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Changes in German pipeline retrofitting potential after the Russian invasion of Ukraine

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Presentation Outline

1. Research Question

- How to measure retrofitting potential in the German gas grid
- How did this potential change during 2022

2. Methods

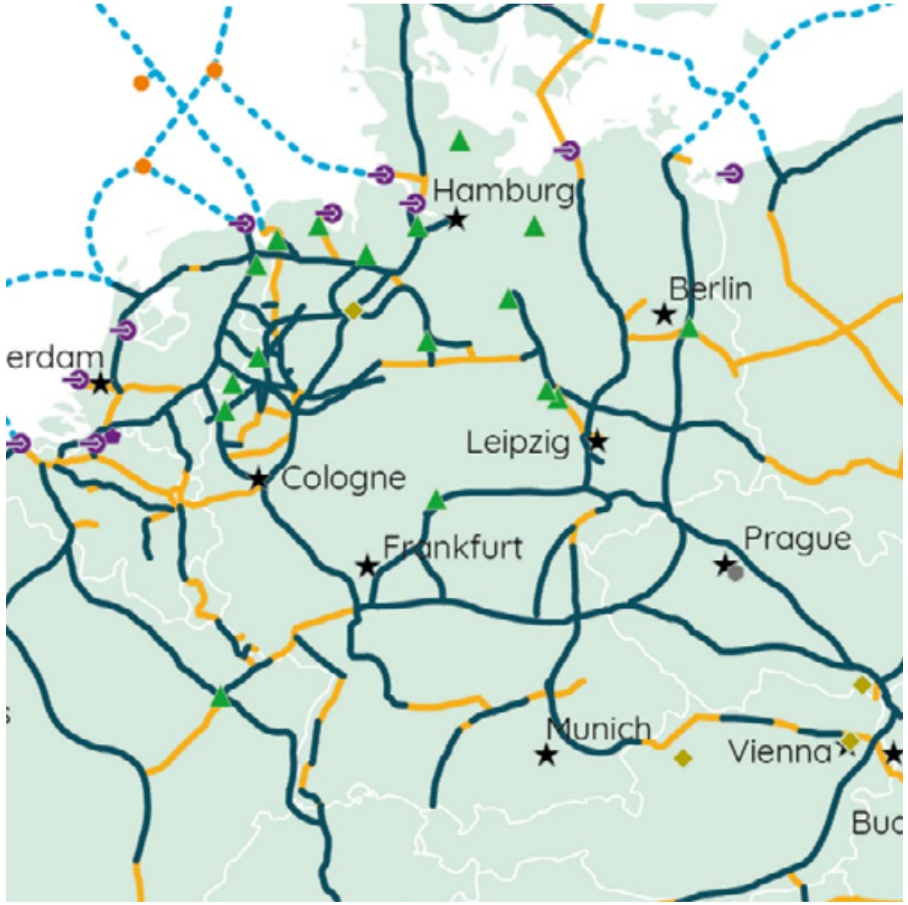
- Making the best of publicly available information
- Simulating optimal flow with GAMAMOD

3. Results

- High potential in the east and west, few connections

Introduction

- Germany transition to Hydrogen openly relies on pipeline retrofitting to reduce costs.
- However, no peer-reviewed study has data on actual availability of these pipelines.
- The transition from a gas to hydrogen grid is often overseen.
- The Russian invasion of Ukraine has made hydrogen an integral part of the energy security strategy.



Source: European Hydrogen Backbone (EHB) initiative

Fig. 1: Prospective 2040 Hydrogen Network

Research Question

How will the gas infrastructure transition to Hydrogen?

Research Context

- Electric and gas transmission systems are similar in functions, legal frameworks, and regulatory entities.

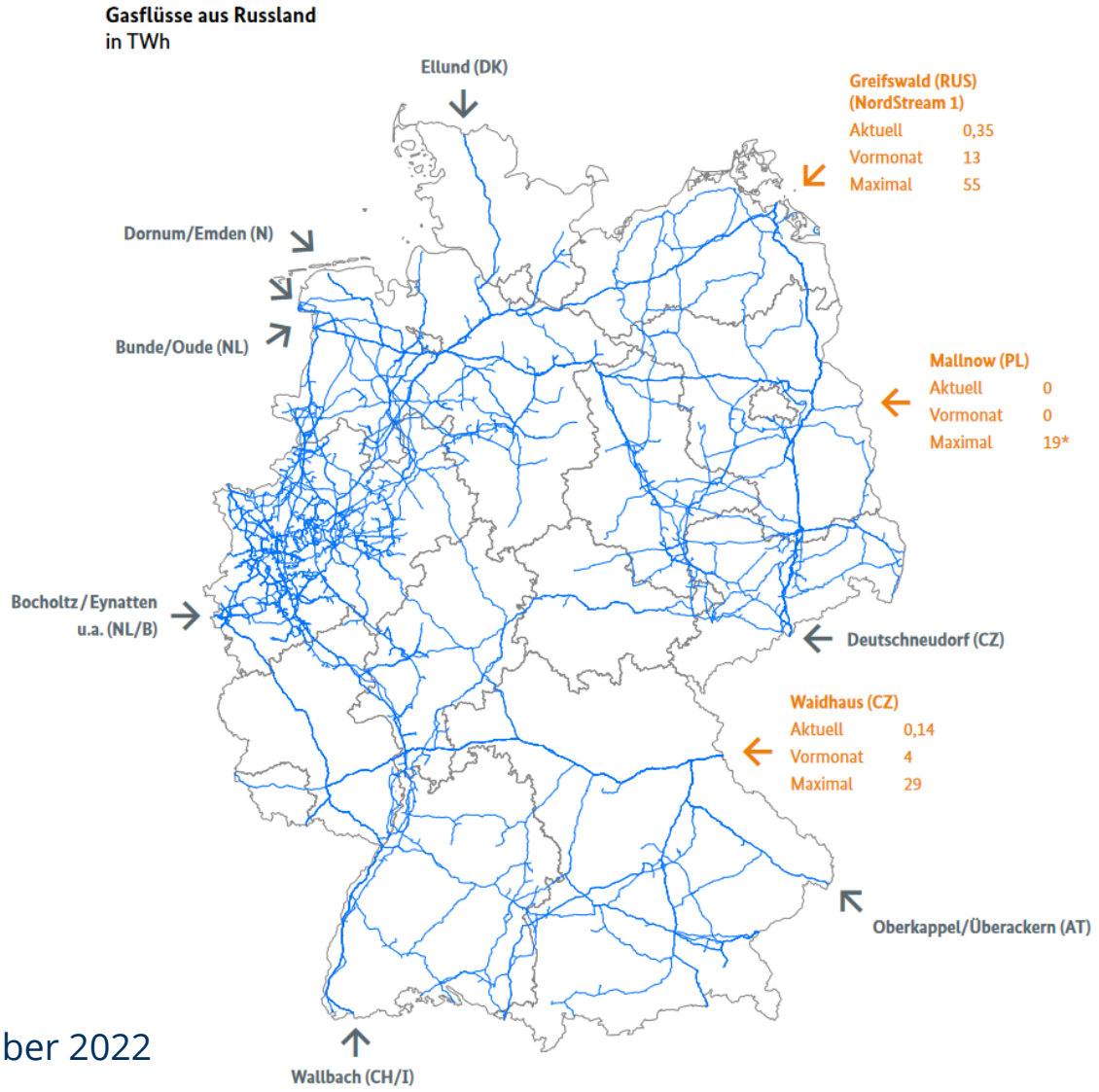
- However information access is widely different:
  - Accurate information is limited to import and storage
  - Consumption data is only roughly approximated daily
  - There is no publicly available information on transmission
  - Grid information is also very limited, transmission capacities only reported at TSOs borders

- This added to old infrastructure, overlapping transmission areas creates an environment with little transparency.

Research Question

- Measure the actual retrofitting potential and its connection to hydrogen development until 2030 in Germany.

- Compare results with existing Hydrogen projects and draw potential improvements or failures in their development.



Source: BMWi 2022

Fig. 2: Russian Gas Imports September 2022

Methods
Modelling the flow of gas in detail

Methods
Modelling the flow of gas in detail

- My research builds on GAMAMOD (Gas Market Model), a bottom-up model introduced and validated by the chair of Energy Economics at TU Dresden.

- The model uses an LP optimization to calculate minimal gas transportation costs

- Advantages of this approach:
  - A detailed flow prediction
  - Storage predictions (used as a calibration tool)
  - Data on relative pipeline usage

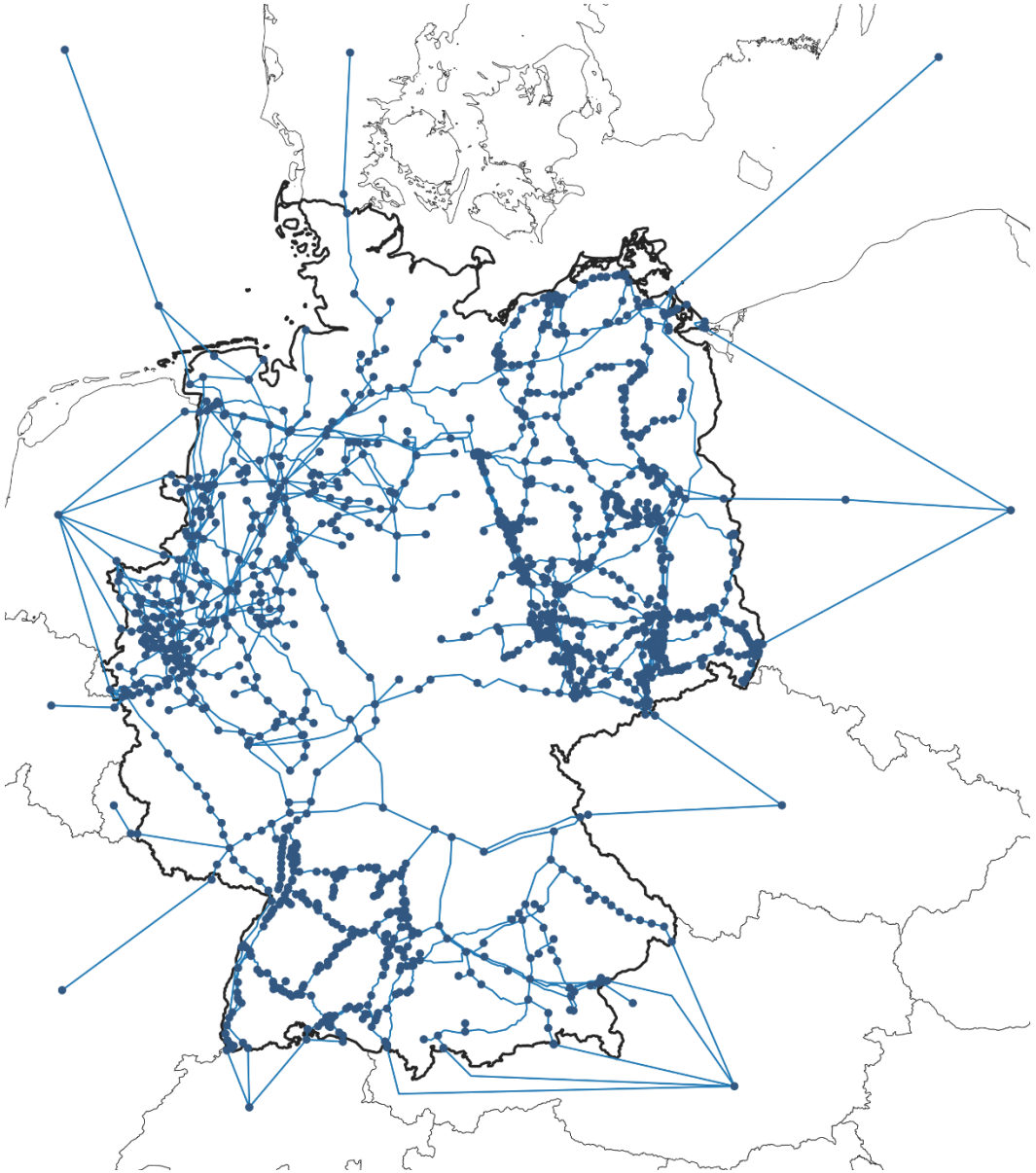


Fig. 3: Pipelines and Nodes modelled by GAMAMOD

Methods
Model Validation

- For this research we will focus on 2022 and use historical data for imports/exports and gas prices and interpolated data for demand.
- As a validation tool we will use historical data on storage facilities.
- GAMAMOD predicts similar trends despite not addressing complex dynamics in gas markets.

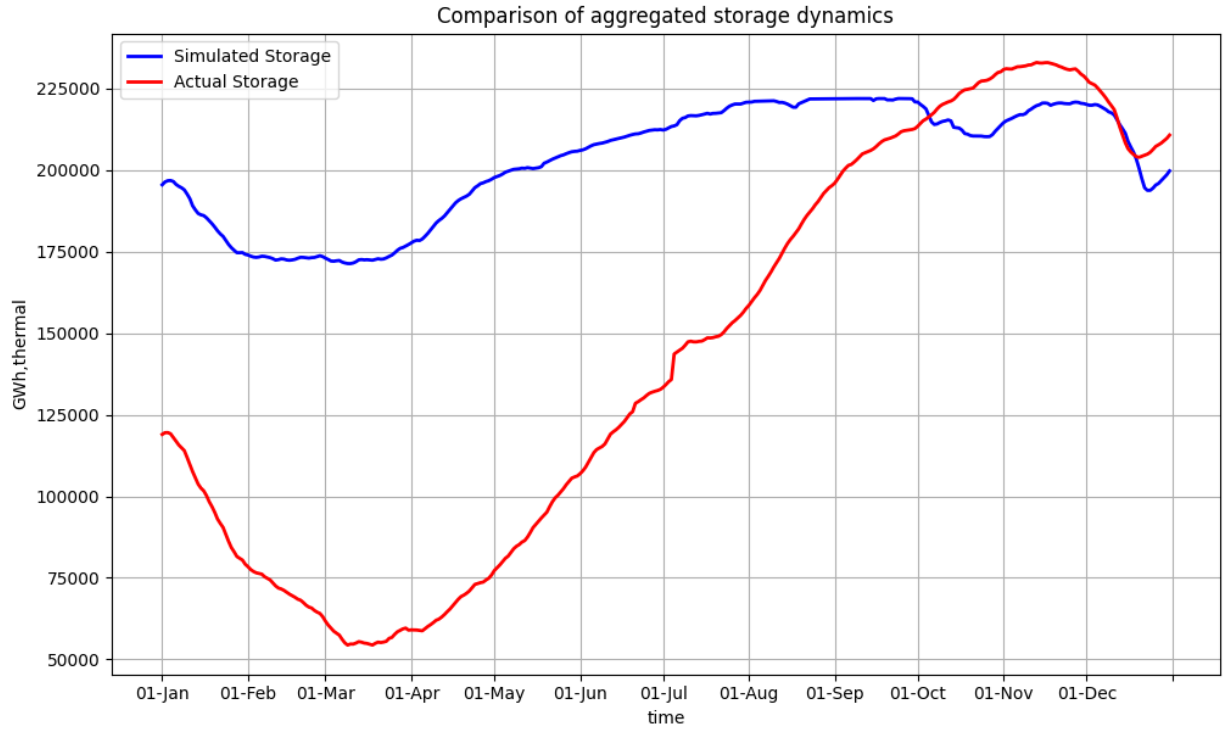
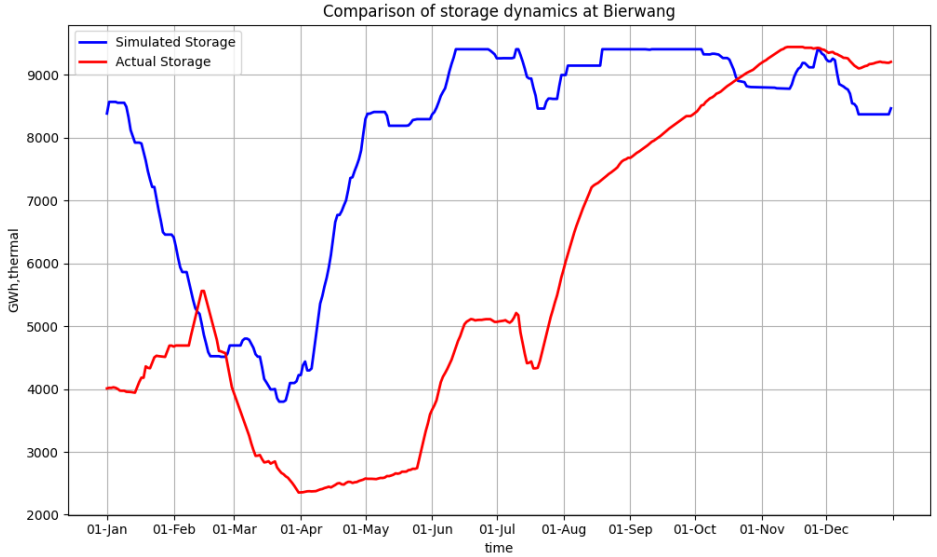
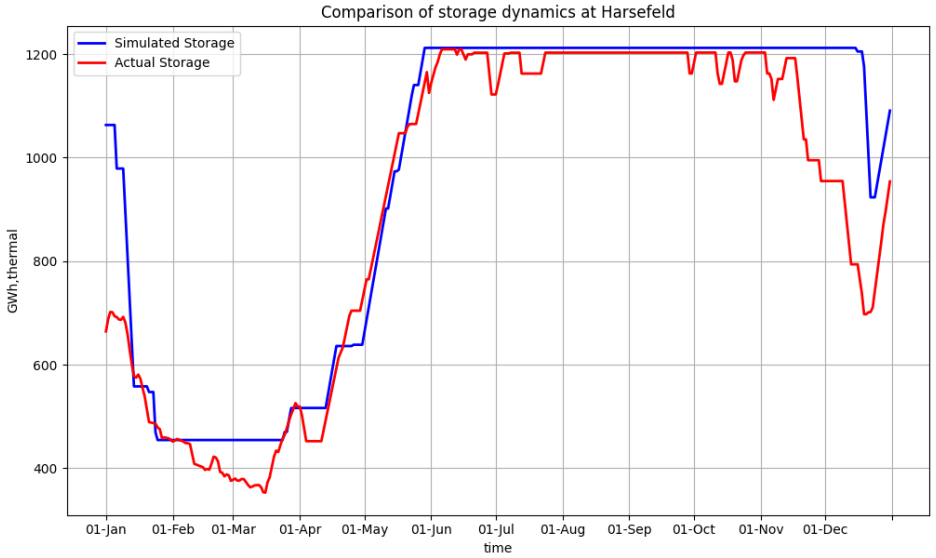


Fig. 4: Actual Storage versus Simulated Storage

Methods
Model Validation

- When looking at particular storages one can see that some of them behave close to the model, while some vary greatly
- It is only when aggregated that larger dynamics emerge.





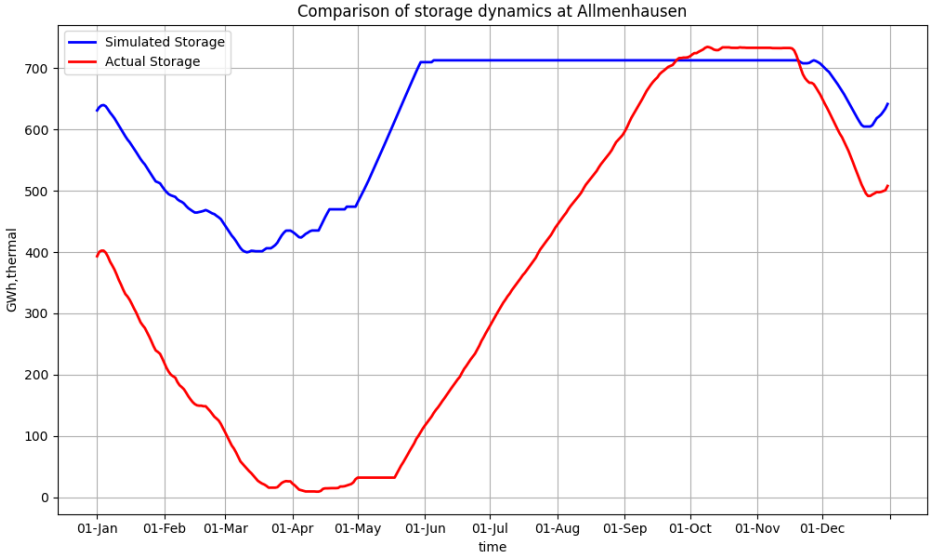


Fig. 5, 6, 7: Examples of specific Storage location comparisons

Methods
New Import Regime

- Russian dramatic import changes provide a good case study for changes in retrofitting potential.

- In order to compare the dynamics more clearly I analyzed the 2022 simulation at two points:
  - Before June
  - After September

- Compared to Russia other big imports had only limited changes in 2022.

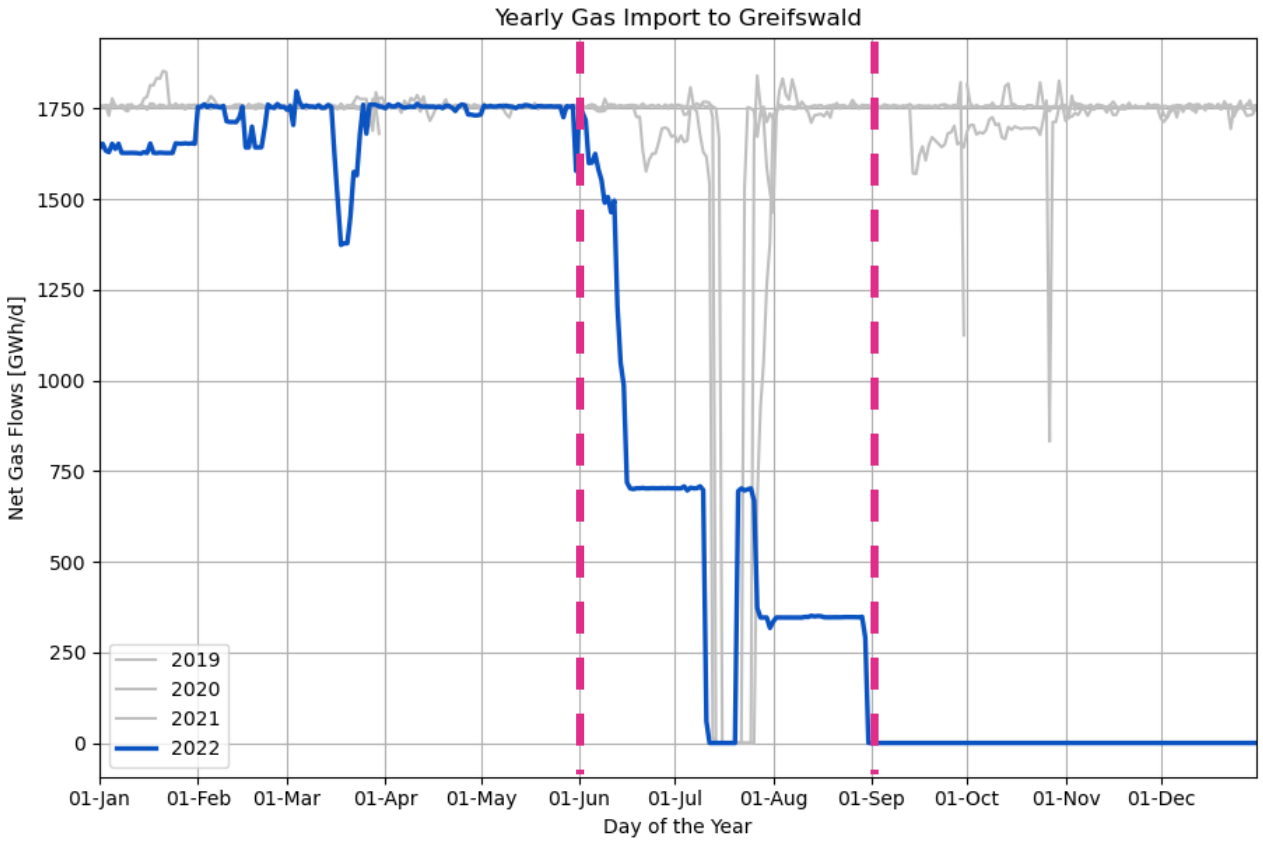


Fig. 8: Yearly Comparison of Russian Imports

Methods
New import regime

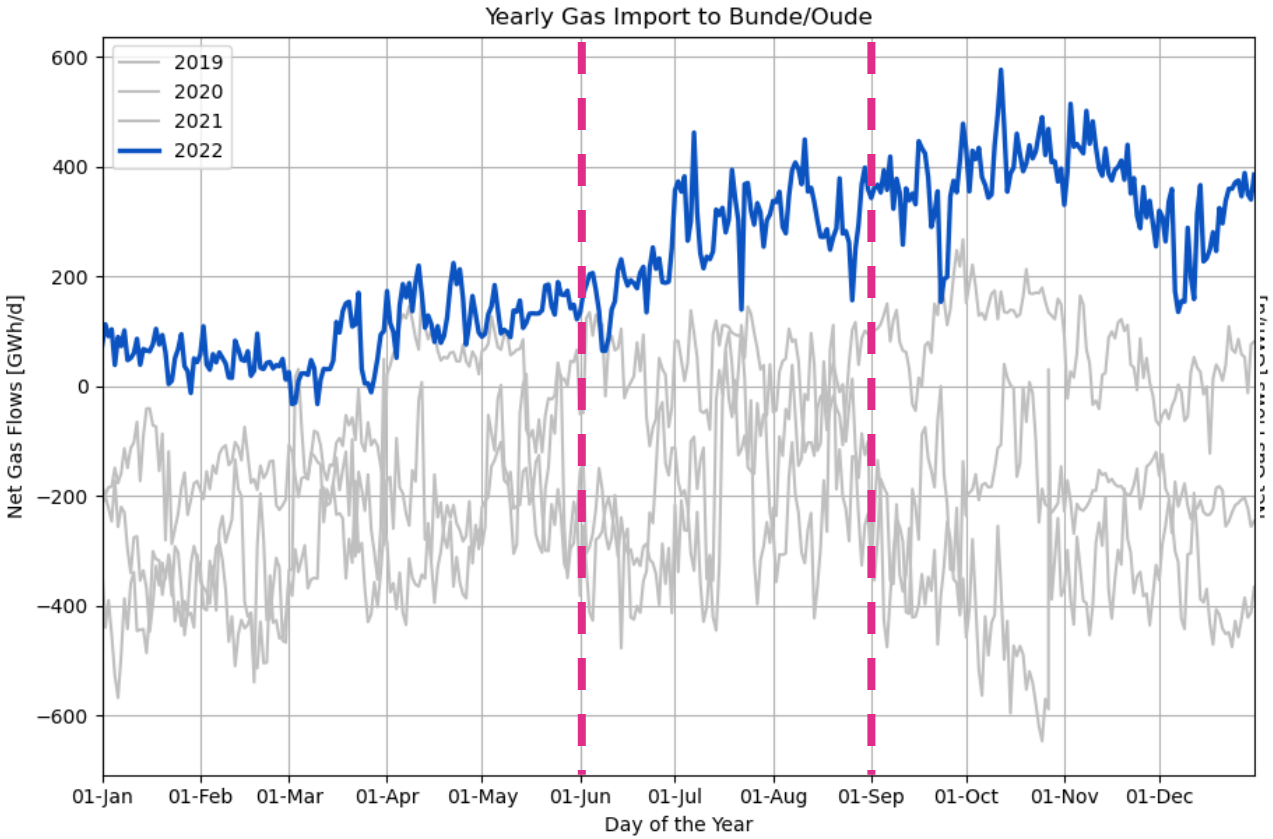


Fig. 9: Yearly Comparison of Imports from the Netherlands

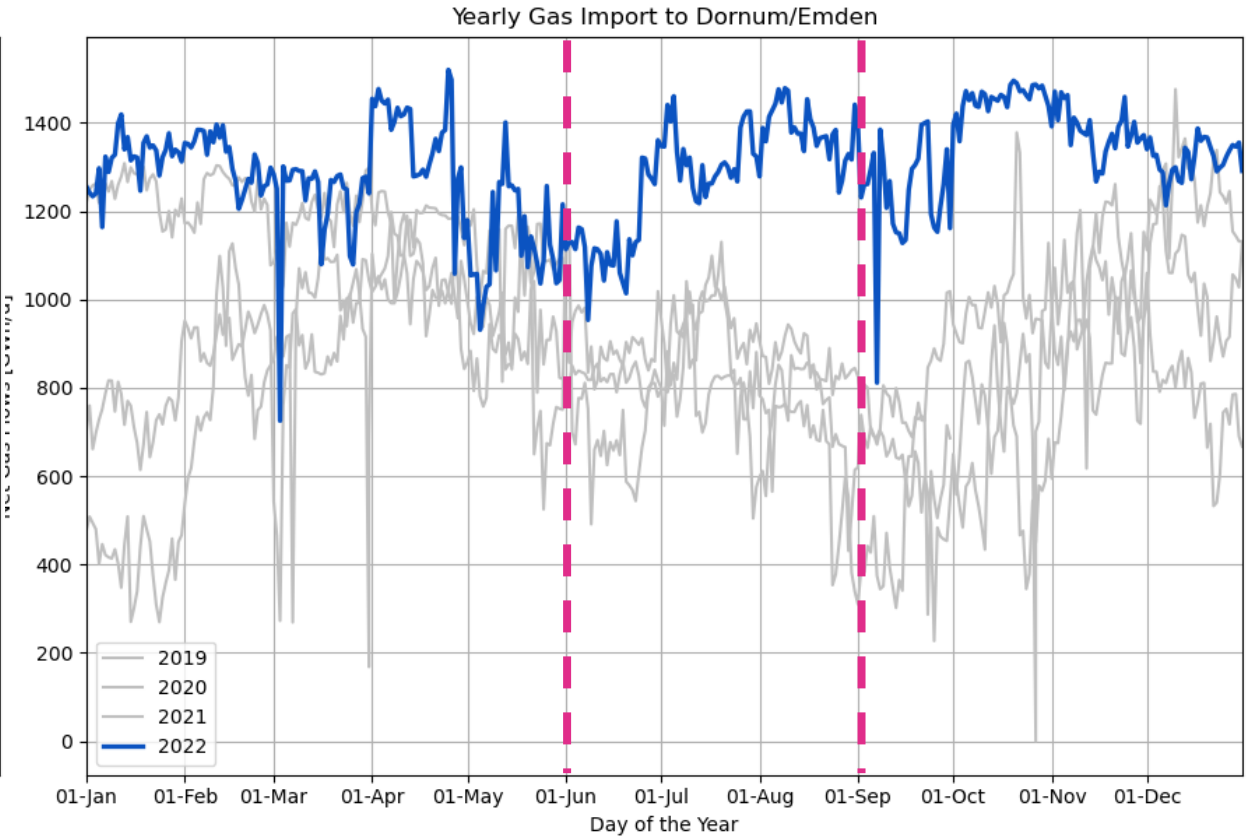


Fig. 10: Yearly Comparison of Norwegian Imports

Results
Getting ahead of transport issues

Results - Flows then and now

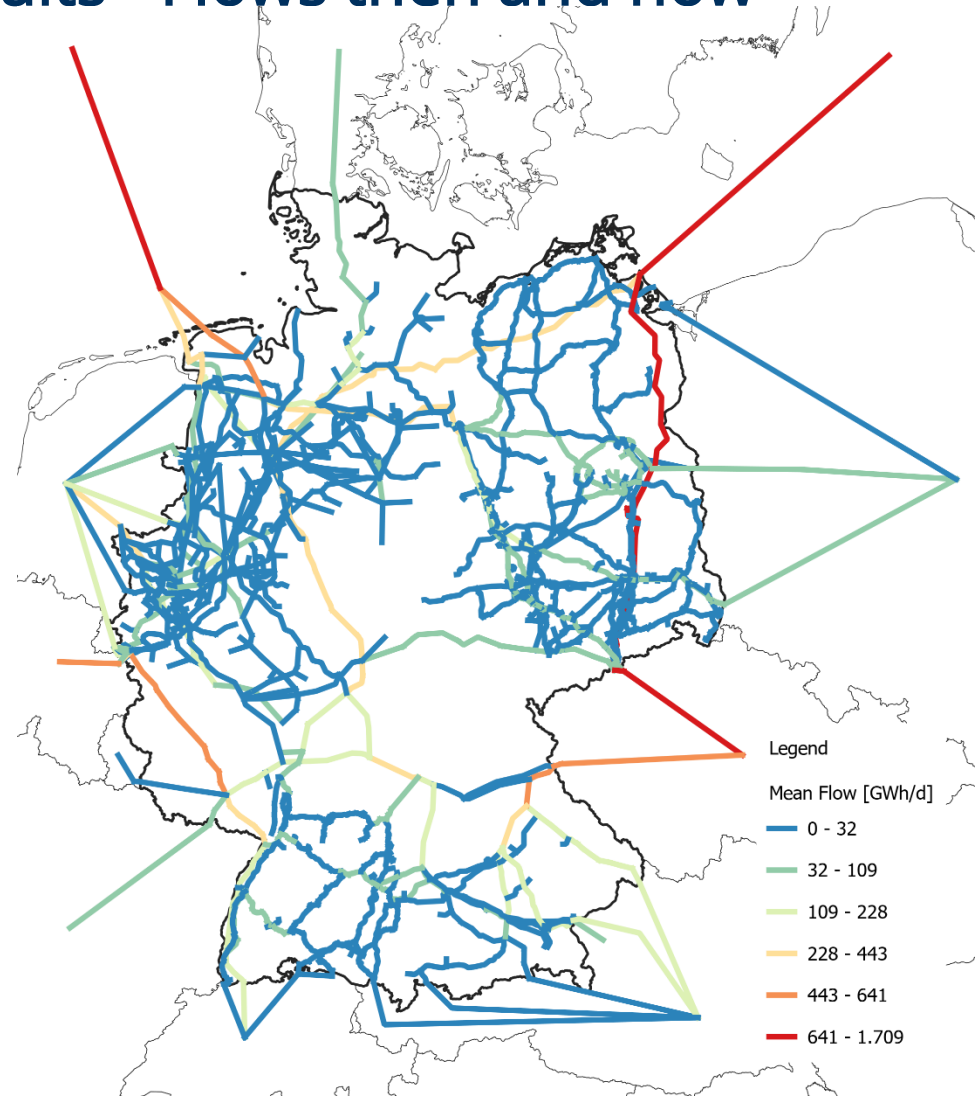


Fig. 11: Mean Flows before July 2022

- GAMAMOD's results include optimal flow, storage use and potential for retrofitting
- As the model assumes perfect competition and optimal flow, its results are not supposed to replicate reality
- Key dynamics to be seen here:
  - Russian importance in supply
  - Import reliance on Norway, the Netherlands and Belgium too

Results - Flows then and now

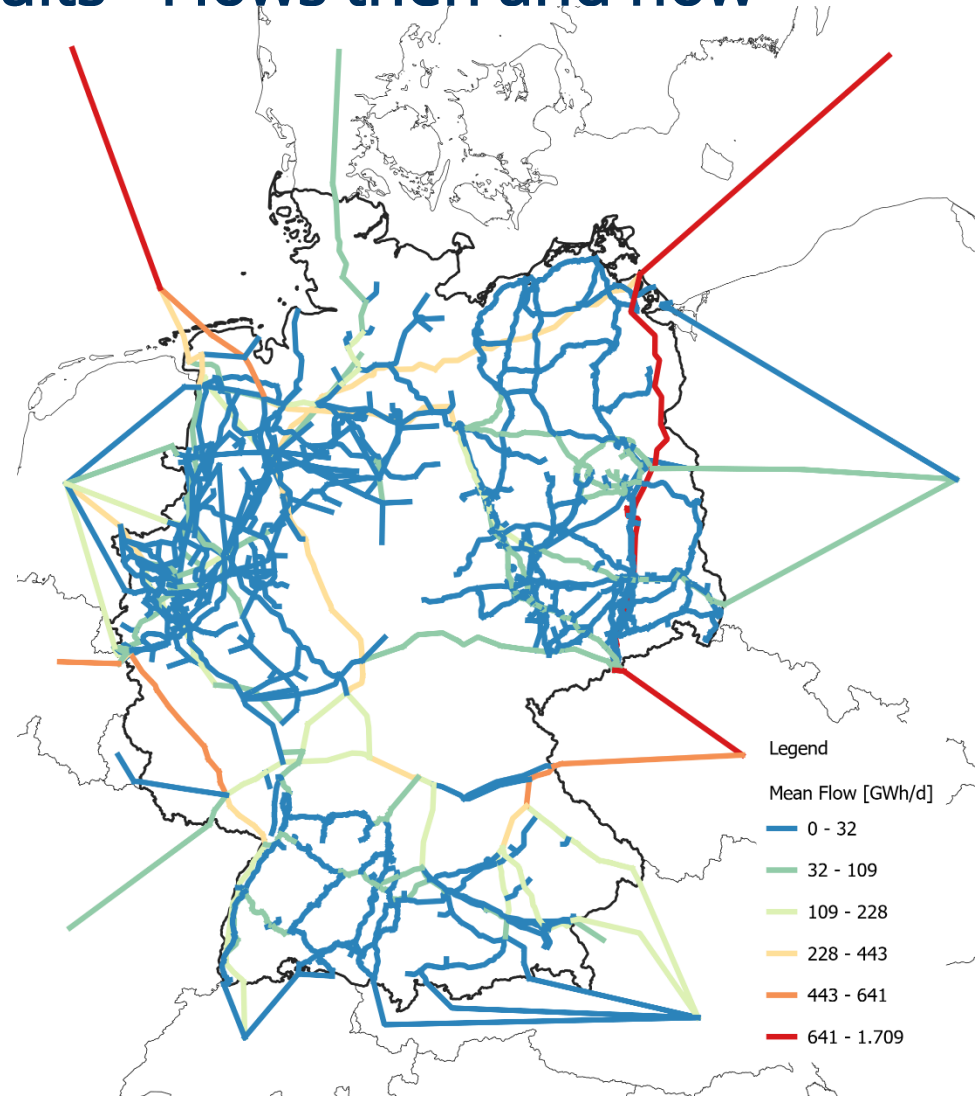


Fig. 11: Mean Flows before July 2022

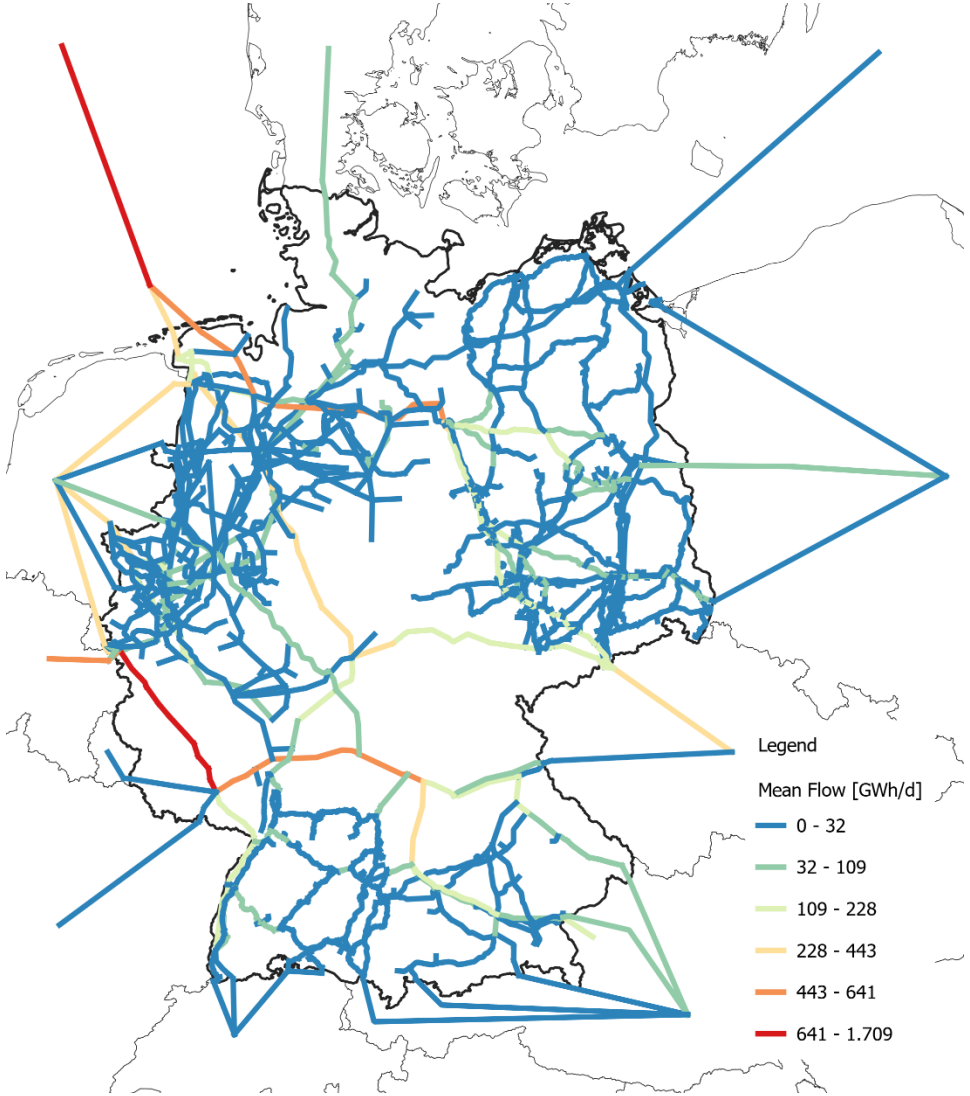


Fig. 12: Mean Flows after September 2022

Results – Retrofit Potential then and now

- Retrofittable pipeline definition:
  - Non-critical transmission elements of the grid
  - Relative capacity use less than 0.1% at every time step

- First conclusions:
  - Retrofitting capacity is large in both scenarios
  - It is unequally distributed and highly dependent on imports (next slides)

	New Status Quo	Pre Invasion Scenario
Total lines available	279	267
Percentage of availability	15.9%	15.2%
Total length of lines available [mill. km]	5.66	4.76

Results – Retrofit Potential then and now

Fig. 13: Retrofitting Potential before July

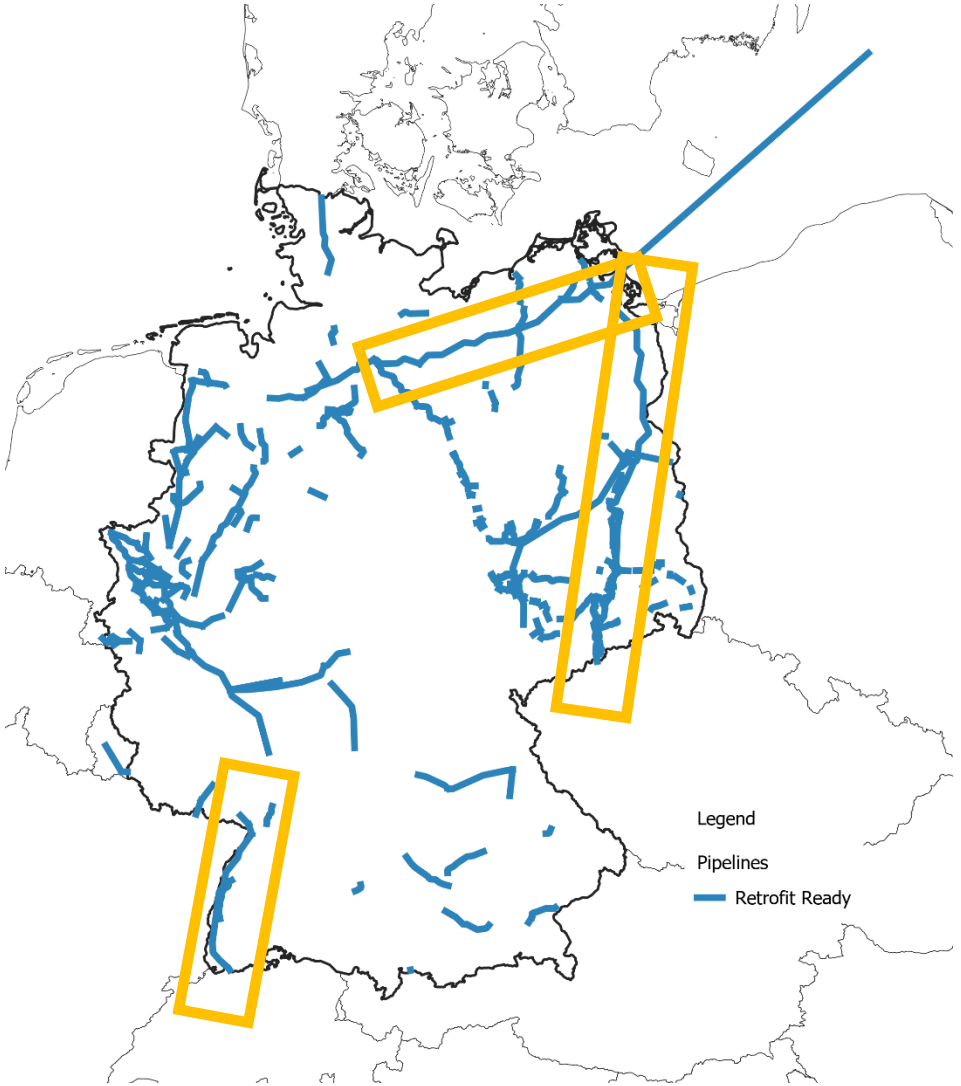
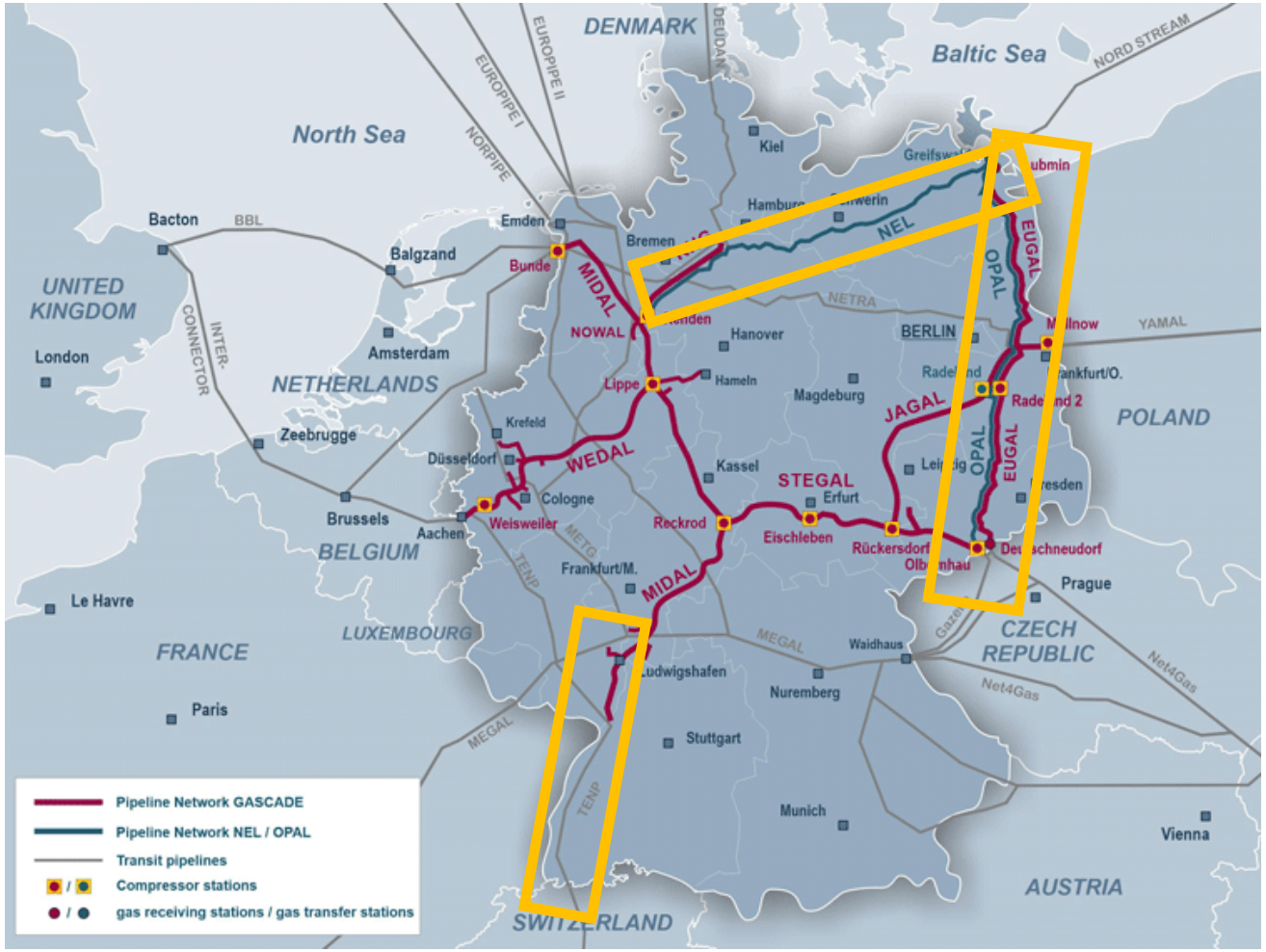


Fig. 14: Retrofitting Potential after September

Results - Implications for the grid

- Results suggest that three large transit pipeline systems are available for hydrogen transit:
  - NEL
  - OPAL/EUGAL
  - TENP

- Additionally many small connections in the Ruhr are open, but fewer than in early 2022

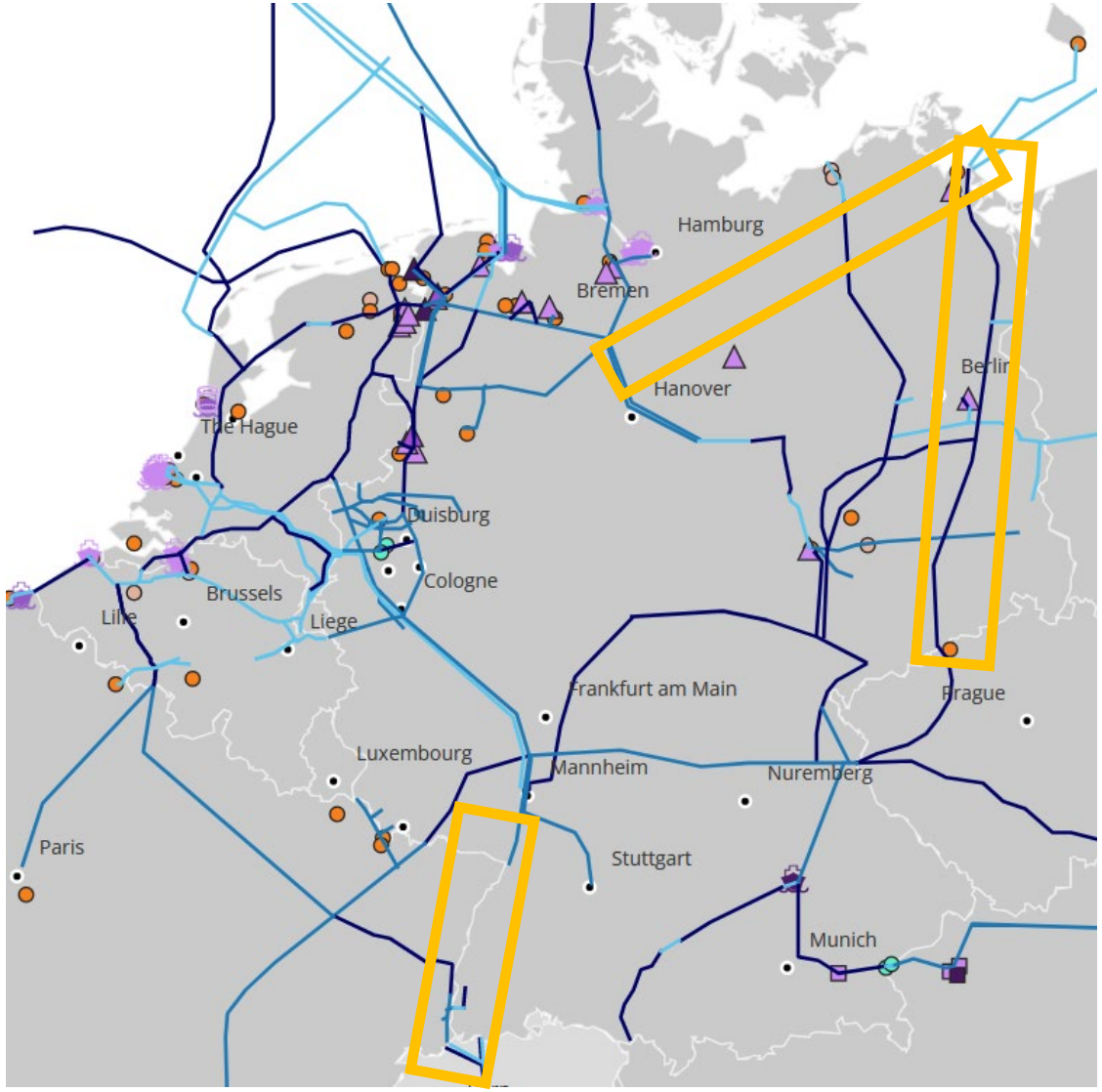


Source: gascade.de

Fig. 15: Retrofitting Potential after September 2022

Results
Fitting Hydrogen Development

- ENTSOG's hydrogen development plans include OPAL/EUGAL corridor but don't favor an east-west connection.
- The utilization of the NEL and TENP corridors presents new alternatives for the development of a hydrogen grid.
- A North to South corridor seems possible, would require little investment, and supply the chemical demand present in that region.



Source: H2 Infrastructure Map

Fig. 16: Projected 2030 Hydrogen Grid by ENTSO-G

In short

- According to my simulations retrofitting potential is around 15-16%. Results being greatly dependent on import regimes.
- There are three transmission corridors particularly interesting, namely: NEL, OPAL/EUGAL, and TENP.
- These potentials could change the way we develop the hydrogen in the coming decade, while demand for both gas and hydrogen is simultaneously high.
- Next Steps include
  - Expand simulation years until 2050 within the larger coupled model (within MINFRA Research Project)
  - Integrate retrofitting potential with hydrogen infrastructure model.

Thank you for your attention!

- Questions?

Fig. 14: Relative Pipeline use after September 2022

Additional Slides

Methods
Model Validation

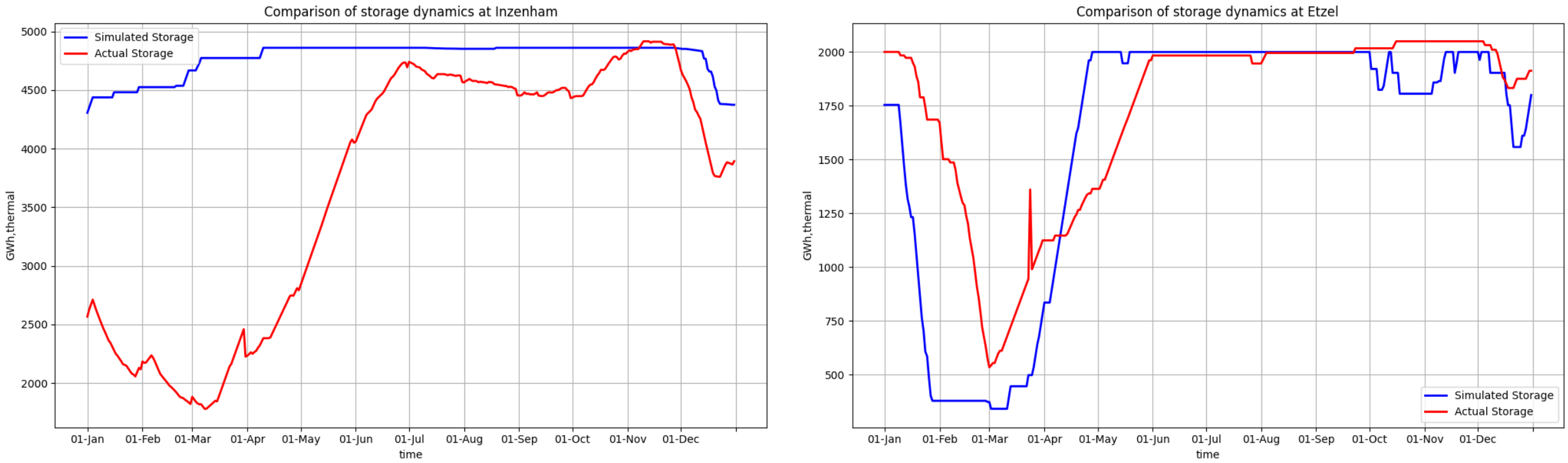


Fig. 9: Actual Storage versus simulated storage

New Import Regime

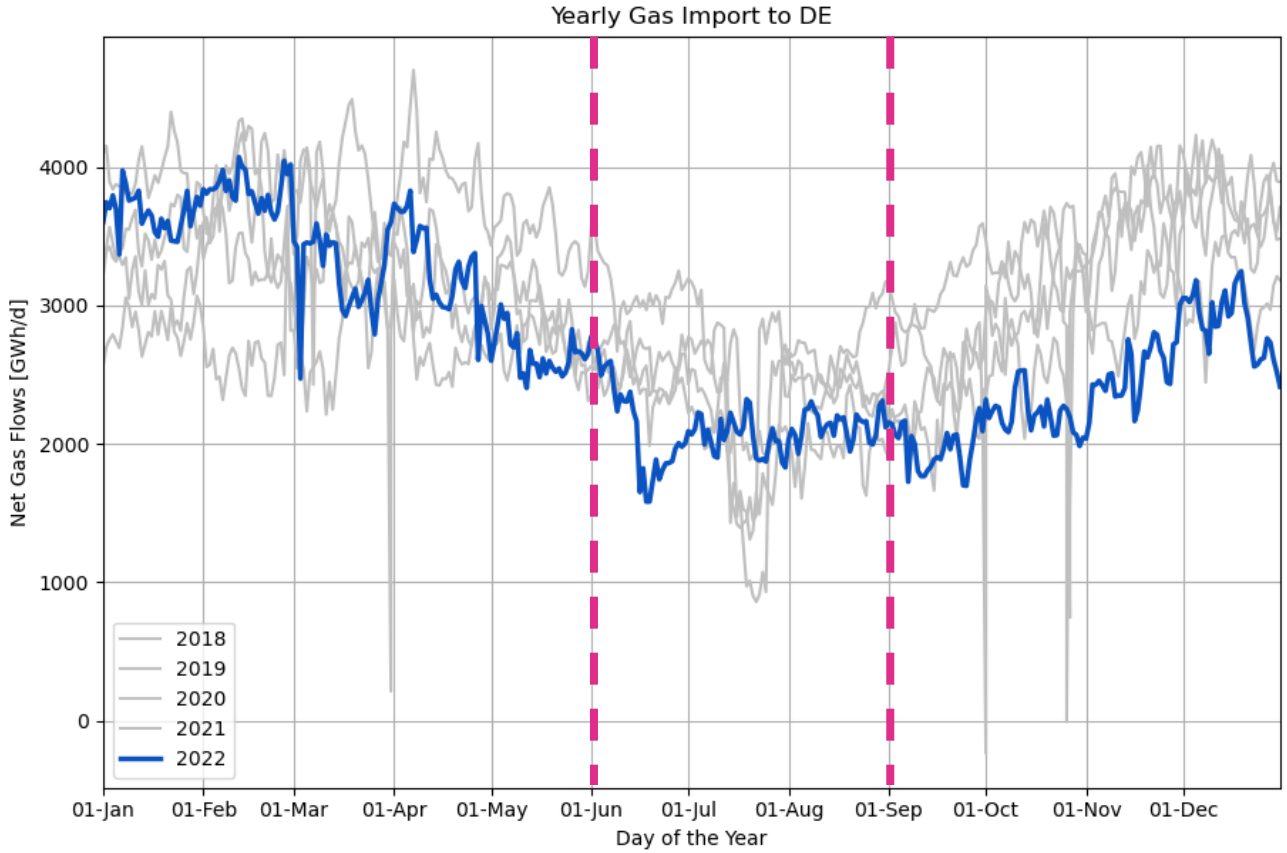


Fig. 8: Yearly Net Gas Import Comparison

Methods
New import regime

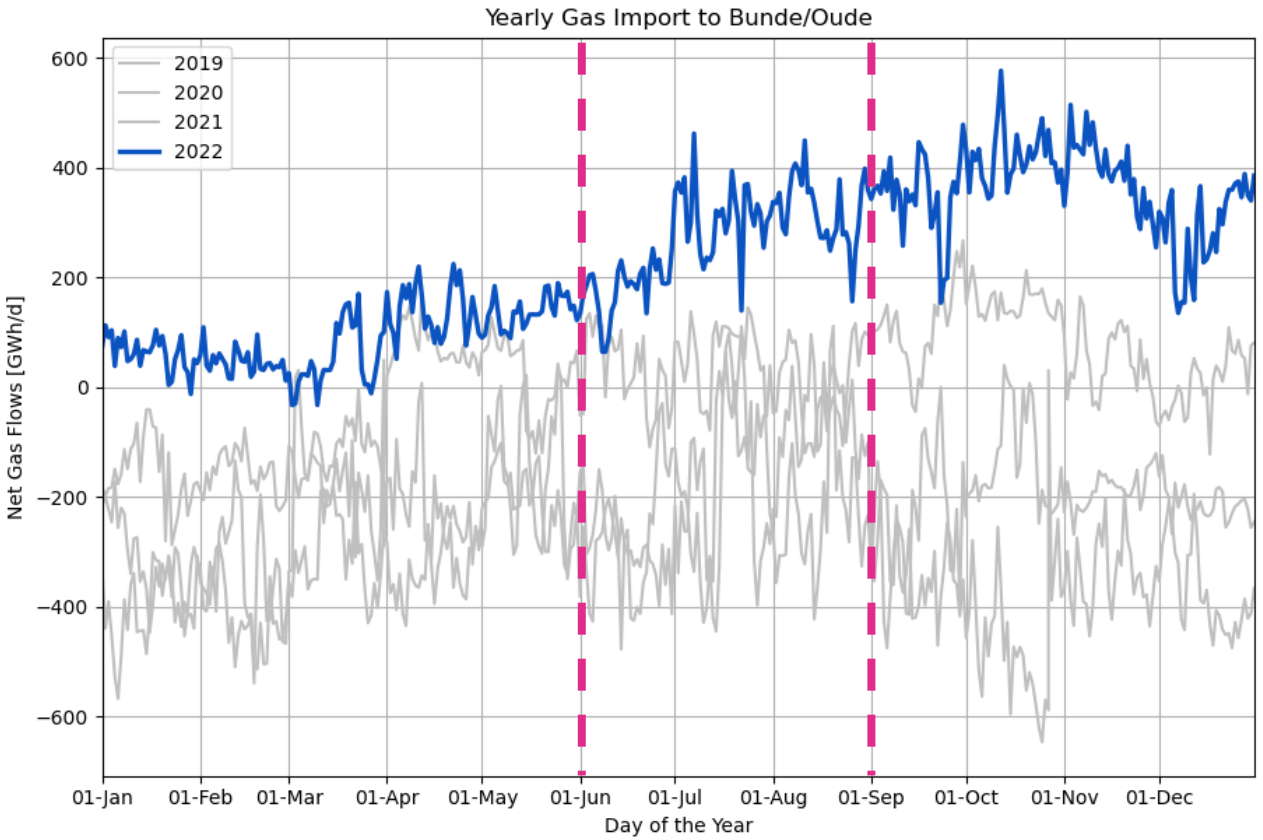


Fig. 5: Yearly Comparison of Imports from the Netherlands

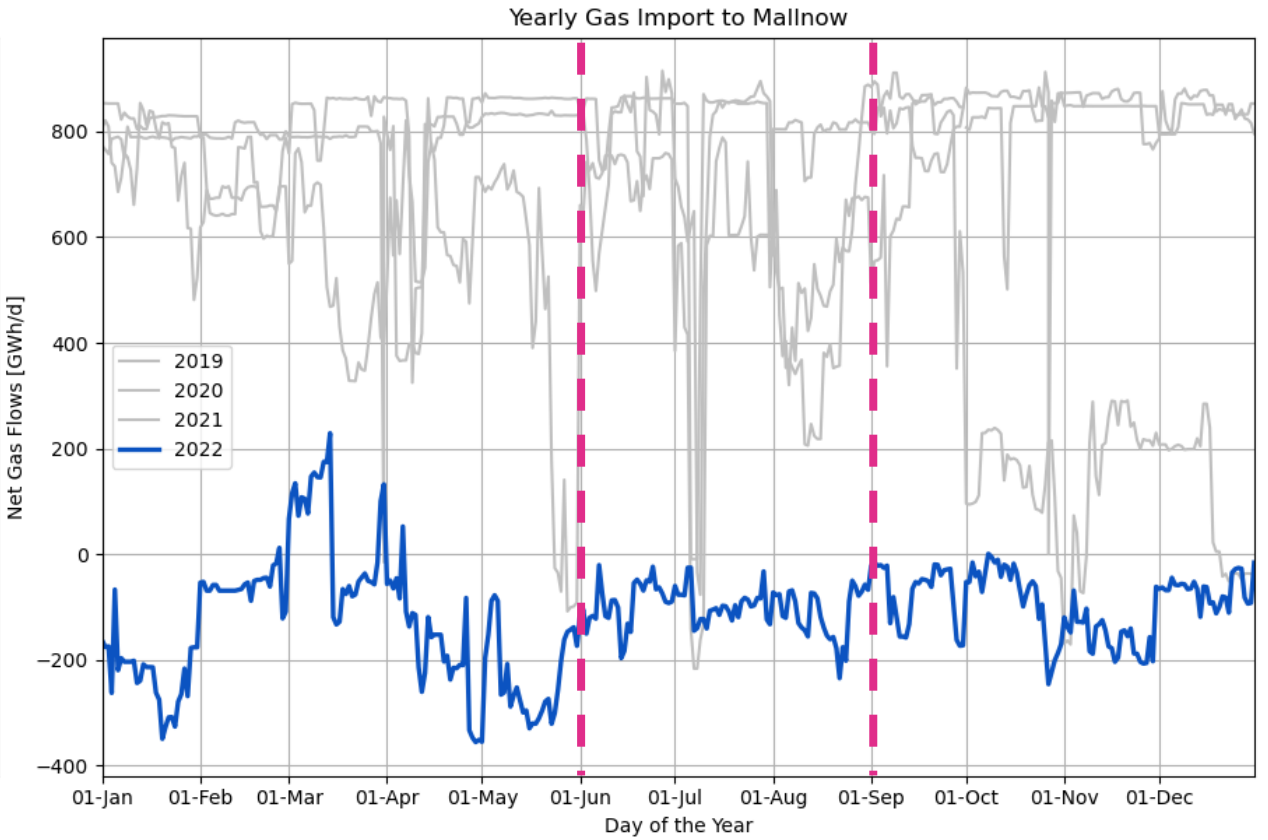
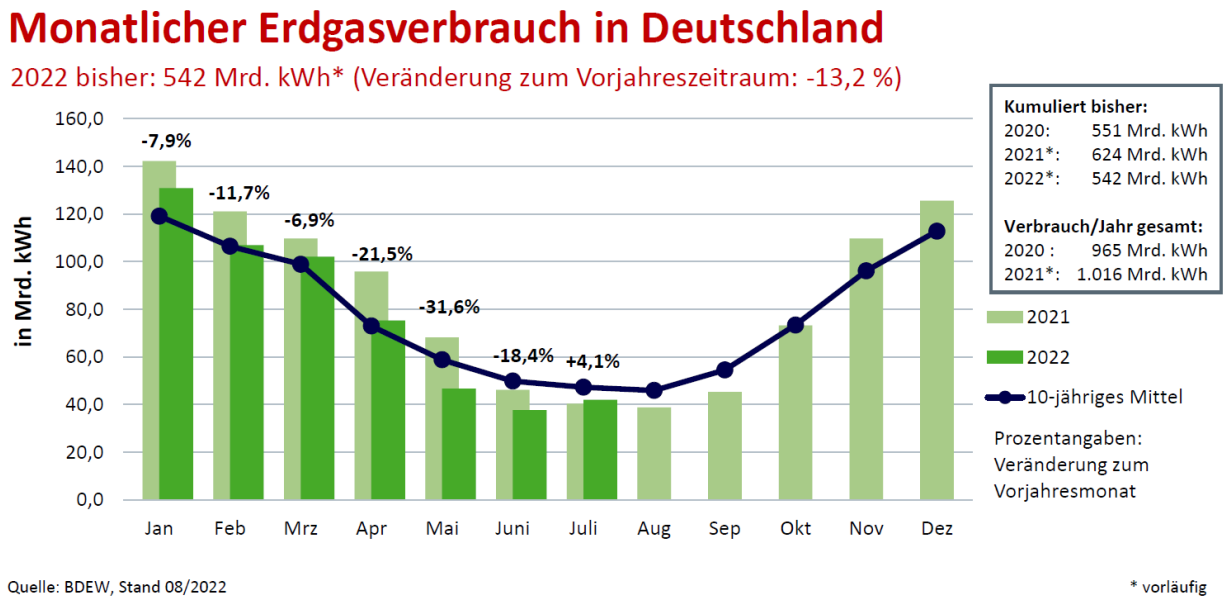


Fig. 6: Yearly Comparison of Polish Imports

Gas transition under stress: System Response since the invasion



Source: BDEW 2022

Fig. 3: Monthly Gas Demand Comparison

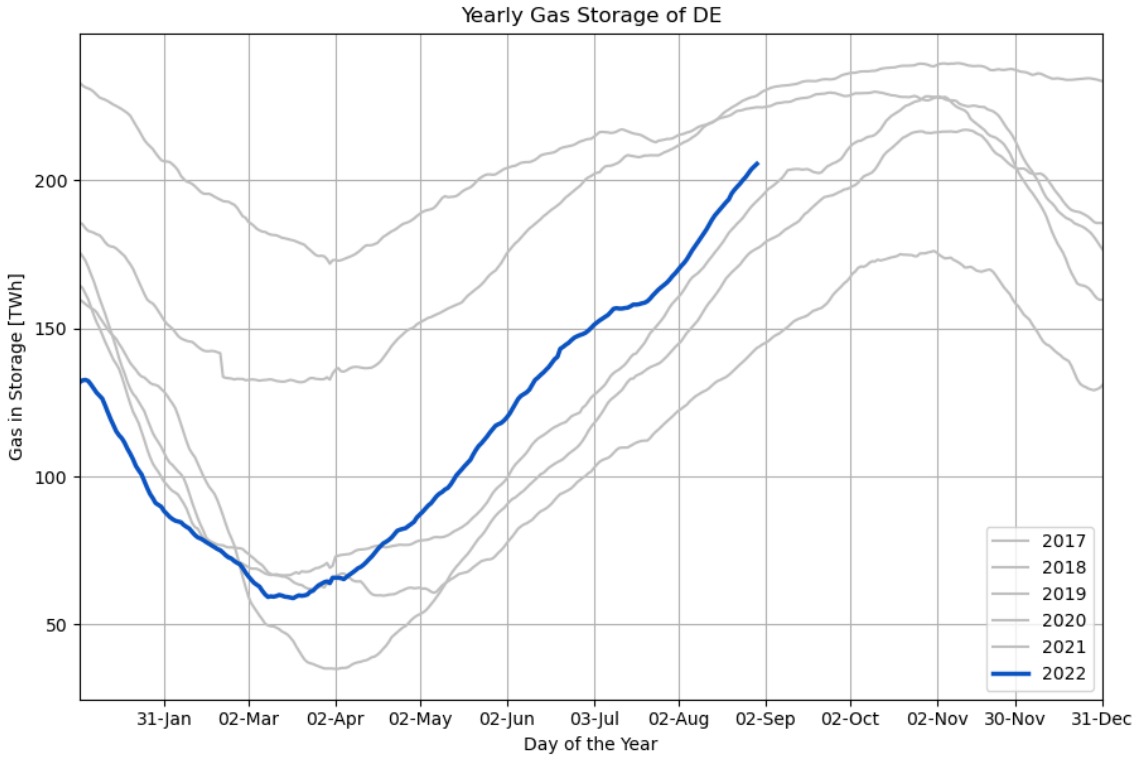


Fig. 4: Yearly Comparison of Gas Storage Level

TYNDP - Current Hydrogen Plans

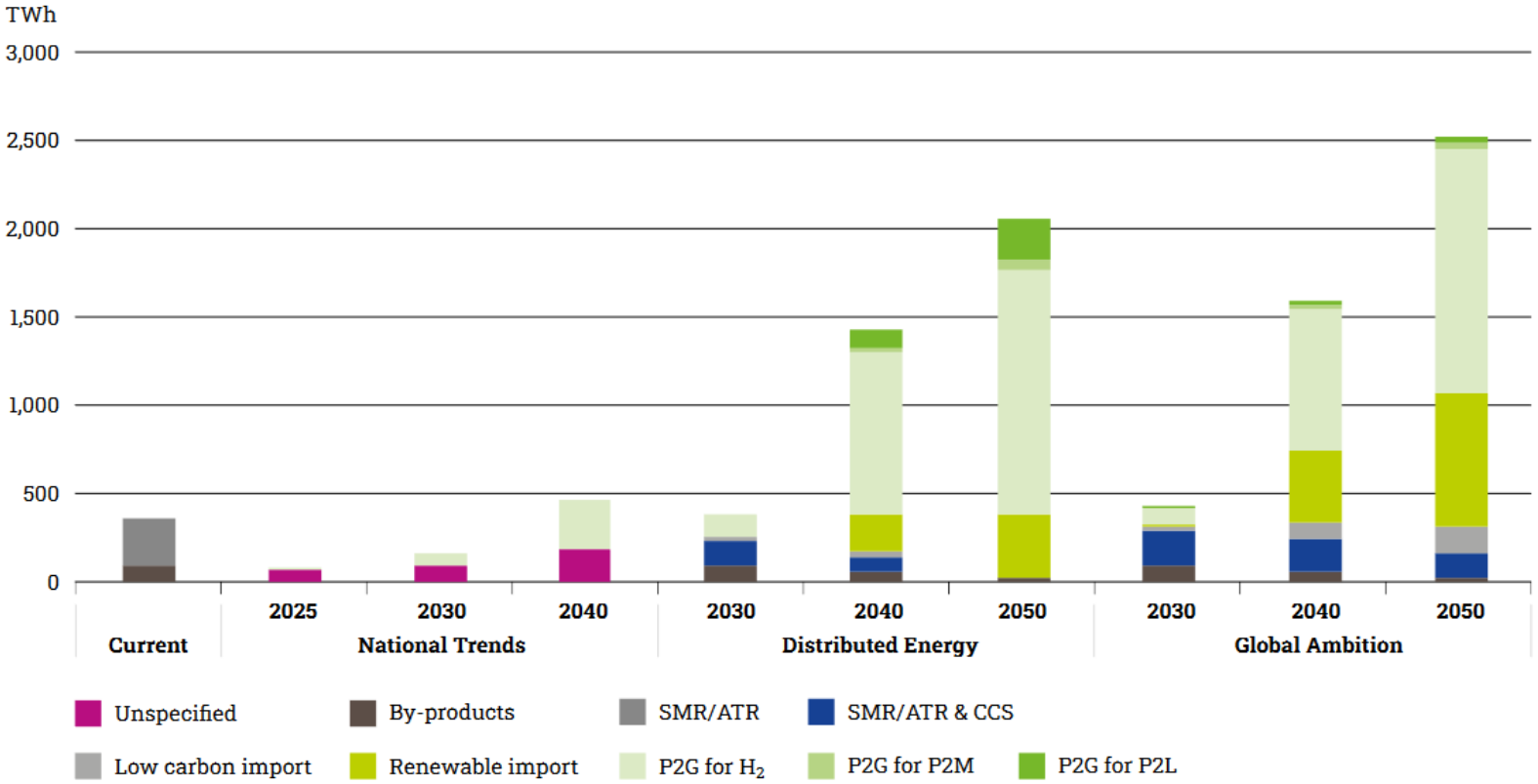


Figure 32: Hydrogen supply for EU27

TYNDP - Current Hydrogen Plans

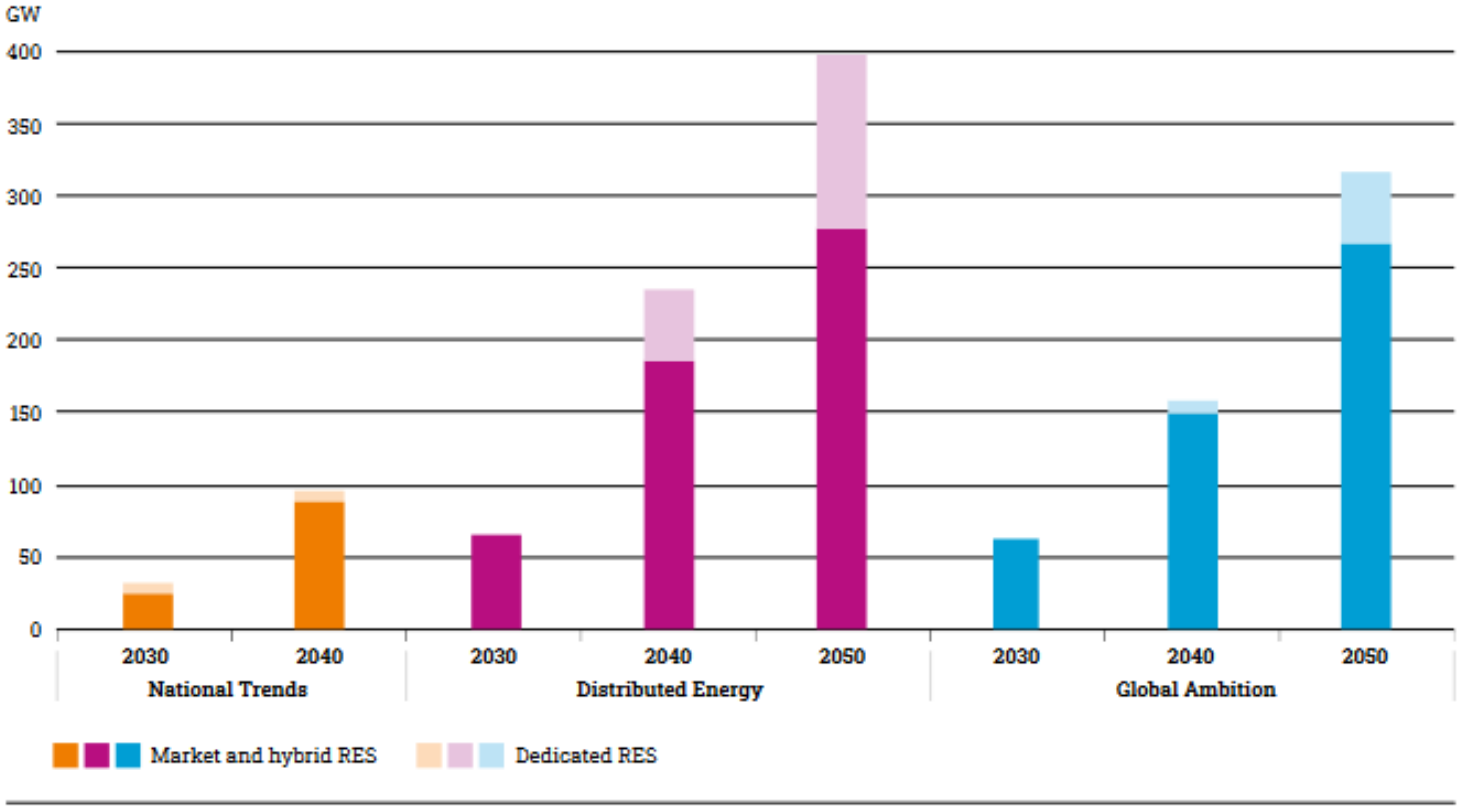
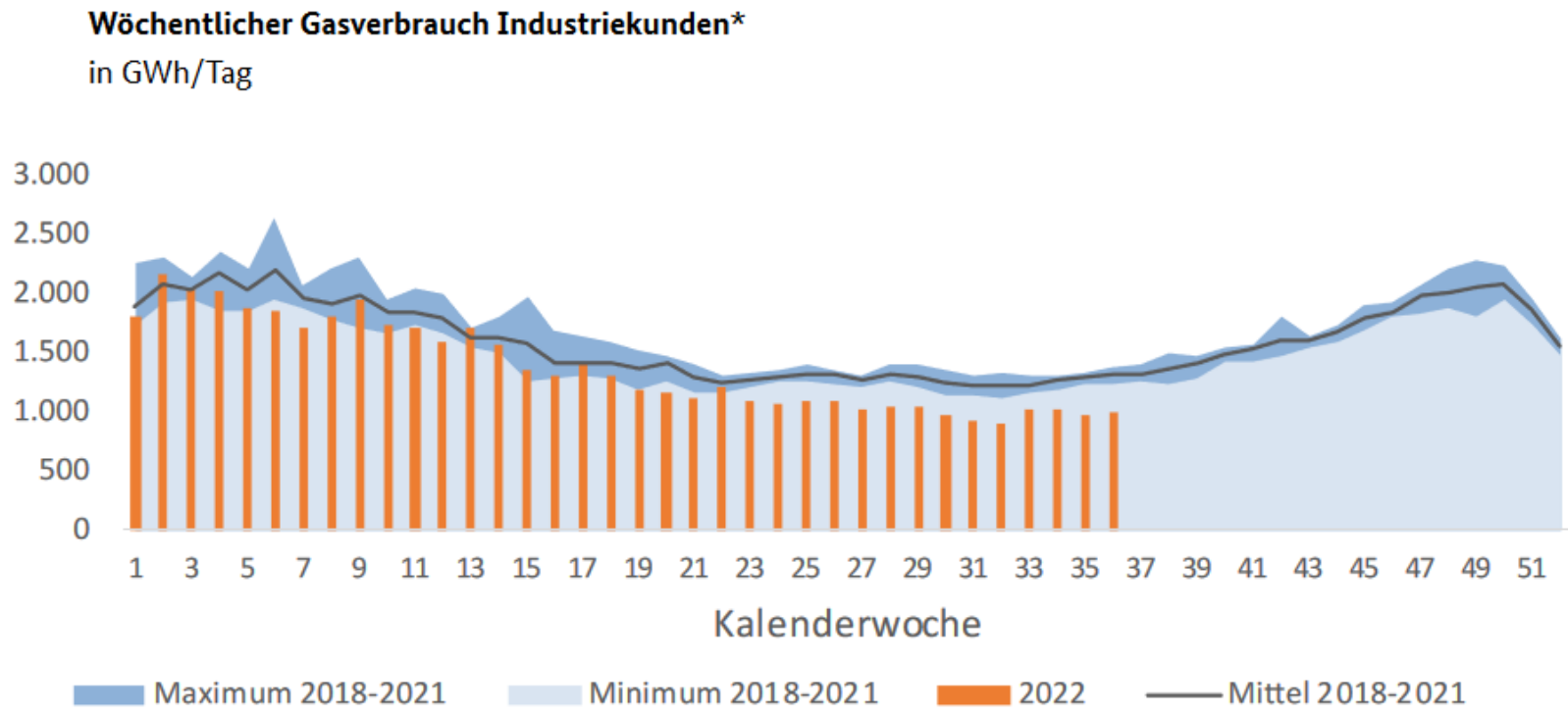


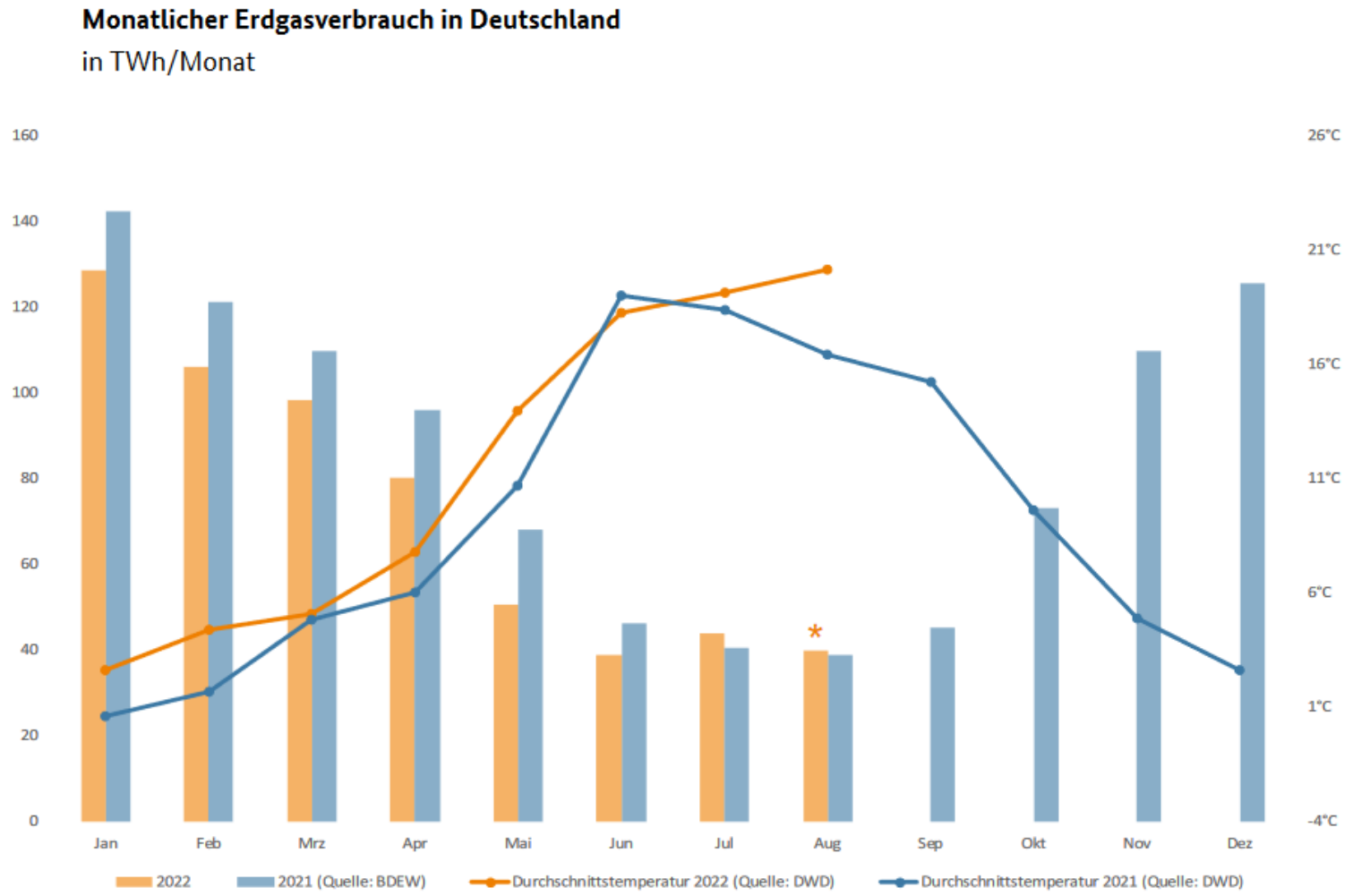
Figure 33: Electrolyser capacity for EU27 (The configurations are explained in the scenario methodology guidelines)

BMWi – Industry Demand

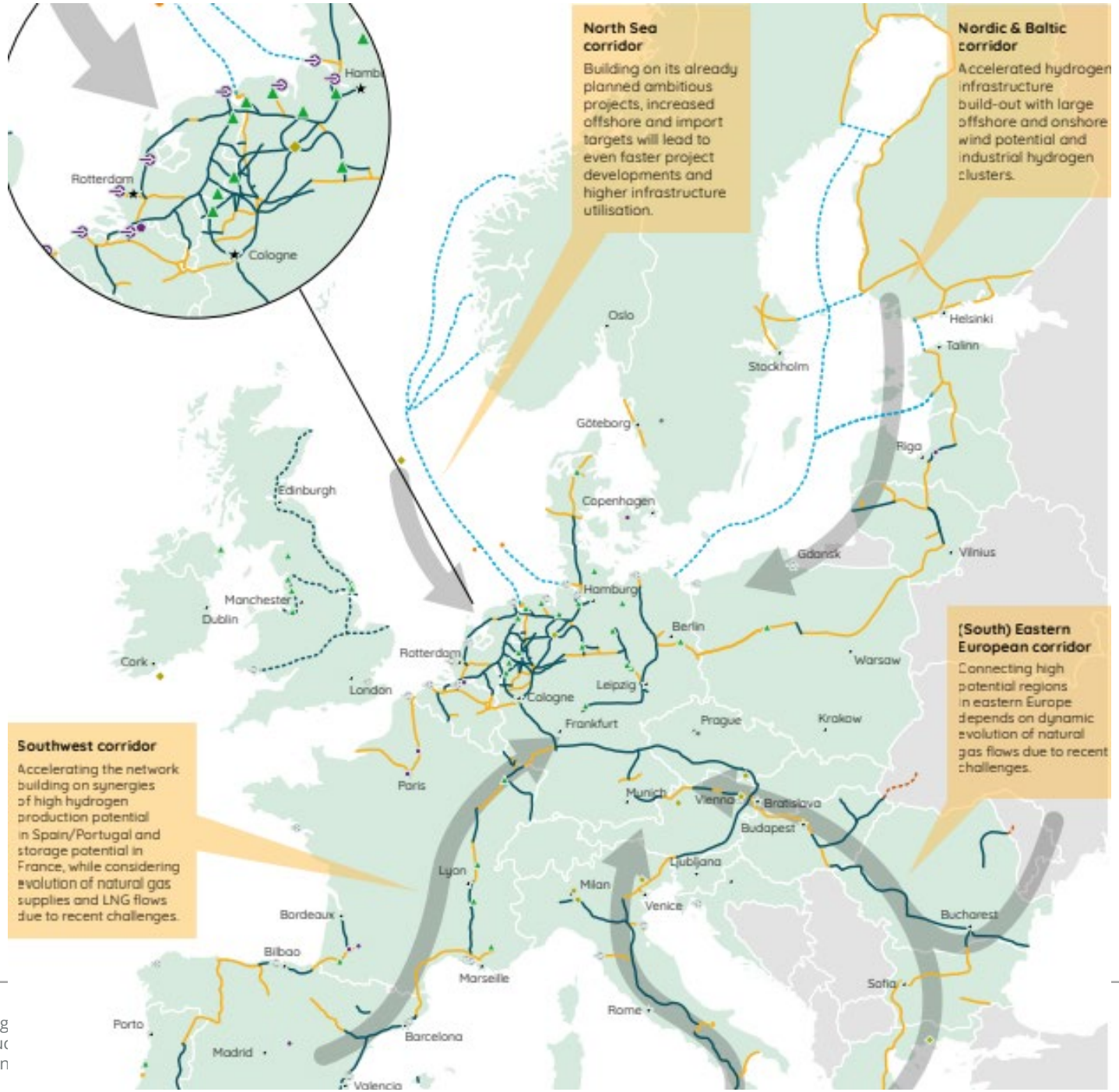


* Verbrauch aller leistungsgemessenen Gaskunden, wie beispielsweise Industrie, Gewerbe und Stromerzeugung aus Gas. Grundlage sind sogenannte RLM-Daten. Diese werden von Trading Hub Europe bereitgestellt. Die Daten sind vorläufig.

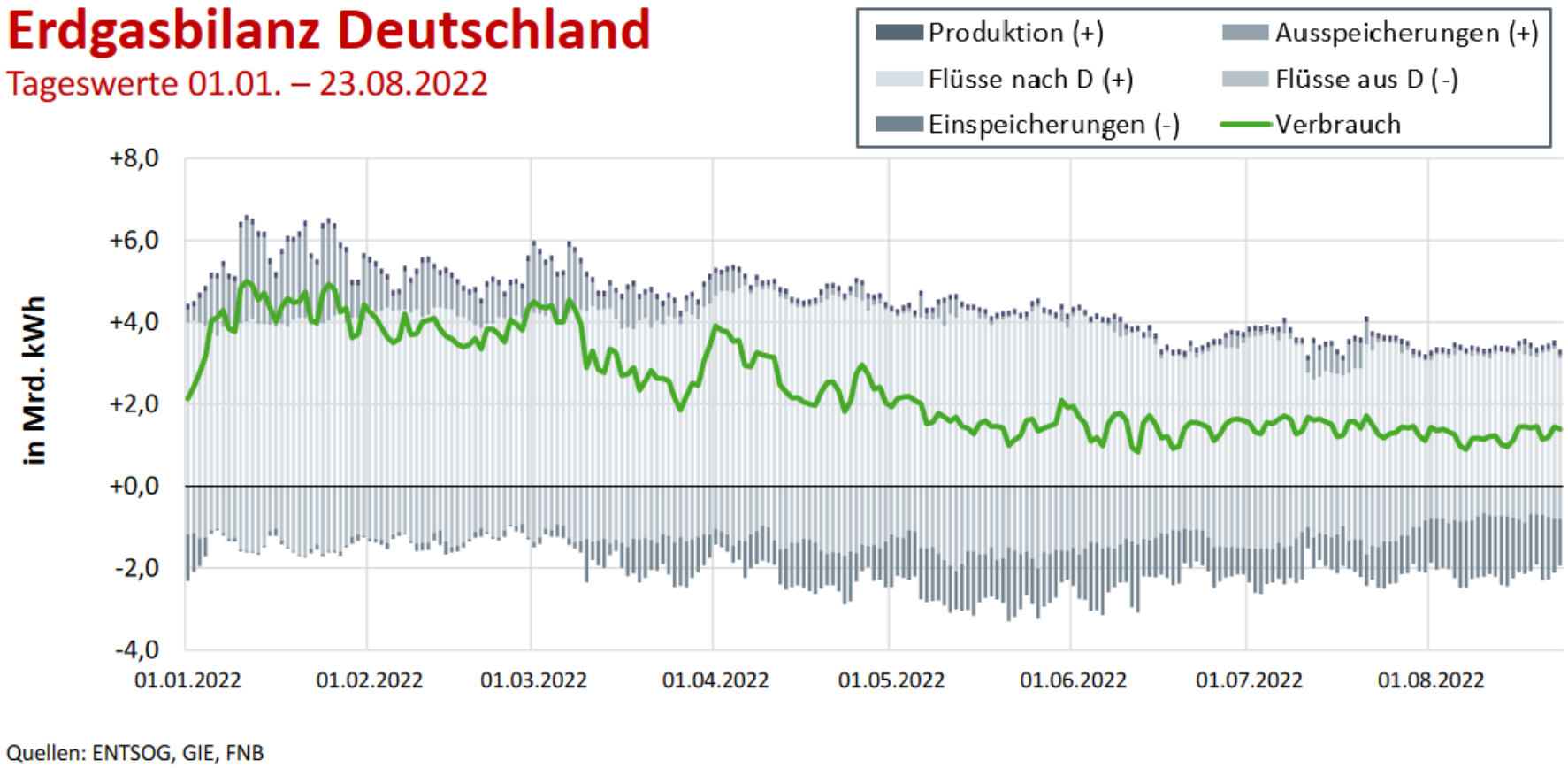
BMWi – Total Monthly Demand



EHB – 2030 Hydrogen Plan



BDEW – Gas Import Balance



Quellen: ENTSOG, GIE, FNB

Gas Price Yearly Comparison