Europe's independence from Russian gas – What effects does a complete import stop have on energy system development?

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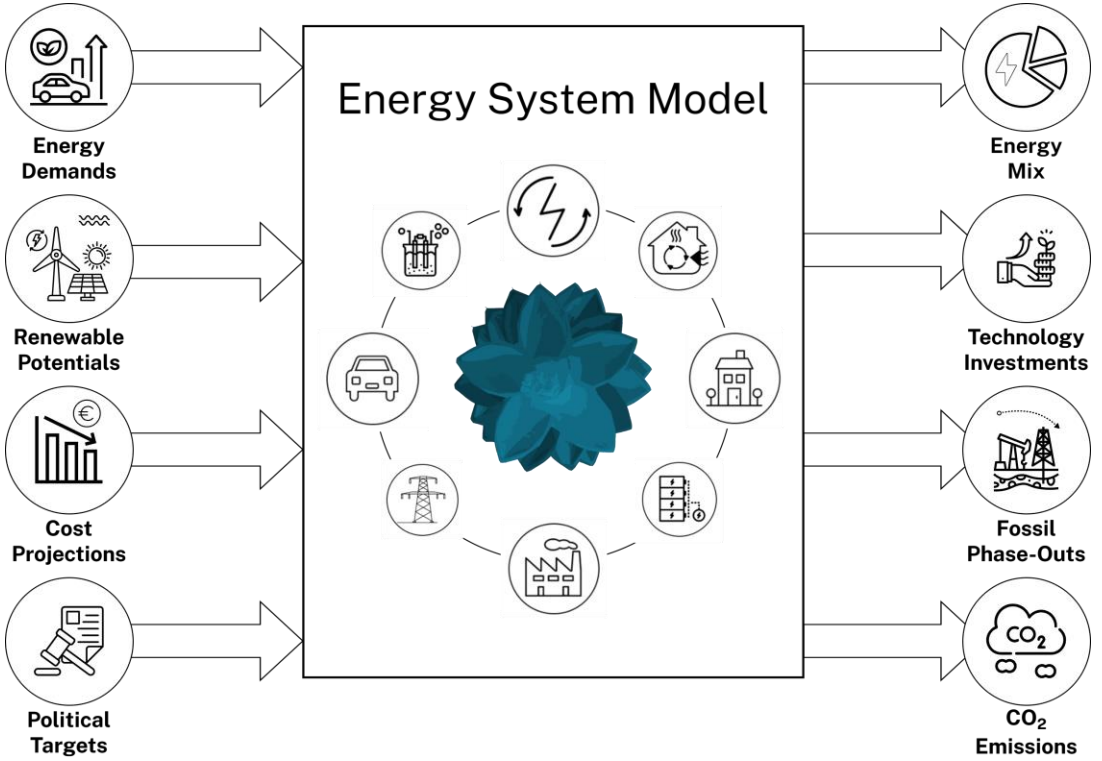
Motivation

- Lack of quantitative research on the impacts of import limitations for Russian natural gas
- Study aims to show short-term as well as long-term effects on energy system development
- Use of the Global Energy System Model (GENeSYS-MOD) to investigate effects of Russian natural gas limitations on:
  - Overall gas consumption
  - Electricity generation and consumption
  - Electricity generation costs
  - CO_2 emissions
- Analysis builds on low-carbon transition pathway for Europe
- Outlook on a more energy independent European energy system

The Global Energy System Model (GENeSYS-MOD) Overview

- based on the Open-Source Energy Modeling System (OSeMOSYS)
  - enhances the framework with multiple additional features.
- linear program which optimizes the net present value of a future energy system based on the given assumptions and bounds (cost-optimizing).
- includes the energy sectors electricity, building, industry, and transport and considers sector-coupling.
- publicly available to the community with both code and model data.



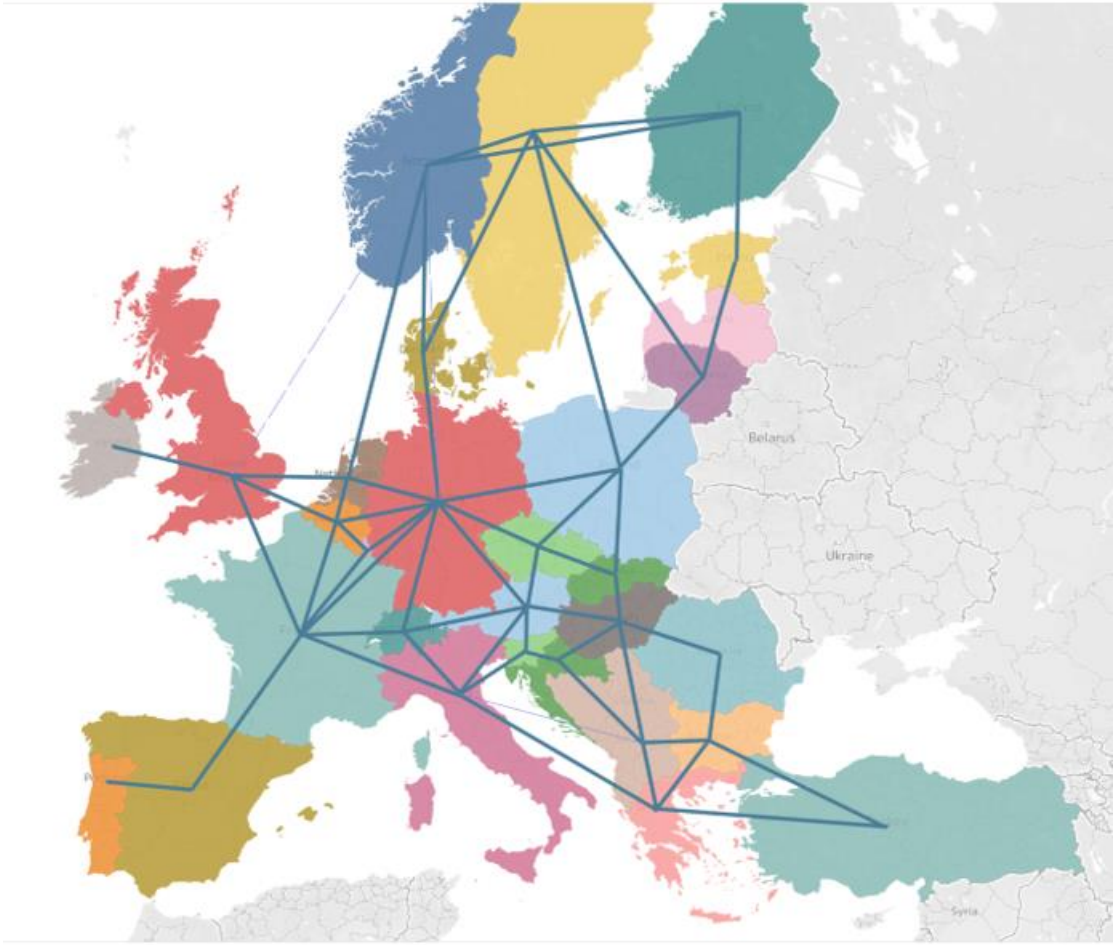
(https://git.tu-berlin.de/genesysmod/genesys-mod-public/-/releases/genesysmod3.0)

Scenario specific model settings

Spatial and temporal resolution

- Europe disaggregated into 30 regions
  - Mainland EU-25
  - Norway, Switzerland, Turkey, UK
  - Aggregated non-EU Balkan region

- Hourly time-series for renewable potentials and demands
  - Reduced by time-series clustering algorithm[1]
  - Results in temporal resolution of every 244th hour (35 time slices)



Model changes regarding gas imports

- Non-EU countries not depicted as individual regions in GENeSYS-MOD
  - Imports aggregated and considered as imports from global market

- New parameter to adjust incoming natural gas from Russia (values between 0-1)
  - Only for regions with pipeline connection to Russia

- New parameter showcasing the share of natural gas pipelines coming from Russia (values between 0-1)
  - Supply ban on Russian fuels has no effects on countries with a value of 0

	DE	EE	ES	FI	HU	IT	LT	LV	PL	RO	SK	TR
Share	1	1	0	1	1	0	1	1	1	1	1	0.64

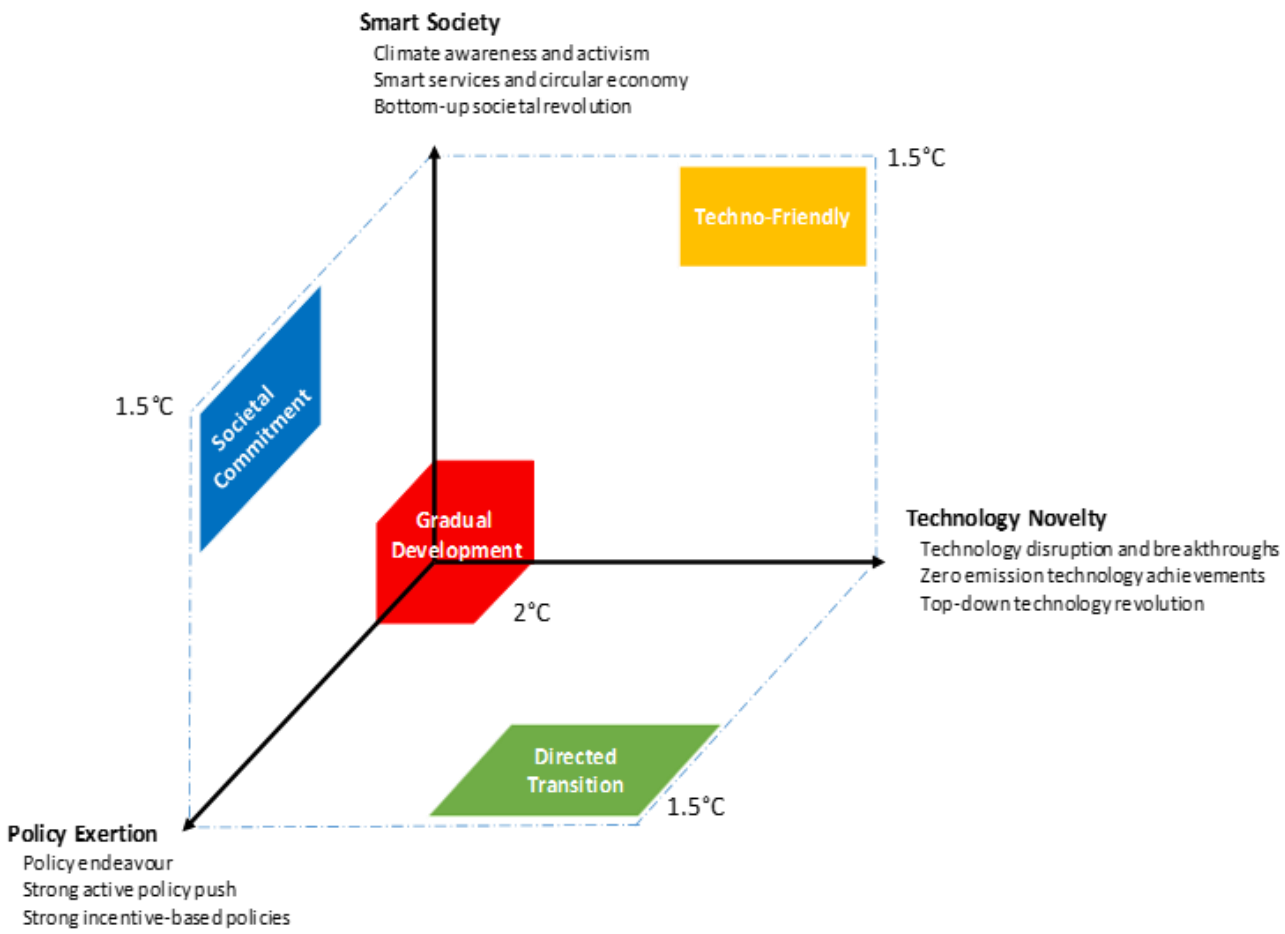
- Upper and lower limit for LNG import development (1.25 and 0.75)

- Maximum available share of total LNG terminal capacity for feed-in into gas network

Scenario definition

H2020 Gradual Development Scenario

- Net-zero 2050 following a 2°C pathway
- Combines societal, technological, and political aspects
- Carbon price drives decarbonization
  - 2030: 76.4 €/tCO_2
  - 2050: 355 €/tCO_2
- Reductions in energy demand until 2050
  - Electricity demand 2018: 10.48 EJ
  - Electricity demand 2050: 10.33 EJ



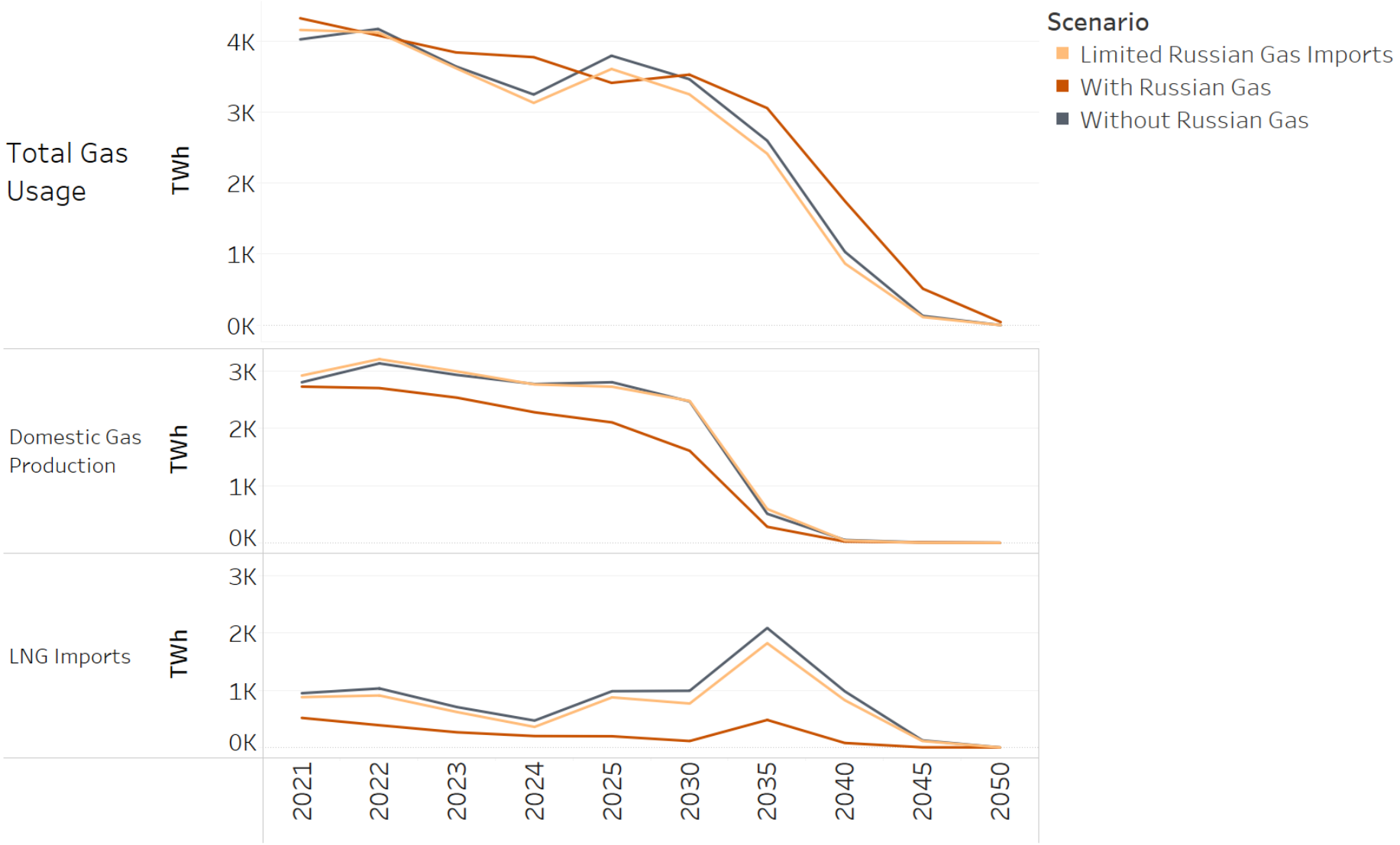
Source: Auer et al 2020[2]

Sensitivities regarding Russian natural gas imports

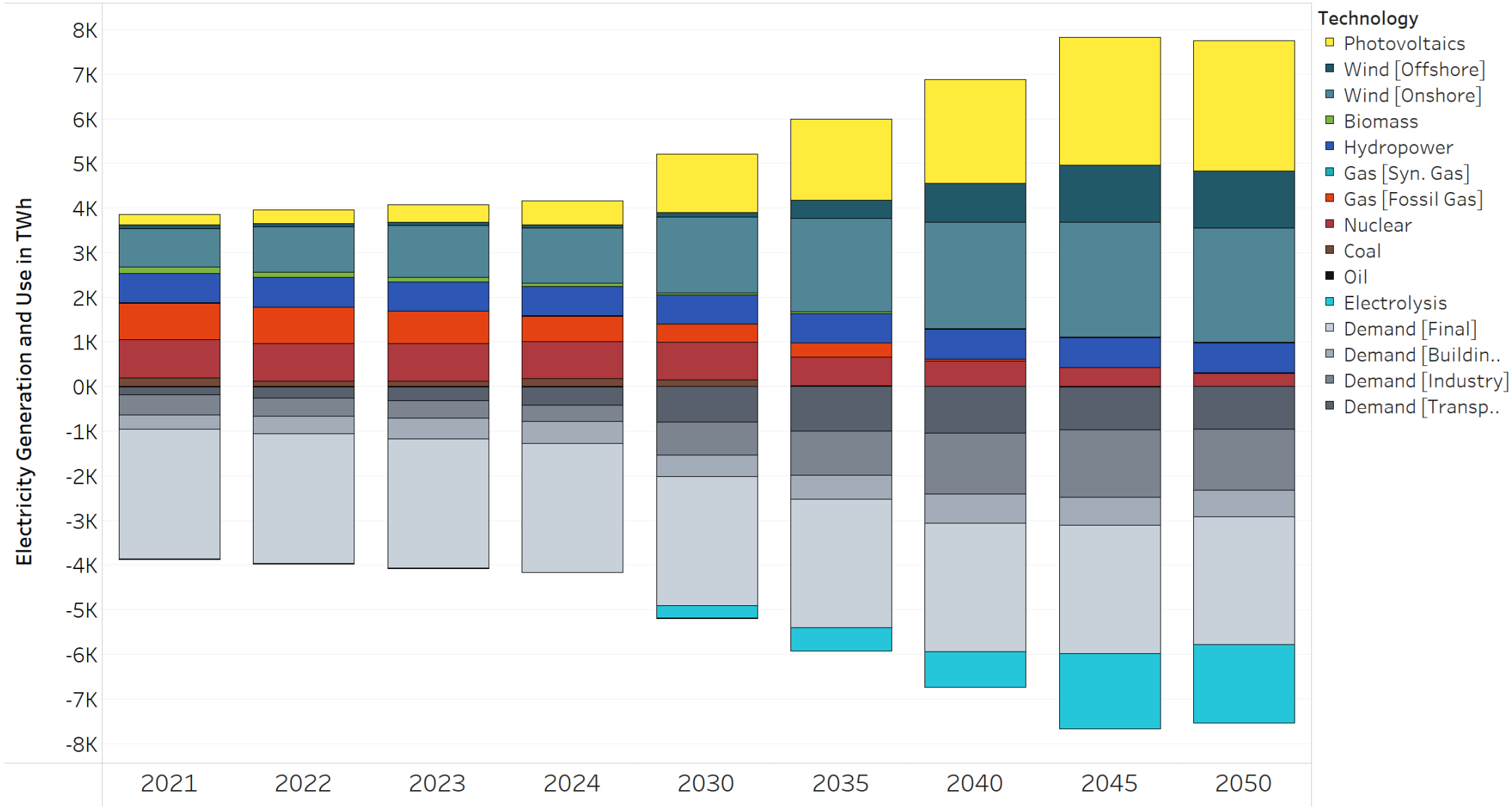
Varying limitation of Russian natural gas imports into Europe

- **With Russian Gas** scenario describing maximum allowed imports of natural gas from Russia
  - Limitation parameter = 1
- **Limited Russian Gas** scenario as a more currently accurate scenario with limited imports
  - Limitation parameter = 0.25
- **Zero Russian Gas** scenario as a more extreme scenario with full import stop of Russian natural gas
  - Limitation parameter = 0

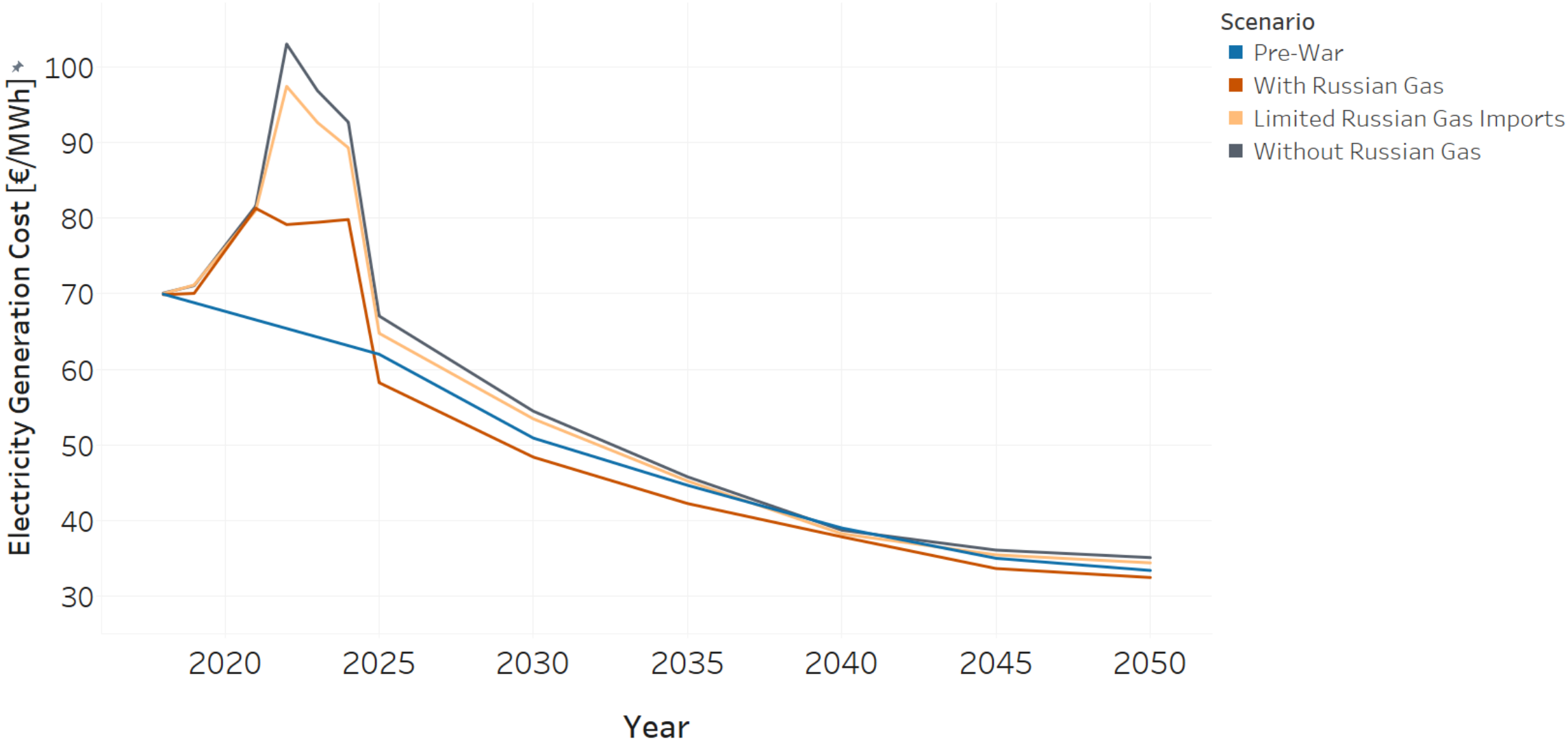
Results I – Gas consumption



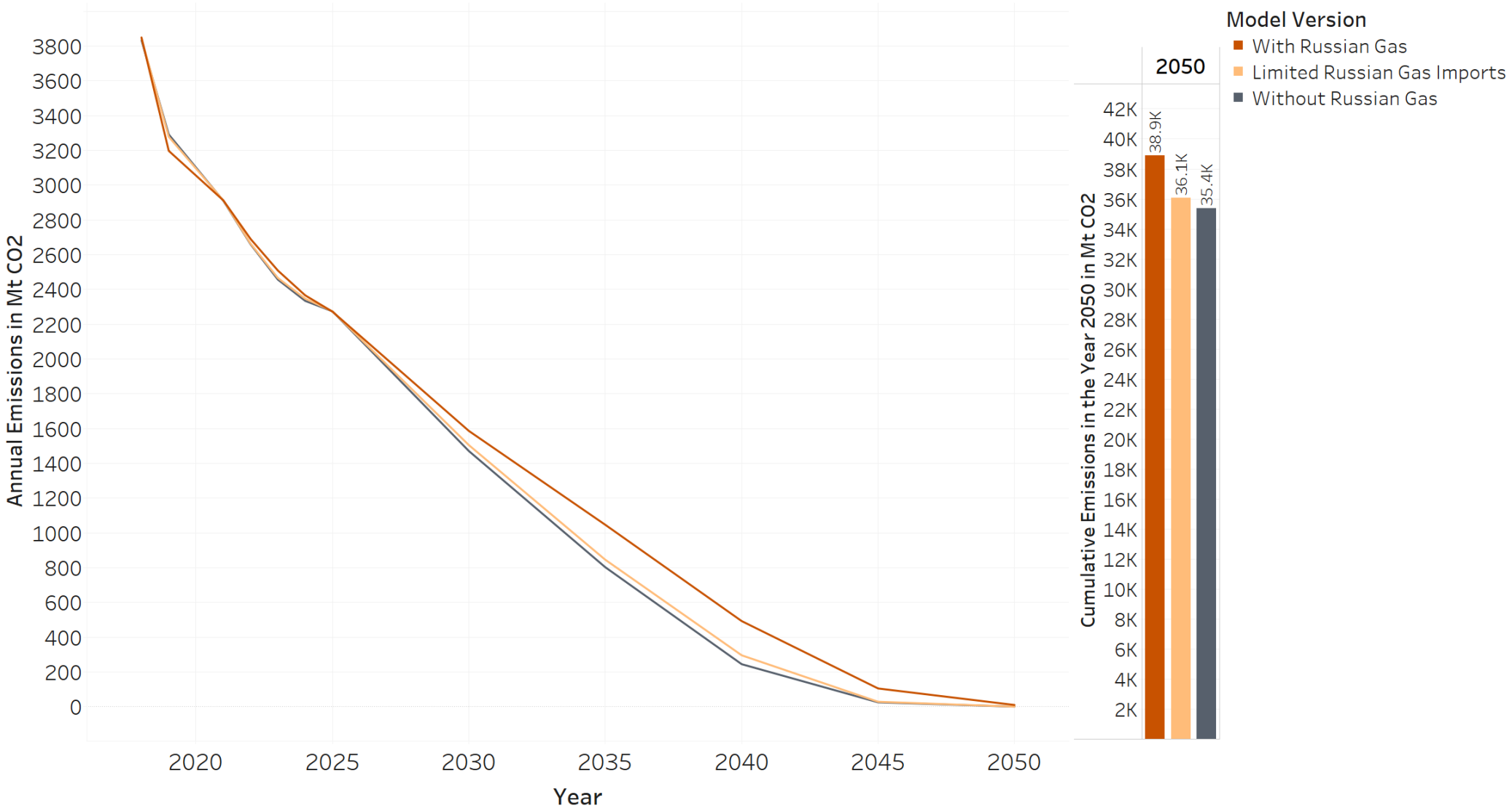
Results II – Electricity generation (Zero Russian Gas)



Results IV – Electricity generation costs



Results III – Emissions



Summary of results

- Increased LNG imports and domestic gas extraction when Russian natural gas is limited
- LNG spike around 2035, when Netherlands stop natural gas extraction
- Overall gas consumption steadily falling after 2035
  - Earlier phase-out of natural gas with limitations on imports from Russia

- 100% decarbonized electricity sector by 2040
- Slightly increased use of coal for electricity generation in short-term
- In mid-term especially onshore wind power replaces generation through fossil fuels

- Electricity generation costs show strong reaction in short-term until 2025
  - The less Russian natural gas, the higher the costs
- Costs normalize after 2025 and difference is negligible in long-term

- Sensitivities with reduced Russian gas show lower total cumulative emissions until 2050
  - 7.2% and 9% lower compared to unlimited Russian gas imports
- Net-zero reached in 2045, compared to 2050 when gas imports from Russia are not limited

Discussion of results

- Mostly strong effects in near to medium future
  - Electricity generation costs react heavily to increased fossil fuel costs
  - Renewable generation not yet enough to overcome gaps in gas supply

- LNG used as bridge solution to replace Russian gas
  - Danger of negative path dependencies and stranded assets
  - However, also chance to enable hydrogen if terminals are hydrogen-ready

- In long-term ambitious 2°C climate target and high fossil fuel prices lead to decarbonization
  - Hence, ban of Russian natural gas has less and less effects
- However, decarbonization of energy system is already possible by 2045 instead of 2050
  - Stronger build-up of renewables needs comprehensive planning and political support

- Results dependent on model formulation and simplifications, as well as input assumptions
  - Especially energy costs are influencing investment decisions
  - Data forecasting subject to uncertainties

Research outlook

Further research that could support and improve results implications

- Earlier phase-out of natural gas leaves pipeline infrastructure unused earlier as well
  - To avoid stranded assets, further research could include ability of hydrogen blending or use of existing infrastructure
- Adding hydrogen-ready LNG terminals could speed up the use of hydrogen
- Other imports from Russia (coal, oil) were not considered in this study
  - Effects on their limitation could be of interest as well
- Current gas prices lower than forecasts believed
  - New runs with lower gas prices as a check of robustness

Thank you for your Attention!

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References

[1] Gerbaulet, C., Lorenz, C., 2017. dynELMOD: A Dynamic Investment and Dispatch Model for the Future European Electricity Market. DIW Berlin, Data Documentation No. 88. DIW Berlin. Berlin, Germany. URL: https://www.diw.de/sixcms/detail.php?id=diw_01.c.558131.de.

[2] Auer, H., Crespo del Granado, P., Oei, P.Y., Hainsch, K., Löffler, K., Burandt, T., Huppmann, D., Grabaak, I., 2020b. Development and modelling of different decarbonization scenarios of the European energy system until 2050 as a contribution to achieving the ambitious 1.5° C climate target—establishment of open source/data modelling in the European H2020 project openENTRANCE. e & i Elektrotechnik und Informationstechnik 2020. doi:https://doi.org/10.1007/s00502-020-00832-7.

Appendix I – Limitations

- Lineares problem → Investmententscheidung nicht immer korrekt abbildbar
  - Fixe Nachfrage und keine Nachfragekurve
- Reduzierte Zeitliche Auflösung
- Limitierte geografische Auflösung

Appendix II – Fossil fuel prices

Fuel	2018	2019	2021	2022	2023	2024	2025	2030	2035	2040	2045	2050
Oil	9.07	9.07	10.35	14.71	13.53	11.76	17.17	16.10	16.61	14.95	12.70	10.80
Hardcoal	2.40	2.40	4.24	9.83	7.37	6.52	6.14	4.55	3.68	2.97	2.39	1.93
Natural gas	4.67	4.09	13.73	34.12	27.30	23.88	23.03	17.91	15.64	13.61	11.84	10.30
LNG	9.04	9.04	9.21	15.70	14.50	13.56	12.97	10.47	9.29	8.08	7.03	6.12

Table 2: Current fuel price projections in M€/PJ after the Russian aggression
Source: World Bank Group 2022

Fuel	2018	2019	2021	2022	2023	2024	2025	2030	2035	2040	2045	2050
Oil	9.07	9.07	10.24	10.65	9.19	6.15	8.97	8.41	8.68	7.81	6.64	5.64
Hardcoal	2.4	2.4	4.27	3.61	2.66	2.51	2.36	1.75	1.41	1.14	0.92	0.74
Natural gas	4.67	4.09	12.37	10.49	7.51	7.17	6.91	5.37	4.69	4.08	3.55	3.09
LNG	9.04	8.55	9.04	8.01	7.71	7.16	6.48	5.46	4.55	3.64	2.76	1.98

Table 3: Fuel price projections in M€/PJ dated October 2021, before the Russian aggression
Source: World Bank Group 2022