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

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Motivation and Background

- The world is committed to achieving carbon neutrality by mid-century
- Increasing shares of renewable energy in the energy system replace fossil energy sources
- However, the speed on the way and the specific target year in which net zero emissions are emitted vary between regions
  - Europe aims to achieve carbon neutrality in 2050
  - While China has defined 2060 as the target year
- Transitional solutions and so-called **bridge technologies** (or bridge fuels) are necessary if renewable energy cannot fully supply the energy system
- A pillar of these bridge technologies, namely **liquefied natural gas (LNG)**, is the subject of this work

The role of LNG in energy systems

- LNG's role has differed significantly among global regions
- Traditionally, the Asian market, particularly the Japanese one, firmly focused on LNG
- Today, as China has become the largest LNG importer worldwide, more than half of China's overall natural gas imports are LNG
- On the contrary, LNG imports to Europe were minor since Europe has been supplied with piped gas in the last decades.
- Collapse of Russian piped gas imports to Europe in 2022 has led to a rethinking of natural gas in Europe
  - Measures were taken to reduce energy and, thus, gas consumption
  - 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

LNG is essential for Europe's energy supply security (Short-term)

- 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 (e.g., Germany, Poland, but also Italy and Greece have already built or are currently in the process to built LNG terminals)
- 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**
- (i) how far LNG can contribute to the achievement of European and global climate targets and what quantities will be demanded regionally; (ii) there is also the significant issue of how a market equilibrium for LNG will develop in the medium to long term (2022's market situation not representative for future market equilibrium)

Core objective

- Investigating 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 market** and its most relevant export countries to cover Europe's demand until 2040
- The analysis furthermore allows **estimating future LNG price** developments until 2040
  - LNG prices are often needed for modeling energy systems and are, in those predominantly, an exogenous input parameter.
  - Present values for LNG price trends, especially for those in Europe considering the absence of Russian pipeline gas, may therefore be of great importance for future work of the scientific community analyzing the trajectory of Europe toward carbon neutrality.

Methodology

- 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

Overview of the model

$DES_{e,i} * q_{e,i}$
(Delivery ex ship price times quantity)

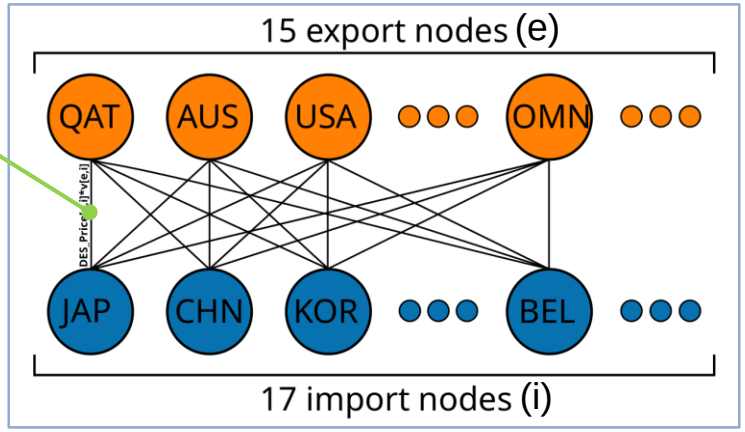


Fig: Links connecting export and import nodes

- Minimizing total system cost: $\min_{q_{e,i}} \sum_e \sum_i DES_{e,i} * q_{e,i}$
- $DES_{e,i}$ … Delivery ex ship price: price of delivered mmBTU of LNG from exporter e at the importer i[1]
- $q_{e,i}$ … Volume of shipped LNG from exporter e to importer i
- $DES_{e,i} = Break\ Even\ Price_e + Transport\ Cost_{e,i}$
- $\sum_i q_{e,i} \leq Export\ Capacity_e$ … Exporter's capacity
- $\sum_e q_{e,i} = Import_i$ … Importer's quantity
- $\sum_e q_{e,i} \leq \frac{1}{3} * Import_i$ … Diversification of exporters

LNG Break Even Price
= feed gas
+ Capex of liquefaction facilitates
+ royalties and taxes

[1]The exporter carries the obligation and cost of transportation.

Geographical locations of LNG export and import nodes (2019)

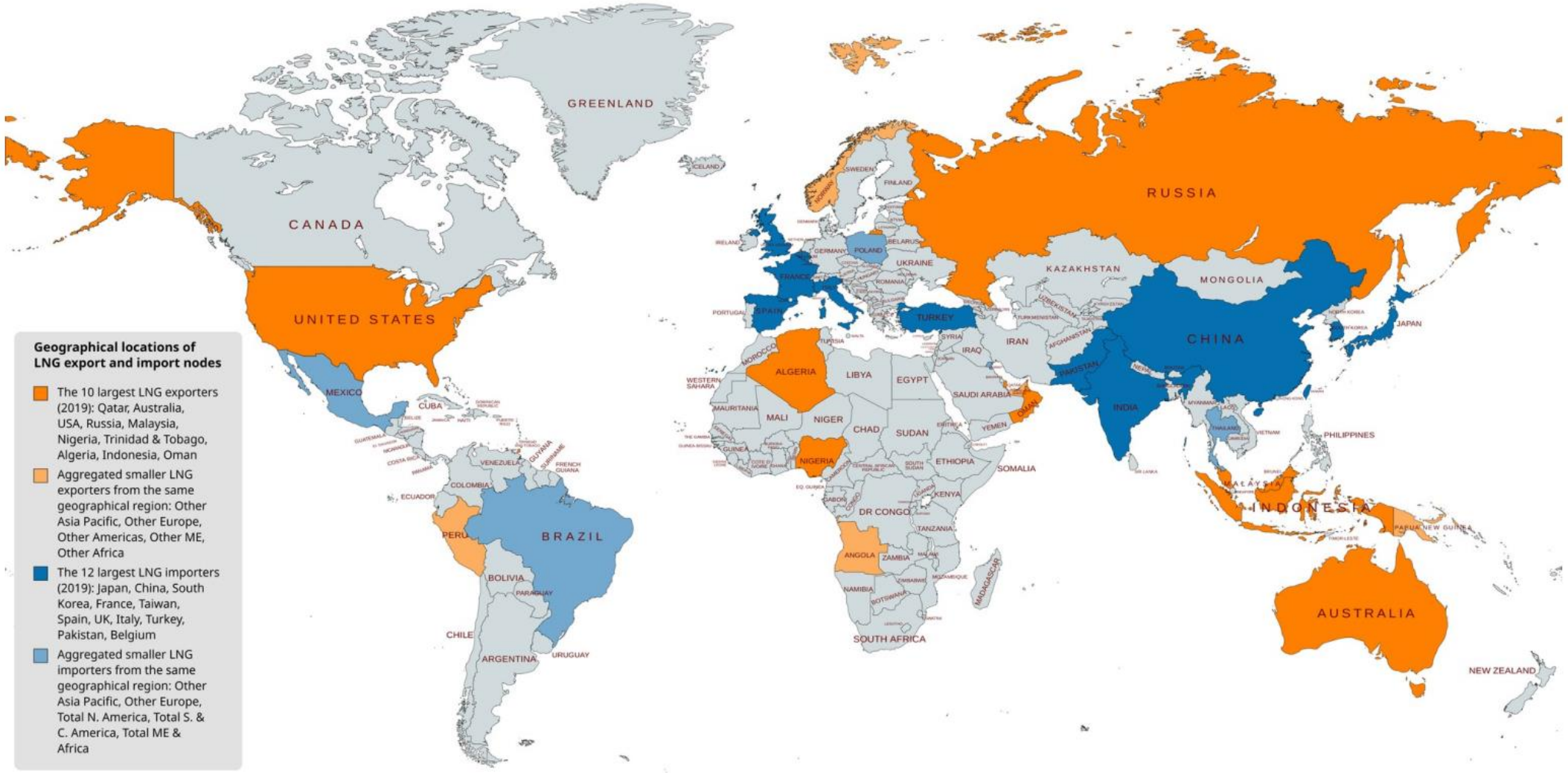


Figure: mapchart.net

Global LNG market in 2019 (validation of the model)

- Determined LNG flows confirm the clear perspective of the geographical **division** of the global LNG market **into three regions** (valid for importers and exporters)
  - (A) Atlantic Basin
  - (B) Pacific Basin
  - (C) Middle East

Japan, China and South Korea are mainly supplied by Australia, Indonesia and Malaysia (➔ **Pacific Basin**)

Qatar: (1) largest LNG exporter; (2) lowest "Break Even Price"; (3) mainly serving the Asian market

USA, Algeria and Nigeria are the main exporters for **Europe's LNG demand** in 2019

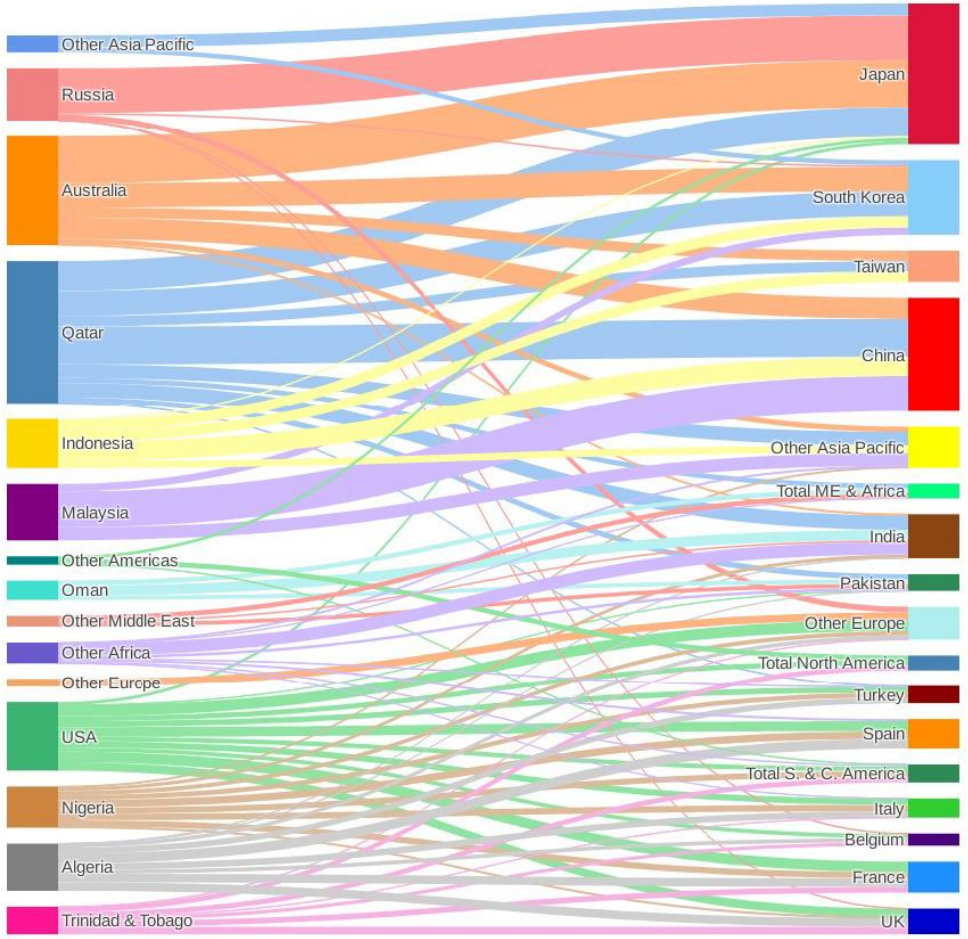


Fig: Determined LNG flows

Value of increasing liquefaction capacities of exporters (2019)

➔ Quantification of the change in exporter's liquefaction capacities on the total cost

- 1. Group: Nodes with no or **minimal** potential for reducing cost (e.g., Australia and USA)
- 2. Group: Nodes with **moderate** potential for reducing cost (e.g., Indonesia, Malaysia, and European countries)
- 3. Group: Nodes with **strong** potential for reducing cost (e.g., Qatar, Algeria)

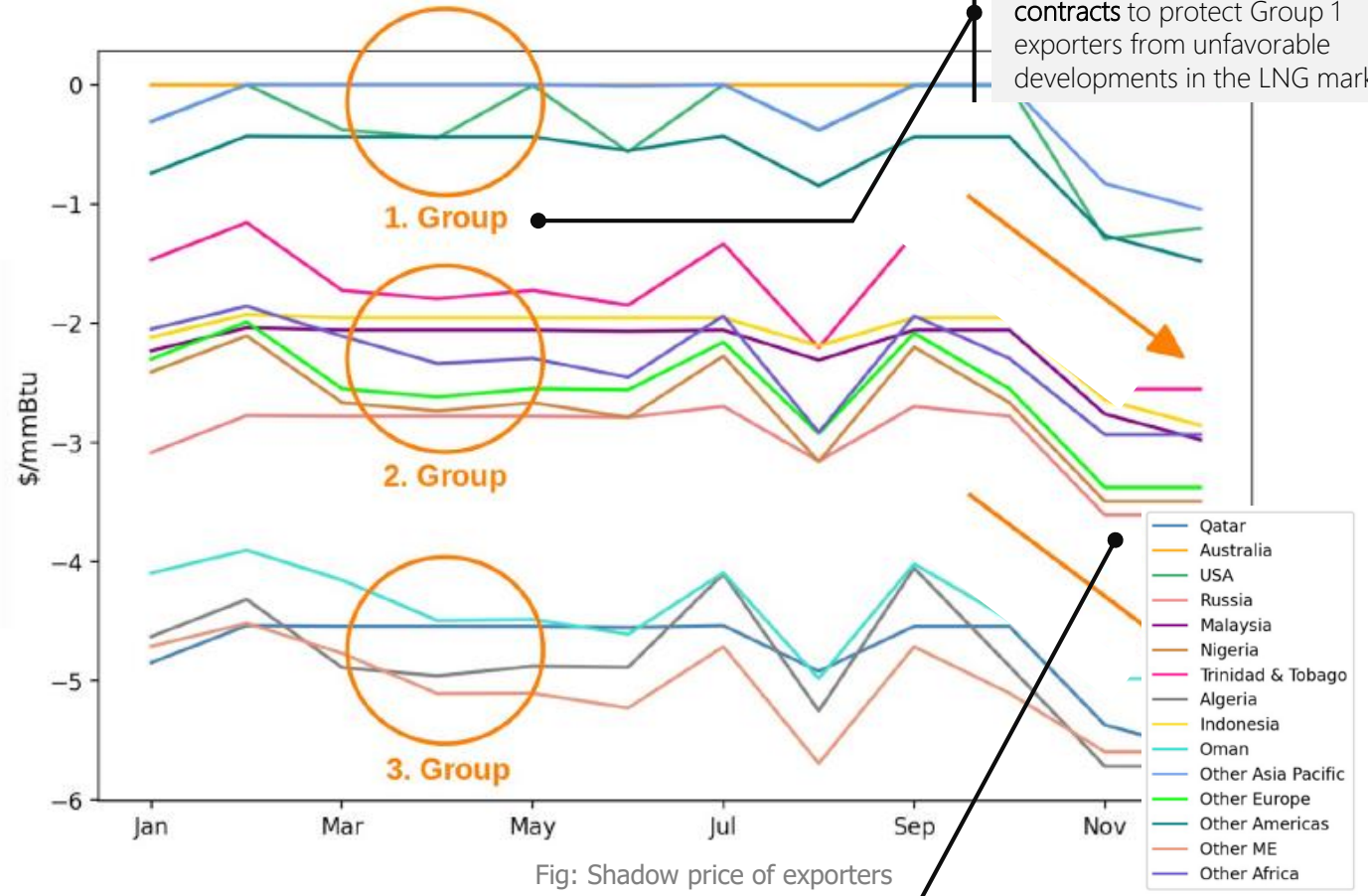


Fig: Shadow price of exporters

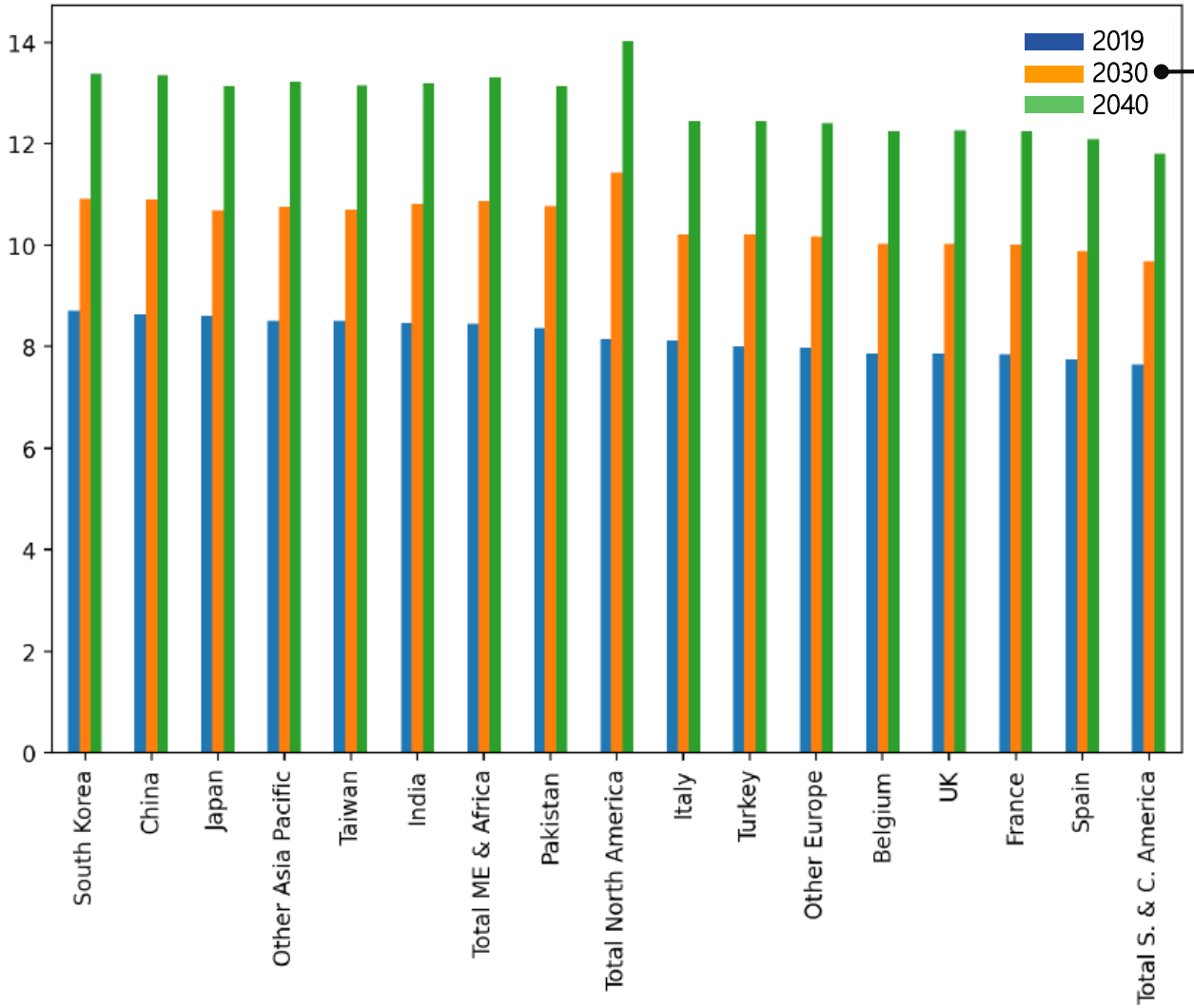
Intention to use **long-term contracts** to protect Group 1 exporters from unfavorable developments in the LNG market

Characteristic **seasonality** of gas market and **limited** LNG **storage** capacities (e.g., China)

Values obtained as the dual variable of the capacity restriction constraint $\sum_i q_{e,i} \leq Export\ Capacity_e$.

Global LNG market development until 2040

Fig: Weighted DES prices of importers until 2040 in $ per mmBTU



Assumption: Steady growth of global LNG trade

- Floating Storage and Re-Gasification Units (FSRU) with low CAPEX
- "LNG to power" possibility with FSRU
- Much shorter time for realization

Geographical trend of LNG market prices in 2040 remain relatively the same compared to 2019

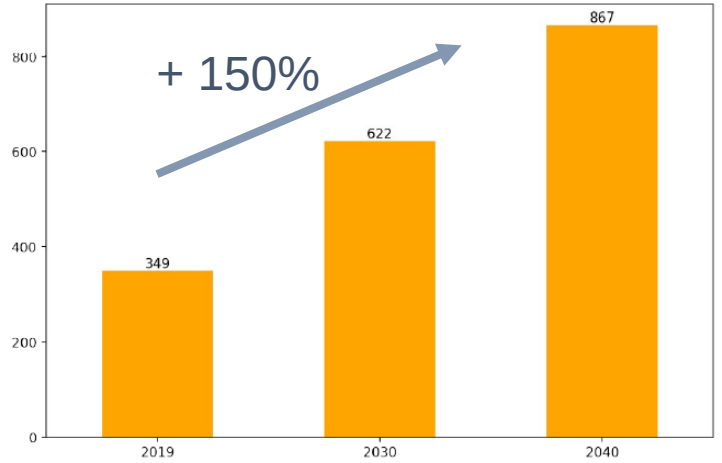
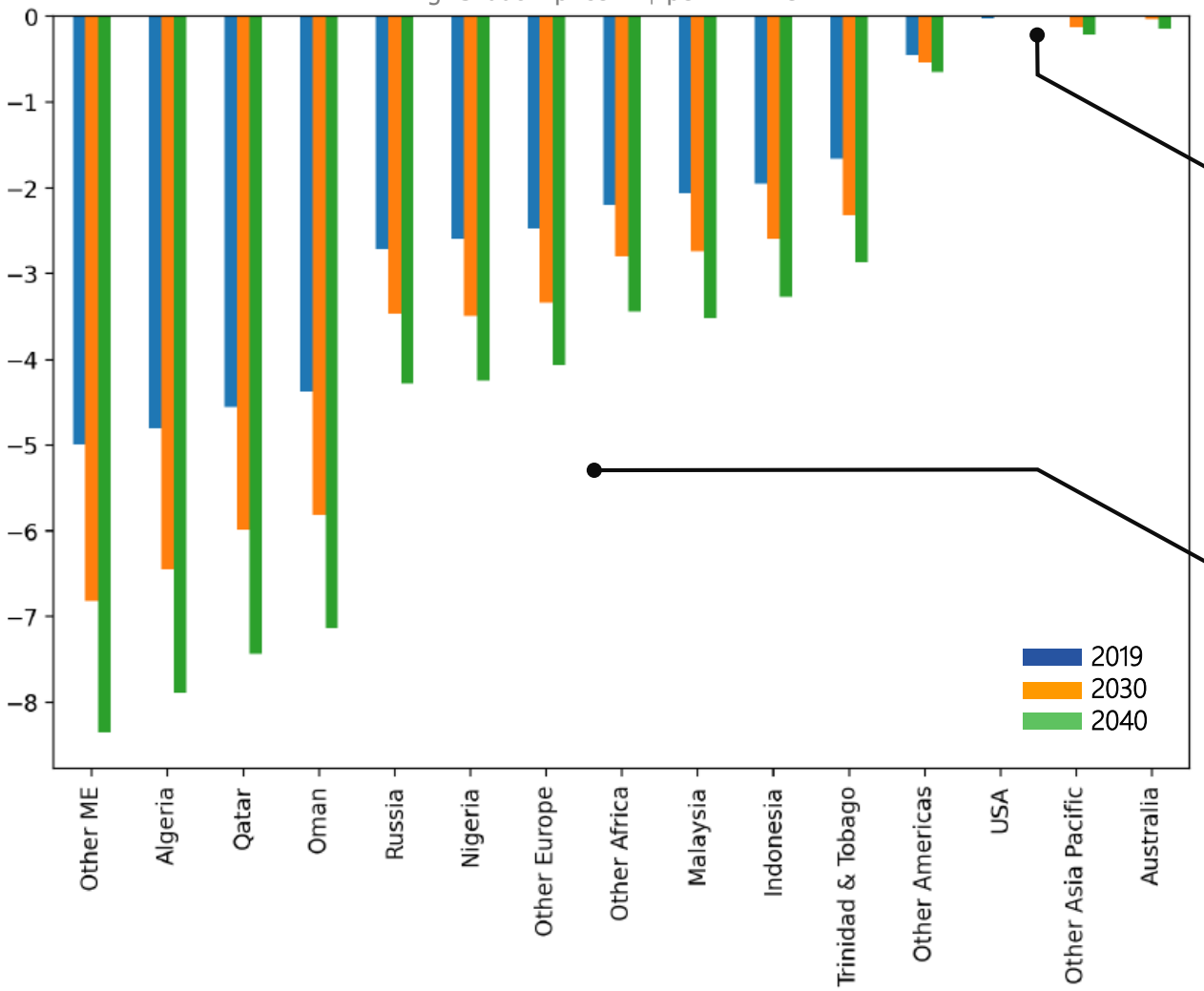


Fig: Number of LNG carriers in 2019, 2030, and 2040

Value of increasing liquefaction capacities of exporters (2040)

Fig: Shadow price in $ per mmBTU



USA as exporter with the largest LNG liquefaction capacity replaces Australia as a **marginal exporter** in 2040 compared to 2019.

In 2040, results indicate the **same** division of exporters into the aforementioned **three groups** as in 2019

Europe’s LNG prices until 2040

8,38 and 5.97 $ per mmBTU in Q4 2018 and Q1 2019

Country / in $ per mmBTU	2019	2030	2040
Belgium	7,9	10,0	12,2
Germany (and other Europe)	7,9	10,0	12,2
France	7,9	10,0	12,1
Italy	8,0	10,0	12,2
Spain	7,8	9,9	12,0
Average	7,9	10,0	12,2

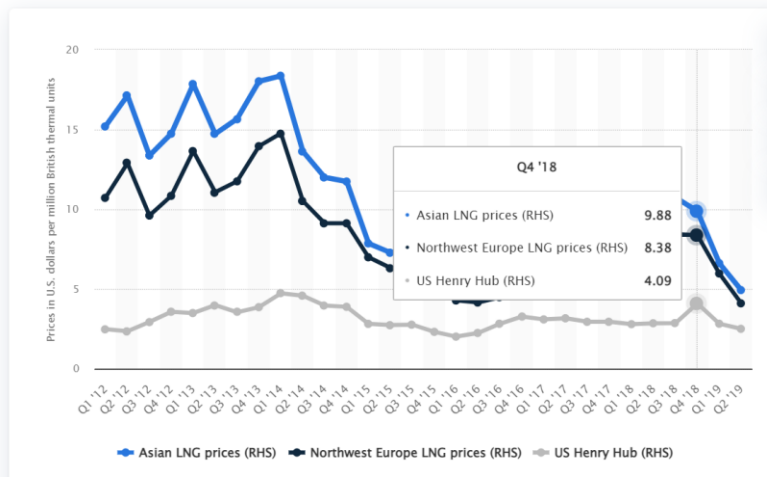


Fig: Quarterly prices of LNG from 2012 to 2019.
Source: Statista

Europe’s LNG import price in 2040:
41.6 EUR per MWh

Comparison of results with previous studies

Commodity	Unit	2019	2020	Forecasts 2021	2022	2023	2024	2025	2030	2035
Energy										
Coal, Australia	$/mt	77.9	60.8	140.0	120.0	90.0	86.4	82.9	67.5	55.0
Crude oil, avg	$/bbl	61.4	41.3	70.0	74.0	65.0	65.4	65.8	67.9	70.0
Natural gas, Europe	$/mmbtu	4.8	3.2	14.6	12.6	9.2	8.9	8.7	7.5	6.5
Natural gas, U.S.	$/mmbtu	2.5	2.0	4.1	4.0	3.9	3.9	3.9	4.0	4.0
Liquefied natural gas, Japan	$/mmbtu	10.6	8.3	11.9	11.4	10.0	9.8	9.5	8.5	7.5

Source: Commodity Markets Outlook – Urbanization and Commodity Demand

Present results suggest higher LNG prices (**about double**) than in existing literature

12,2 $ per mmBTU in 2040

Key-Takeaways

- Significant increase in the consumption of LNG expected up to 2040 due to the comparatively short start-up time and flexible use in energy systems
- The trends in the geographical distribution of LNG prices remain the same in 2040 compared to historical values
- In Europe, the present results indicate a rise in LNG prices to around 12,2 $ per mmBTU by 2040
- Potential increase in export capacity of individual countries leads to the need for mid- and long-term supply contracts for marginal exporters (e.g., USA in 2040)