planning[3]. However, many questions are unclear in this context so far. In addition to uncertainties regarding how far LNG can contribute to the achievement of European and global climate targets and what quantities will be demanded regionally, there is also the significant issue of how a market equilibrium for LNG will develop in the medium to long term. Particularly, the market situation in 2022 is not representative for future market equilibrium projections as China's LNG demand is considerably low due to effects of Covid measures there.

Against this background, this papers aims to answer the following three research questions:

- How, in terms of import volumes from regions and related supply costs, does Europe meet its expected LNG demand in the global market in 2040 under an increasing global LNG demand driven primarily by developing countries like India, Nigeria, and others?
- What impact do geopolitical tensions between import and export regions and using global LNG trade as a political weapon have on the European LNG supply?
- What global LNG trade equilibrium results from a unilateral deep decarbonization of the entire European energy system (i.e., no European LNG demand) while other regions continue to demand significant volumes of LNG? Which importing and exporting regions are most affected in a potentially oversupplied global LNG market in volumes and cost?

The core objective of this work is to investigate the global LNG market equilibrium until 2040. Thereby, exchanged LNG quantities between the most relevant import and export countries to meet expected demands and resulting regional LNG prices are in the foreground of the analysis. We focus on the European

[3]For example, the LNG terminal in Poland mentioned above will not start operations until 2025.

market and the most relevant export countries to cover Europe's demand until 2040. The analysis furthermore allows estimating future LNG price developments until 2040. Latter is not only a main novelty of the present work but can also be seen as a relevant contribution to the literature. LNG prices are often needed for modeling energy systems and are, in those predominantly, an exogenous input parameter. The present values for LNG price trends, especially for those in Europe that consider the absence of Russian pipeline gas, may therefore be of great importance for future work of the scientific community analyzing the trajectory of the European energy system toward carbon neutrality.

The method applied is the development of a linear optimization model. The objective function is to minimize the total LNG import costs (i.e., the sum of all import countries) while fulfilling all importer's exogenously predefined LNG demands. Import and export countries are represented by nodes in the model. Optimality of the model finds, among others, optimal LNG flows from each export to each import country. Input parameters encompass LNG import volumes (i.e., demands) with a monthly or yearly resolution, LNG export capacities, and LNG break-even prices. Additionally, spatial and further techno-economic data is used to calculate LNG transportation between each export and each import country.

The paper is organized as follows. Section 2 provides relevant background information from the scientific literature and outlines the novelties of this work beyond existing research. Section 3 presents the materials and methods developed in this work, including the mathematical formulation of the model, input data, and scenarios. Section 4 presents the results of this work, including sensitivity analyses of key determining parameters. Section 5 discusses the results, concludes the work, and outlines possible future research.