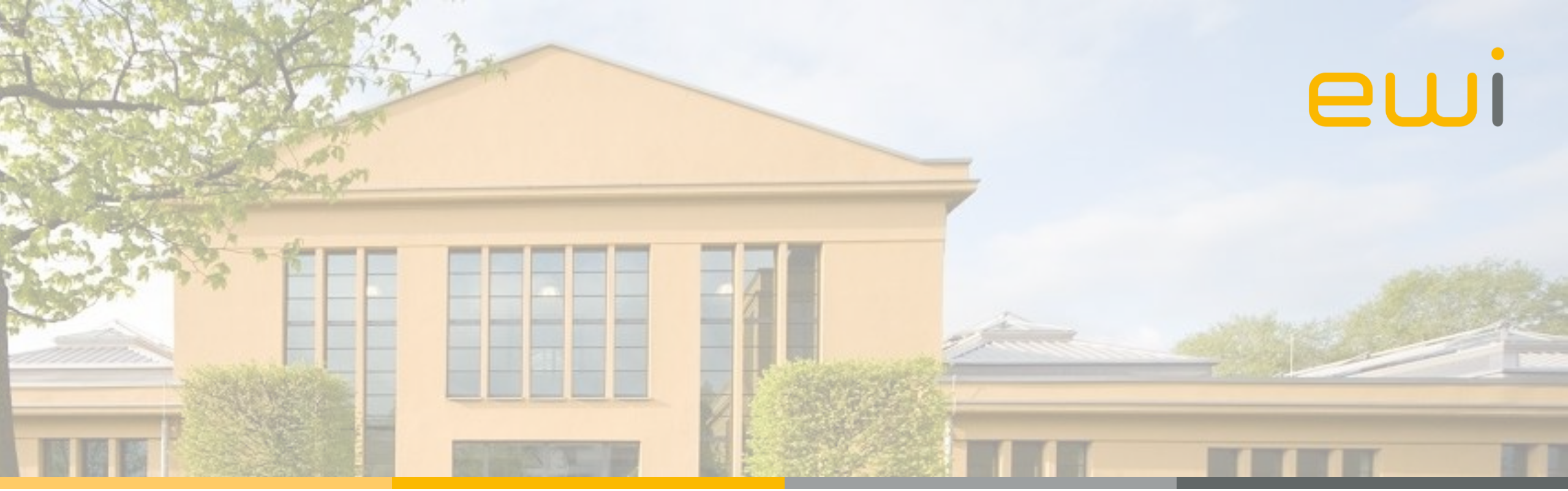


Gas-fired power generation in winter 2022/2023

Commissioned by the Society for the Promotion of the Institute of Energy Economics at the University of Cologne e.V.

Dr Johannes Wagner, Dr Philip Schnaars, Nils Namockel, Hendrik Diers, Julian Keutz

Energiewirtschaftliches Institut an der Universität zu Köln (EWI) gGmbH | 10. November 2022

Introduction

Motivation and results

This analysis depicts the possible development of electricity prices and power plant deployment in the German and French electricity markets in the period from November 2022 to April 2023. For this purpose, the electricity market is simulated with the EWI model DIMENSION in hourly resolution. As part of the results, the hourly power plant input and the resulting electricity prices are calculated as marginal costs of the respective price-setting power plant. The main short-term factors influencing electricity prices are the prices for natural gas, the availability of power plants in France and the extended power operation ("Streckbetrieb") of three German nuclear power plants until mid-April 2023 decided by the German government. These factors are varied within the framework of a simulation of the European electricity market using three scenarios. In all three scenarios, it is assumed that additional coal and oil-fired power plants are available to the market according to the plans of the German government.

If the three nuclear power plants are used until mid-April 2023 as decided by the German government, the scenario considered, together with lower availability of French power plants, results in an electricity price that is up to 8.7 percent lower than in the scenario without extended power operation. Higher availability of power plants in France could increase electricity imports from France. The monthly electricity price in Germany in winter 2022/2023 could be up to 6.1 percent lower in this scenario than in the case of lower French nuclear power availability.

Higher electricity generation from nuclear power plants in France and extended power operation in Germany could also reduce gas-fired power generation in Germany and Europe. In this case, European gas-fired power generation could be up to 10 per cent lower, and German gas-fired power generation 2 per cent lower. One reason for this is increased electricity exports from France. Extended operation of German power plants could reduce gas-fired power generation in Europe by about 2 percent in individual months of the coming winter.

In hours with high residual load, a significant part of the electricity demand in Germany is covered by imports and storage. For the 200 hours with the highest residual load, the share of imports and storage use in electricity demand is shown in this analysis. Due to the extended power operation decided by the federal government, the average imports and storage used could be about 2 GW lower in the 200 hours considered. Additional electricity generation in France could influence the German electricity trade balance in the period under consideration. In the scenario considered, the mean contribution of imports and storage could increase by 2 GW in periods with high German residual load.

Content

1

Key assumptions for electricity market modelling

The scenarios examined

Overview of the scenario framework

Scenarios

Simulation period: 01. November 2022 – 30. April 2023.

Analysed electricity market: EU27 incl. GB, NO and CH without MT and CY.

Scenario "Stretch operation DE - low nuclear FR": Low availability of French power plants and extended power operation of the three German nuclear power plants until 15 April 2023

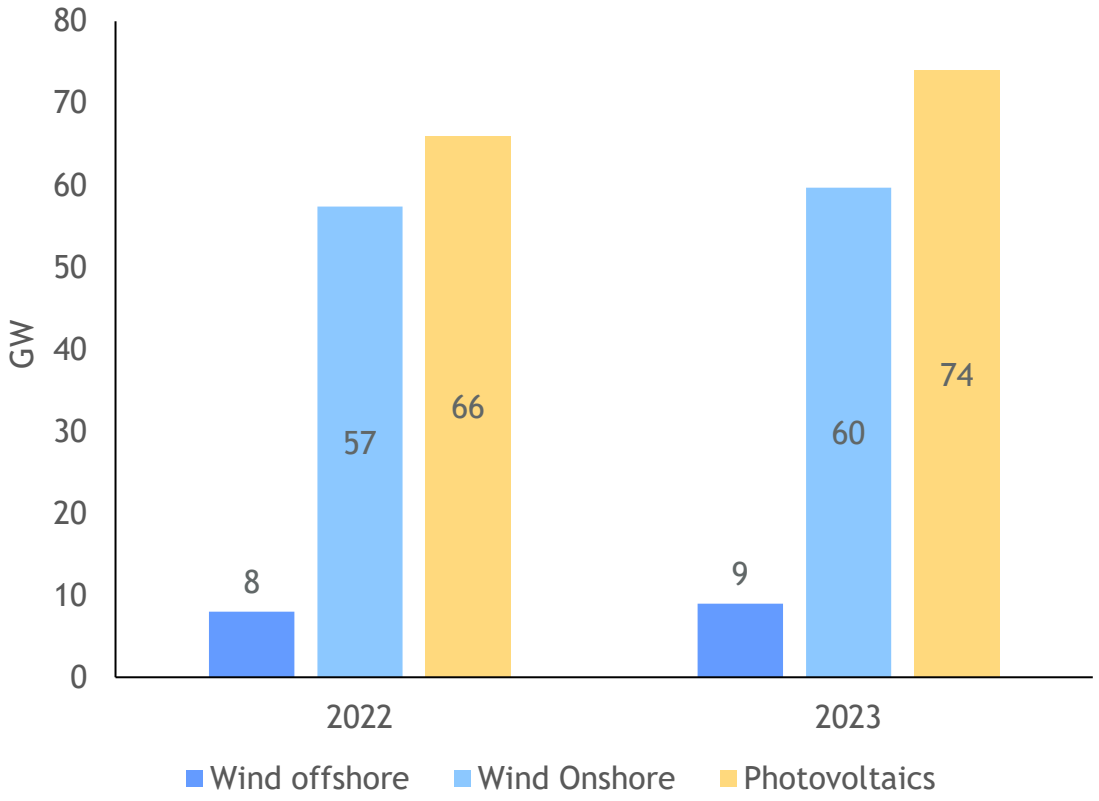
Scenario "Stretch operation DE - more nuclear FR": Higher availabilities of French power plants and extended power operation of the three German nuclear power plants until 15 April 2023

Scenario "no stretch operation DE - low nuclear FR": Low availability of French power plants and phase out of German nuclear power plants at the end of 2022

Expansion of renewable energies

Renewable energy generation capacity in Germany

Installed capacities of renewable energies at the end of each year

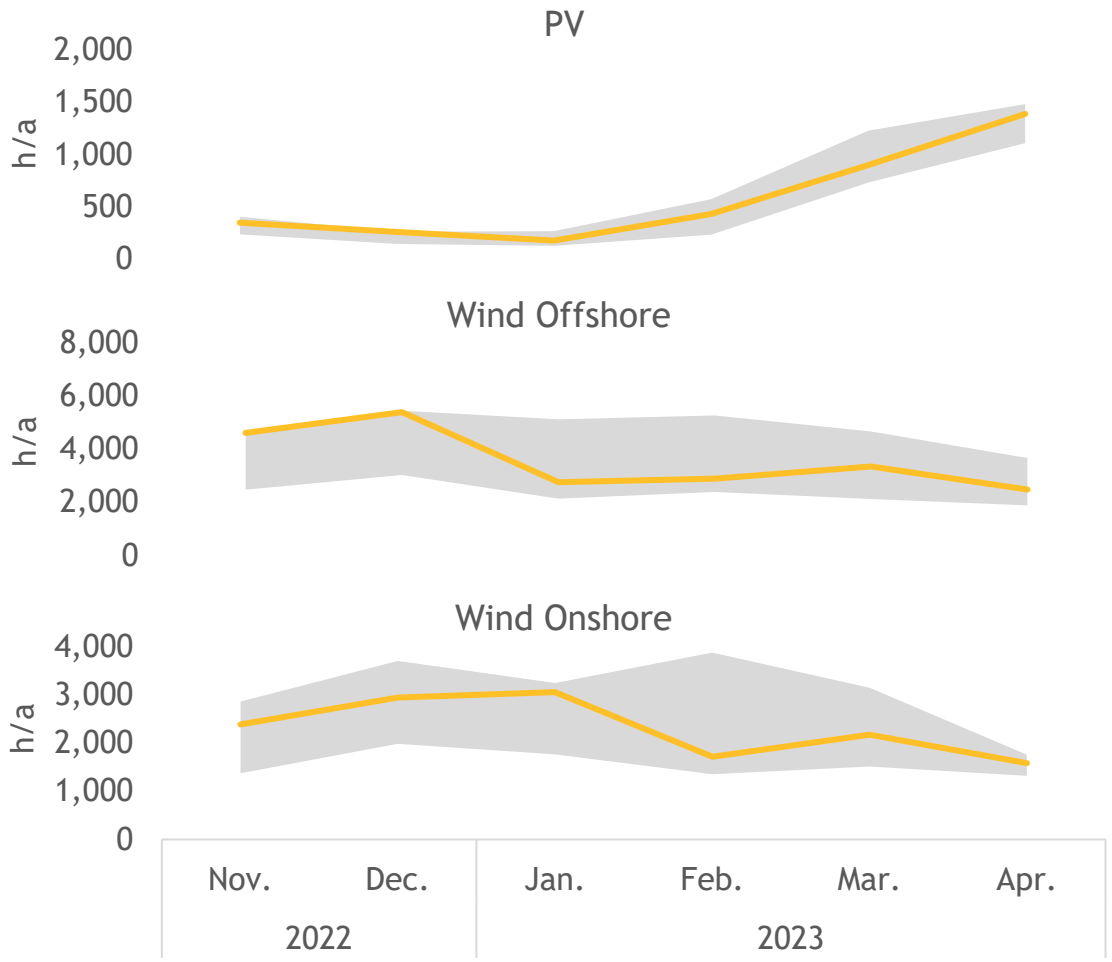


Source: BMWK (2022)

- Over the period under consideration, a net addition of renewable energies is assumed for all three scenarios based on the BMWK's opening climate protection balance sheet of 11 January 2022, taking into account expected reversals.
- Starting from 56.9 GW of onshore wind at the end of 2022, around 3 GW will be added over 2023.
- Wind offshore capacity increases by 0.4 GW to 8.6 GW over the course of 2023.
- The largest capacity increase is assumed for photovoltaics. A total of 8.8 GW of generation capacity will be added to reach a total of 74.4 GW at the end of 2023.
- For the model calculation, it is assumed that this expansion takes place in a linear fashion. This means that the same additional capacity is available for electricity generation every month over the period under consideration.

Weather development over the considerd period

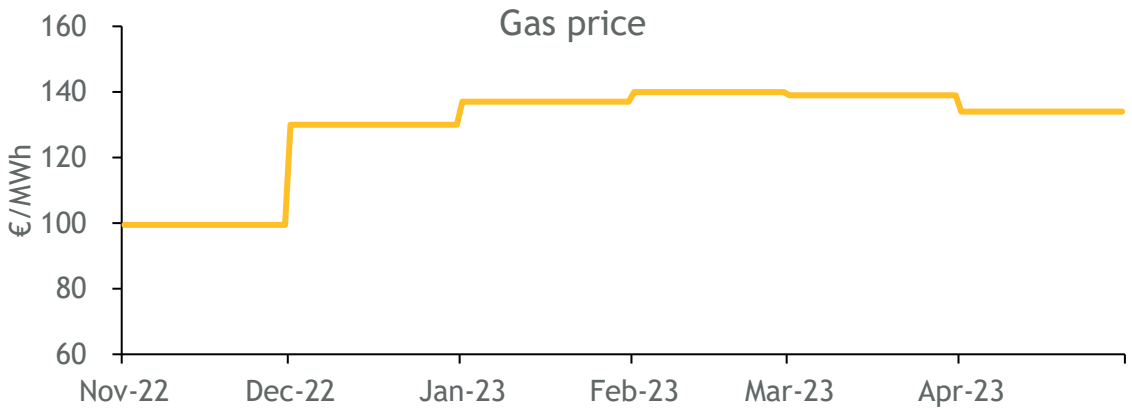
Assumed monthly full load hours of renewable energies

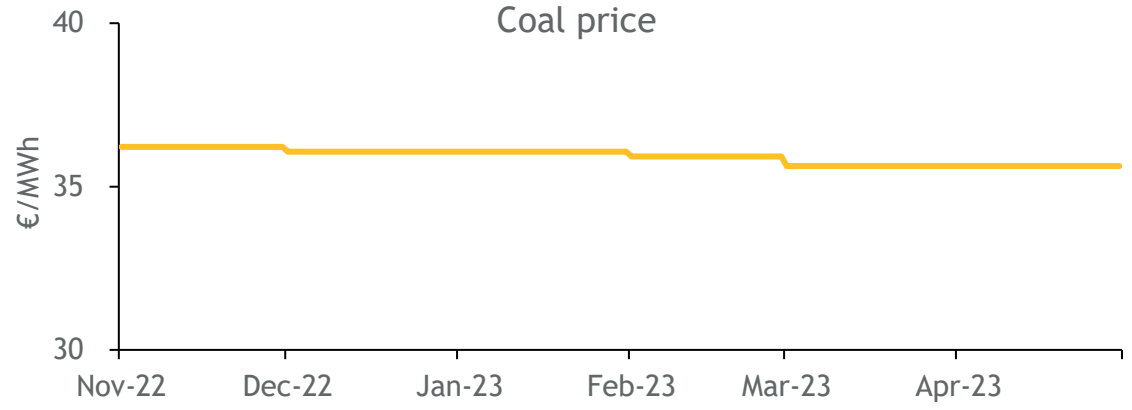


- The structure of generation from renewable energies is based on the weather year 2015 in all scenarios.
- The full load hours are shown per month and extrapolated to an annual value. The grey shaded area shows the historical range of monthly full load hours in the period 2011 to 2021.
- The full load hours for **PV** amount to an annual average of around 950 hours per year.
- The full load hours for **Wind Onshore** are on average around 1750 hours per year and for **Wind Offshore** around 3000 hours per year. These vary greatly between the individual months. February is very windless, whereas November is quite windy.
- The assumption of full load hours affects the results. For example, with more wind in February, the use of gas-fired power plants could be lower in these months and thus electricity prices could fall.

Marginal costs of thermal power plants

Fuel prices and demand for the period under consideration





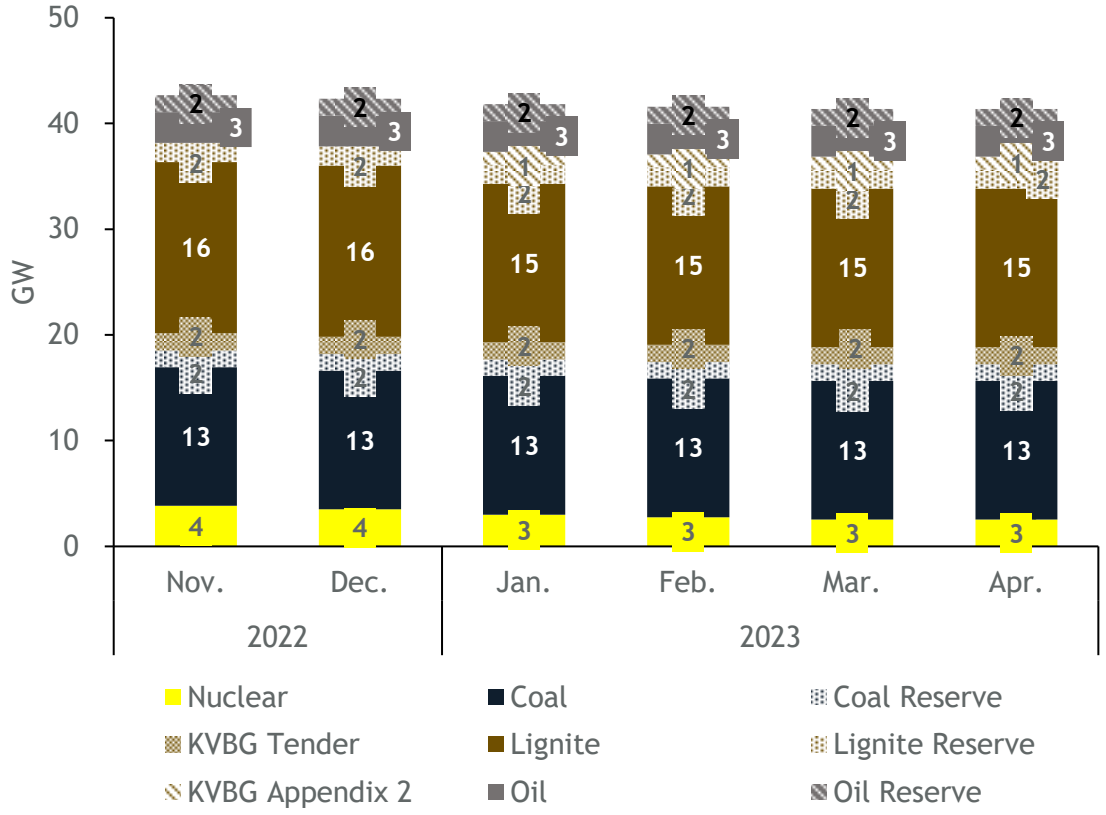
Sources: THE (2022), CME (2022)

- The prices for natural gas in all scenarios are based on the currently traded futures (as of 27.10.2022). The November values were still trading at a lower price level, then the values rise to up to 140 euros/MWh in February 2023. In the further course of time, a slight decline in prices is assumed.
- The prices for hard coal are based on current futures prices (as of 27.10.2022). Here, the highest price is already reached in November, after which a price decline occurs.
- The price for allowances in the EU ETS is assumed to be 77 euros/t CO_2 equivalent for all scenarios in the period under consideration.
- For the 6 months considered, the net electricity demand including grid losses is 263 TWh in Germany and 262 TWh in France. Due to the stronger provision of heat in winter by electricity, the demand in France is almost at the level of Germany.
- The peak load is assumed to be 83 GW in Germany and 92 GW in France over the period under consideration and is based on historical values.

The scenario "Stretch operation DE – low Nuclear FR"

Conventional generation capacities

Available conventional generation capacity in Germany in the Scenario "Stretch operation DE - low nuclear FR“



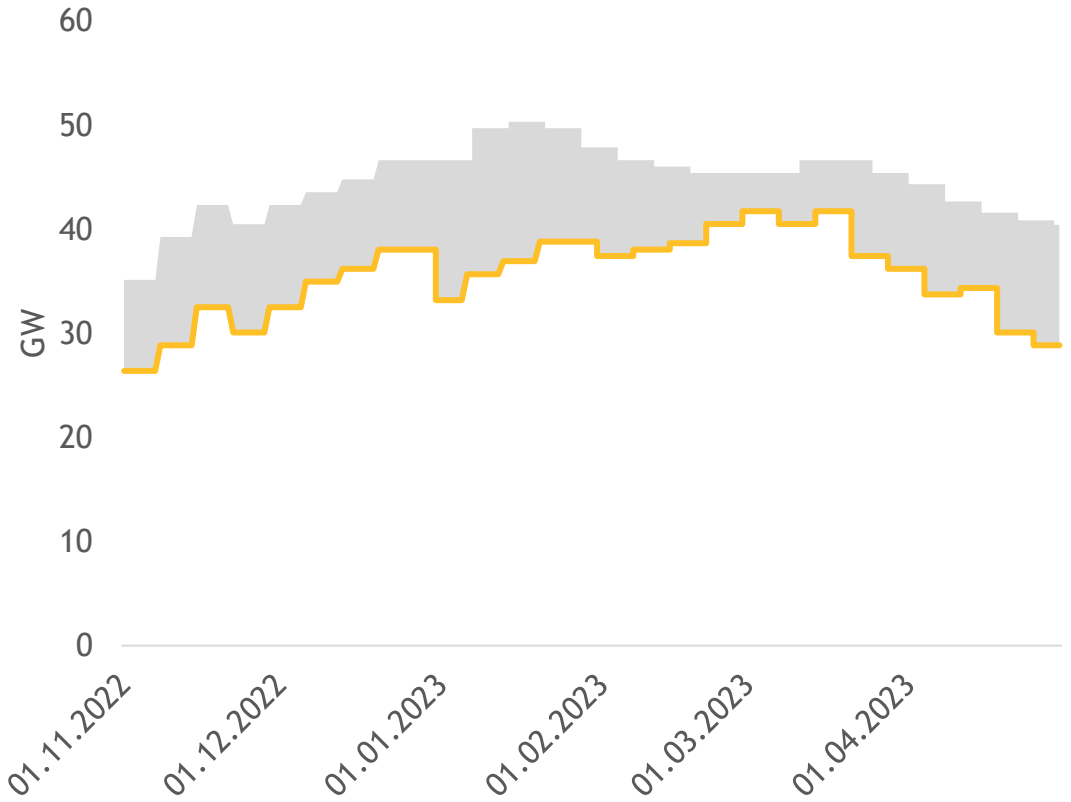
Sources: BNetzA (2022a), BNetzA (2022b) * until 15 April 2023

- The assumed power plant fleet in Germany is based on the current power plant list of the Federal Network Agency as of 31 May 2022.
- By using the grid and security reserves, an additional 1.8 GW of lignite, 1.6 GW of hard coal and 1.6 GW of oil will be available in November 2022. This additional capacity will then be market active. In November 2022 and at the beginning of 2023, the shutdown of corresponding 1.6 GW of hard coal capacity (KVBG tender) and 1.2 GW of lignite capacity (KVBG Annex 2) will be waived.
- In this scenario, the operating times of the three existing German nuclear power plants are extended with stretch operation until 15 April. Starting from 3.9 GW of electricity generation capacity from the Emsland, Neckarwestheim II and Isar 2 nuclear power plants in November, the capacity is reduced by 10 percent per month. At the beginning of April 2023, a total of around 2.5 GW of capacity from the three German nuclear power plants will thus be available.

The scenario "Stretch operation DE – low Nuclear FR"

Available power plant capacity in France

Development of the availability of nuclear power plants in France in the scenario "Stretch operation DE – low nuclear FR".



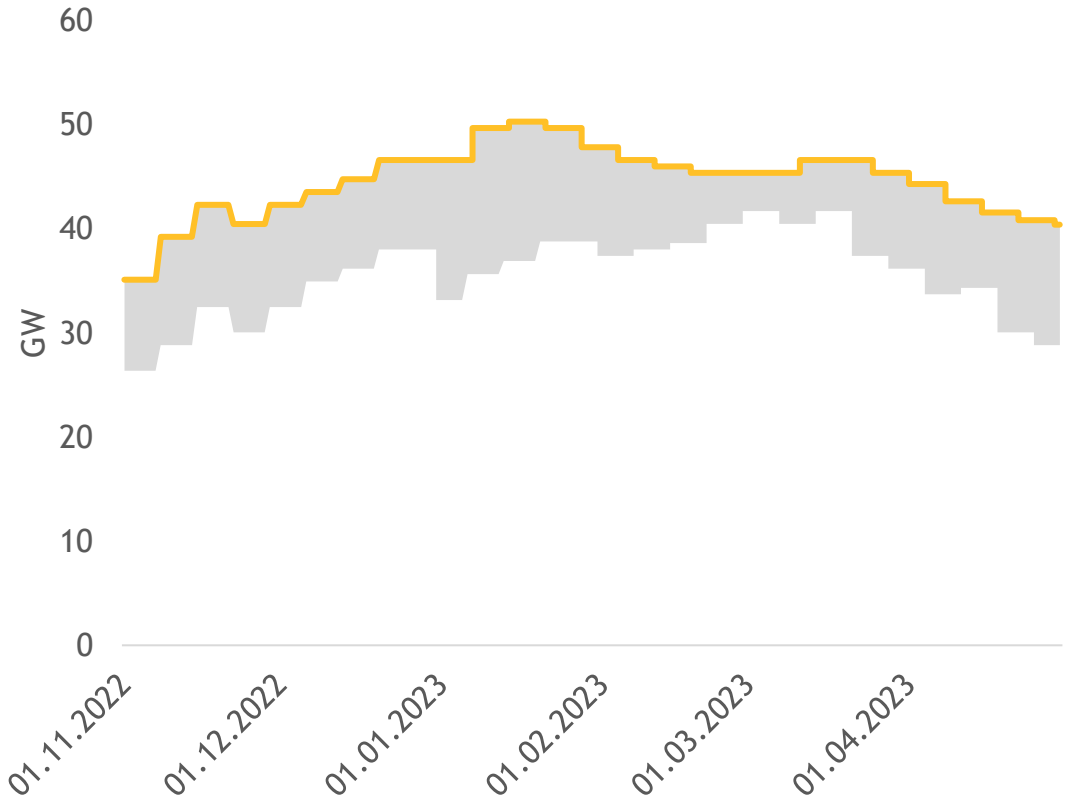
Source: RTE (2022)

- The values for power plant availabilities in this scenario are based on the forecasts of the French transmission system operator RTE regarding the planned resumption of power generation. These values enter the model as a weekly average.
- For the reference scenario, the lower limit of the confidence interval (grey area) of RTE is used.
- In November 2022, approximately 26 GW of power plant capacity will be available in this scenario.
- From November to the end of January, availabilities rise to a maximum of 38.8 GW.
- This value remains at a comparable level until the end of February and then decreases continuously to 28.8 GW until the end of April. This results from the fact that renewed maintenance work by RTE is expected.

Variation in the scenario "Stretch operation DE - more Nuclear FR"

Higher available power plant capacity in France

Development of nuclear power availability in France in the scenario "Stretch operation DE – more nuclear FR"



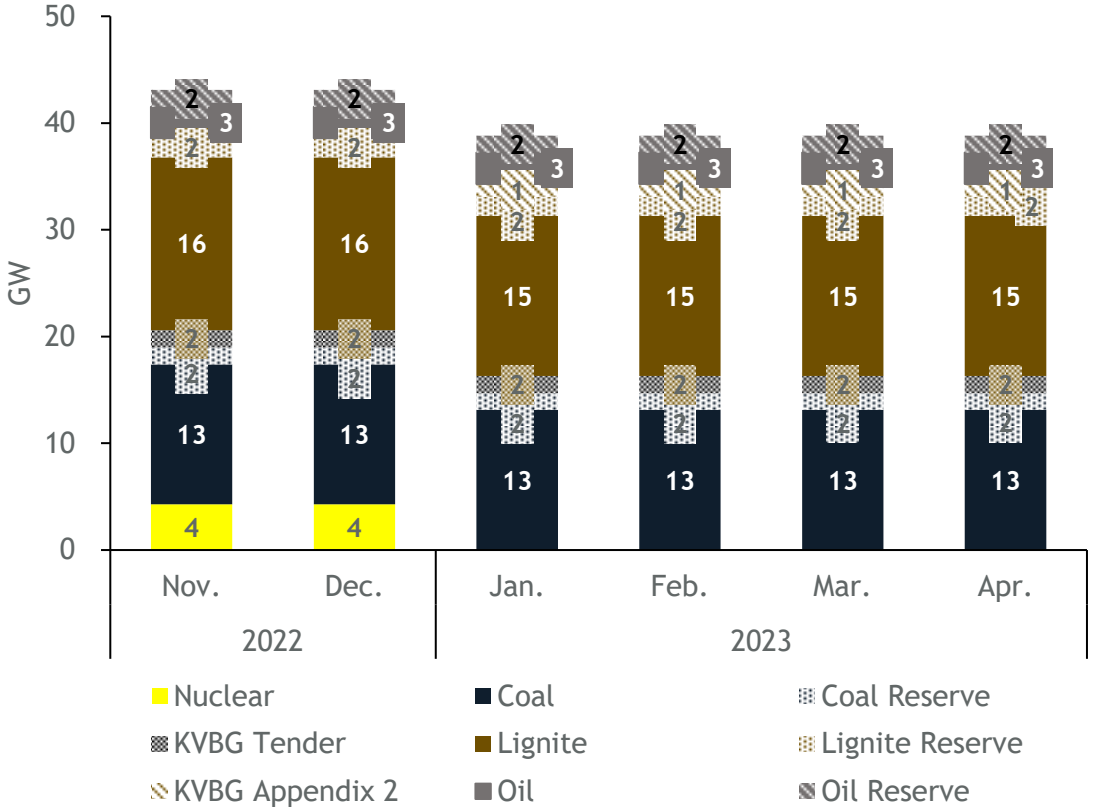
Source: RTE (2022)

- In this scenario, a higher availability of French nuclear power plants is assumed. The upper limit of the confidence interval, which is expected as a possible range by the French transmission system operator RTE, serves as a basis. All other assumptions remain unchanged compared to the scenario "Stretch operation DE – low Nuclear FR".
- In November 2022, 35 GW of power plant capacity is available in this scenario. In the following months, more power plants will be continuously reintroduced to the market and power plant availabilities will increase.
- In mid-January 2023, a maximum availability of 50.3 GW is expected. This maximum is about 9 GW higher than in the reference scenario.
- Subsequently, the value drops to 44.4 GW, as maintenance work is again expected at individual power plants by RTE. This expected maintenance work includes less power plant capacity than in the scenario "Stretch operation DE – low Nuclear FR".

Variation in the scenario "no stretch operation DE - low Nuclear FR"

Conventional generation capacities

Available conventional generation capacity in Germany in the scenario "no stretch operation DE - low Nuclear FR"



- In this scenario, the three existing German nuclear power plants are shut down by the end of December 2022. All other assumptions remain unchanged compared to the scenario "Stretch operation DE – low Nuclear FR".
- The assumed power plant fleet in Germany is based on the current power plant list of the Federal Network Agency as of 31 May 2022.
- By using the grid and security reserves, an additional 1.8 GW of lignite, 1.6 GW of hard coal and 1.6 GW of oil will be available in October 2022. This additional capacity is then market active. In November 2022 and at the beginning of 2023, the shutdown of corresponding 1.6 GW of hard coal capacity (KVBG tender) and 1.2 GW of lignite capacity (KVBG Annex 2) is waived.

Sources: BNetzA (2022a), BNetzA (2022b)

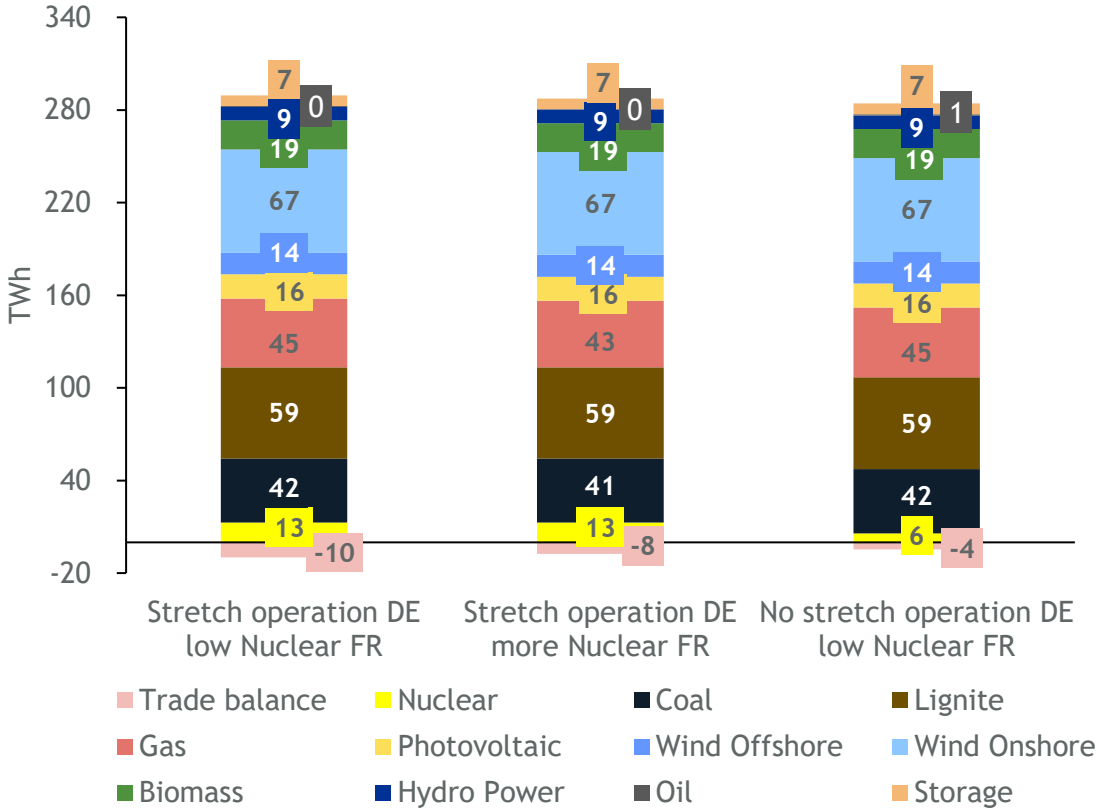
2

Results of the electricity market modelling

Power generation

Electricity generation by energy source in Germany

Electricity generation volumes per energy source and scenario for the observation period Nov. 2022 - Apr. 2023

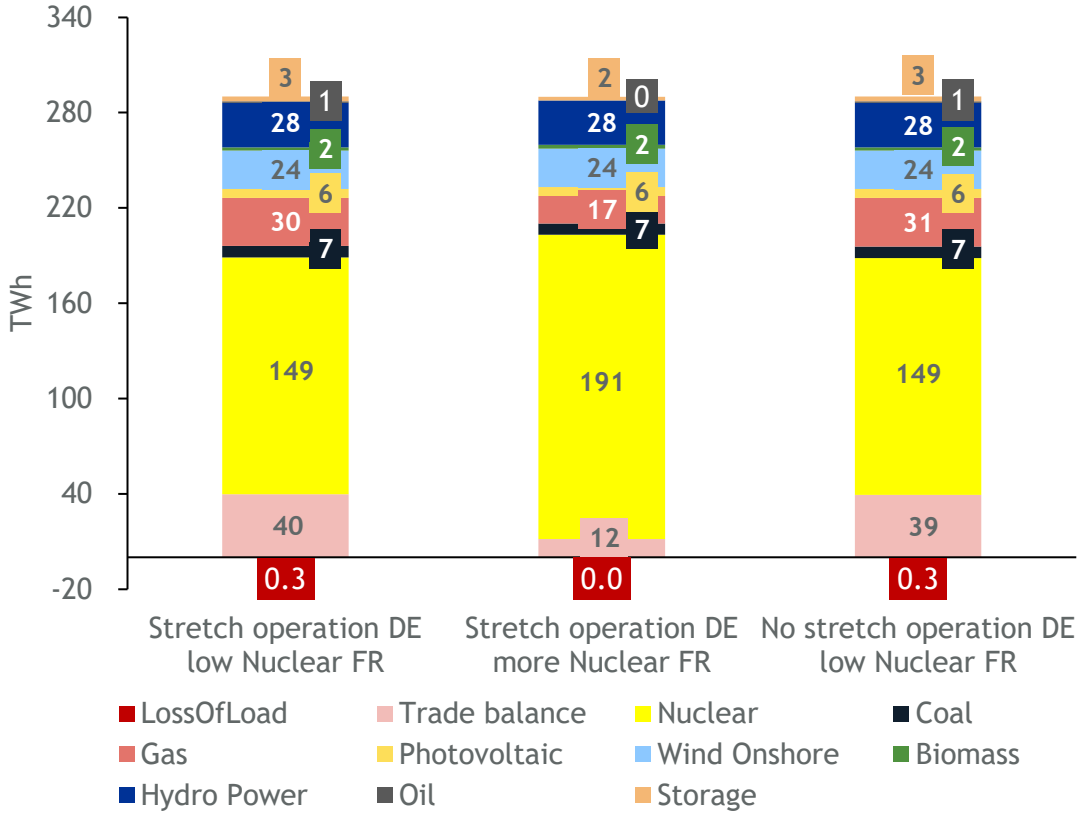


- In all three scenarios considered, wind energy is the largest supplier of electricity in Germany, followed by lignite and gas-fired power plants.
- Germany is a net exporter of electricity in all three scenarios, but the trade balance varies between the scenarios considered.
- Higher availability of French nuclear power plants could lead to about 2 TWh less electricity being generated in Germany due to higher imports. The largest reduction, 1.5 TWh, would be accounted for by gas-fired power plants.
- If three nuclear power plants in Germany were phased out by the end of the year, this could result in 0.7 TWh more being generated from gas-fired power plants and 0.4 TWh more from hard coal and lignite-fired power plants compared to the scenario „Stretch operation DE - low nuclear FR". Net electricity imports could increase by about 5.2 TWh.

Power generation

Electricity generation by energy source in France

Electricity generation volumes per energy source and scenario for the observation period Nov. 2022 - Apr. 2023

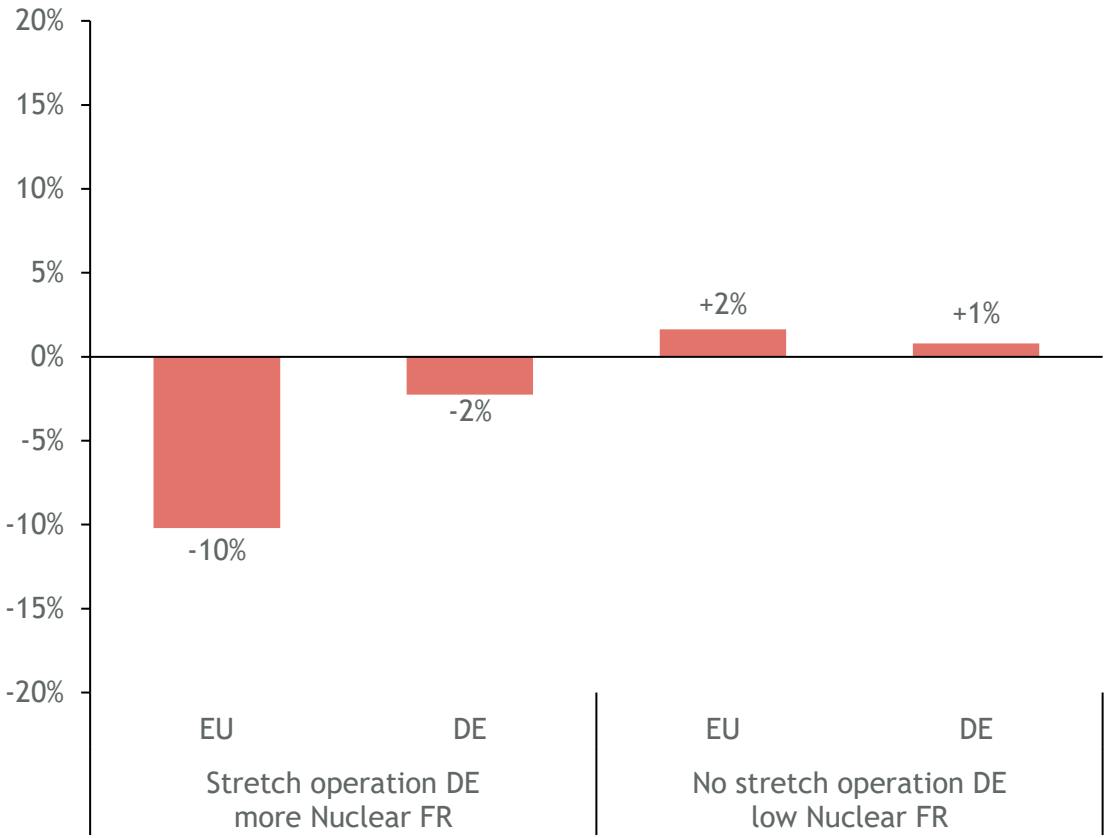


- With a lower availability of the French nuclear power plants, 42 TWh less electricity will be generated from nuclear energy in France.
- As a result, loss of load in France is possible in some hours in the scenarios „Stretch operation DE - low Nuclear FR" and „No stretch operation DE - low Nuclear FR". A total of 0.3 TWh of the load could then not be served.
- The lower electricity generation from nuclear power plants in the scenarios „Stretch operation DE - low Nuclear FR" and „No stretch operation DE - low Nuclear FR" leads to an increase of around 28 TWh higher net electricity import compared to the scenario „Stretch operation DE - more Nuclear FR".
- Extended power operation in Germany could mean that net electricity imports to France increase by 0.5 TWh. In the case of lower availability of French nuclear power plants, electricity imports would be the second largest source of electricity in France.

Primary energy consumption

Use of gas for power generation in Europe and Germany

Changes in gas consumption compared to "Stretch operation DE - low Nuclear FR" in the period Nov. 2022 - Apr. 2023

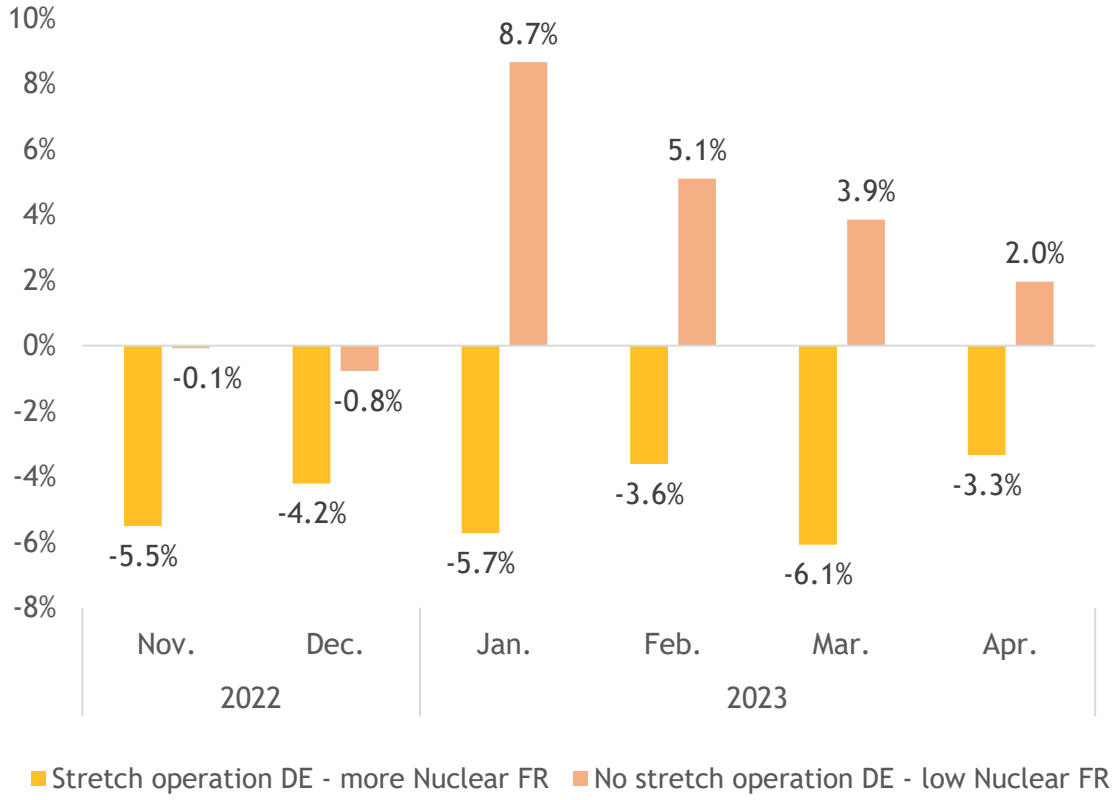


- The figure shows percentage changes in gas consumption in the electricity sector in Europe and in Germany in the considered period compared to the scenario "Stretch operation DE - low nuclear FR".
- Additional power plant capacity in France could reduce gas consumption in the European and German electricity sector over the considered period.
- Higher power plant availability in France could reduce gas consumption across Europe by about 10 per cent (48 TWh). In Germany, 2 percent less could be used for electricity generation in this scenario. This would correspond to about 3 TWh.
- Without extended power operation of nuclear power plants in Germany, European gas-fired power generation could increase by about 2 percent. In Germany, about 1 percent more gas could be consumed in the electricity sector in this case.
- The electricity sector can contribute to the need for gas demand reduction identified in EWI (2022).

Electricity price

Monthly electricity price in Germany per scenario

Change in the electricity price in Germany compared to the scenario "Stretch operation DE - low nuclear FR"

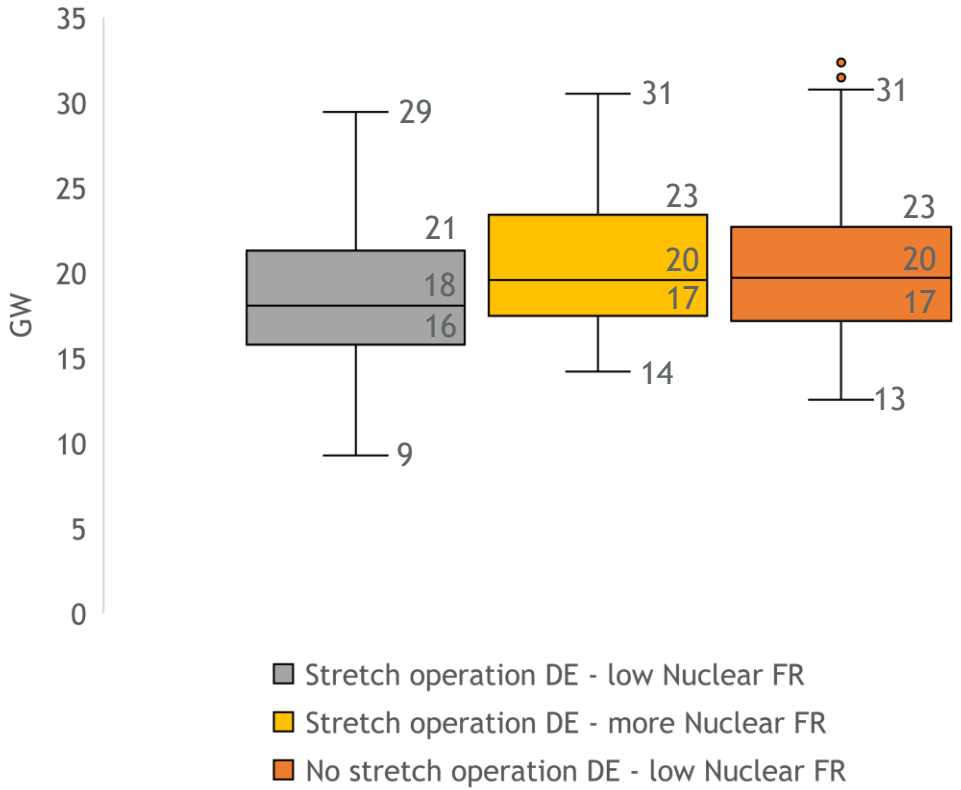


- The hourly electricity prices resulting from the electricity market model and shown here in aggregated form correspond to the marginal costs of the pricing power plant.
- In the case of higher availability of French power plants, the monthly German electricity price could be about 4.2 percent lower in December 2022 and up to 6.1 percent lower in March 2023 than in the case of low French power plant availability. The reason for this is, among other things, the lower net electricity exports from Germany to France.
- In the event of a shutdown of the German nuclear power plants at the turn of the year, the electricity price in the first quarter of 2023 could be up to 8.7 percent higher compared to the scenario "Stretch operation DE – low Nuclear FR".
- The price effect for November and December 2022 shown for the scenario „No stretch operation DE – low Nuclear FR" can be explained by a reduction in power plant capacity in the scenario „Stretch operation DE – low Nuclear FR", which is caused by the stretch operation in this scenario.

Electricity trading and storage use during high residual load

Contribution of net imports and storage to demand coverage

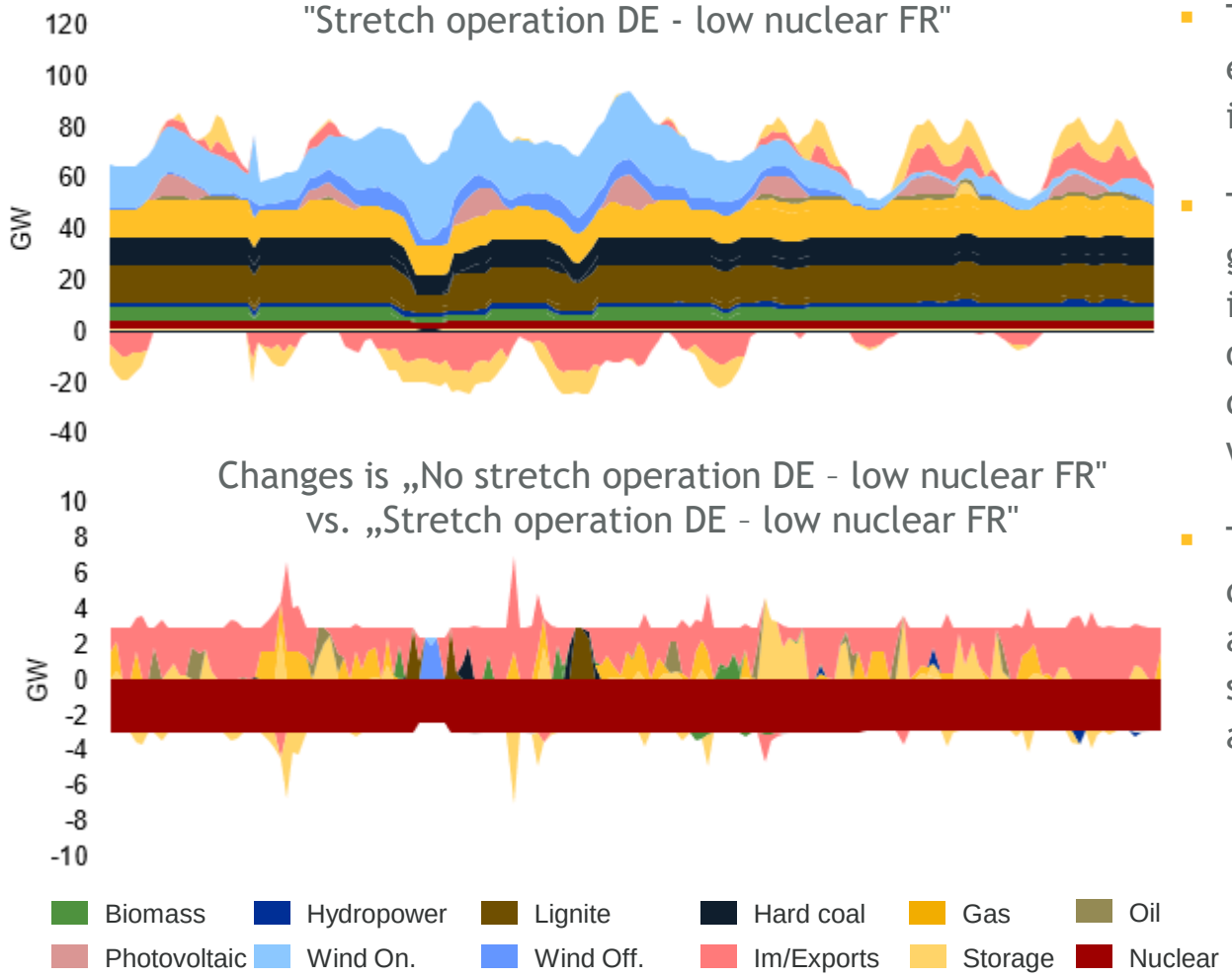
Distribution of net imports and storage use in the 200 hours with the highest residual load



- This figure shows the simulated contribution of electricity imports and domestic storage to meeting German electricity demand. Only the 200 hours with the highest residual load during the period under consideration are considered, as the contribution of imports and storage is expected to be highest in these hours.
- These boxplots show, from bottom to top, the minimum, the 1%, 25%, 50%, 75% and 99% percentiles, and the maximum.
- In the scenario „Stretch operation DE - low nuclear FR", a maximum of 29 GW is covered by imports and domestic storage over the period under consideration. This value could increase to 31 GW due to higher power plant availability in France and consequently higher imports.
- If German power plants are shut down at the turn of the year, the amount of imported electricity could increase. In this case, more electricity could be imported to cover German demand in the hours considered here.

Power plant deployment

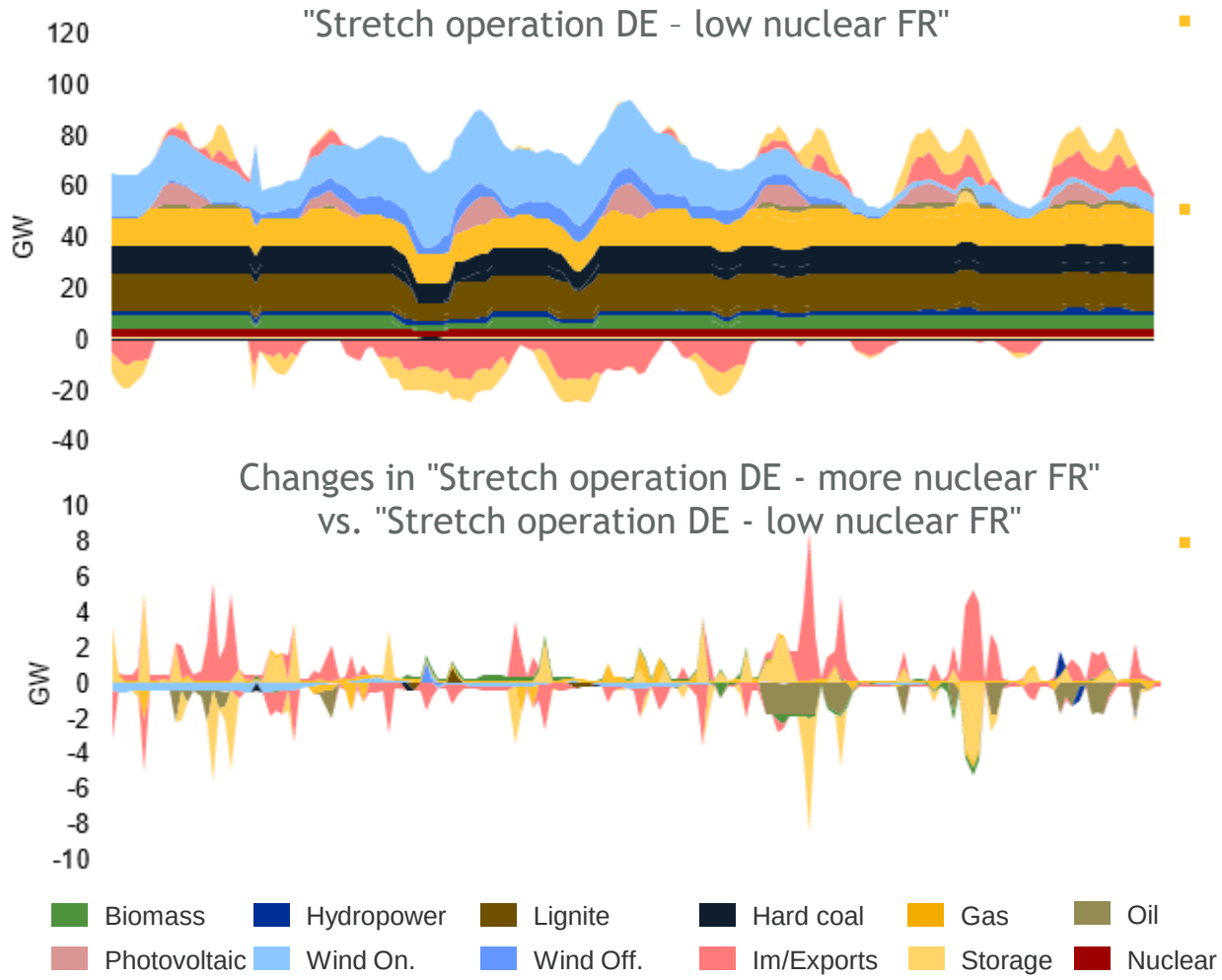
Exemplary use of the power plants in one week in February 2023



- The figure above shows the hourly feed-in of renewable energies, the power plant deployment decision and the net import balance for one week in February 2023.
- The week is initially characterised by significant power generation from onshore wind. During these hours, electricity is exported and the storage facilities are charged. At the end of the week, the wind decreases and the storage facilities are discharged. Electricity imports from abroad are necessary, as well as the use of oil-fired power plants.
- The lower figure shows the delta in the electricity mix as a deviation from the upper figure. If stretch operation were abandoned, the output of the nuclear power plants would be significantly replaced by additional imports as well as storage and gas-fired power plants.

Power plant deployment

Exemplary use of the power plants in one week in February 2023

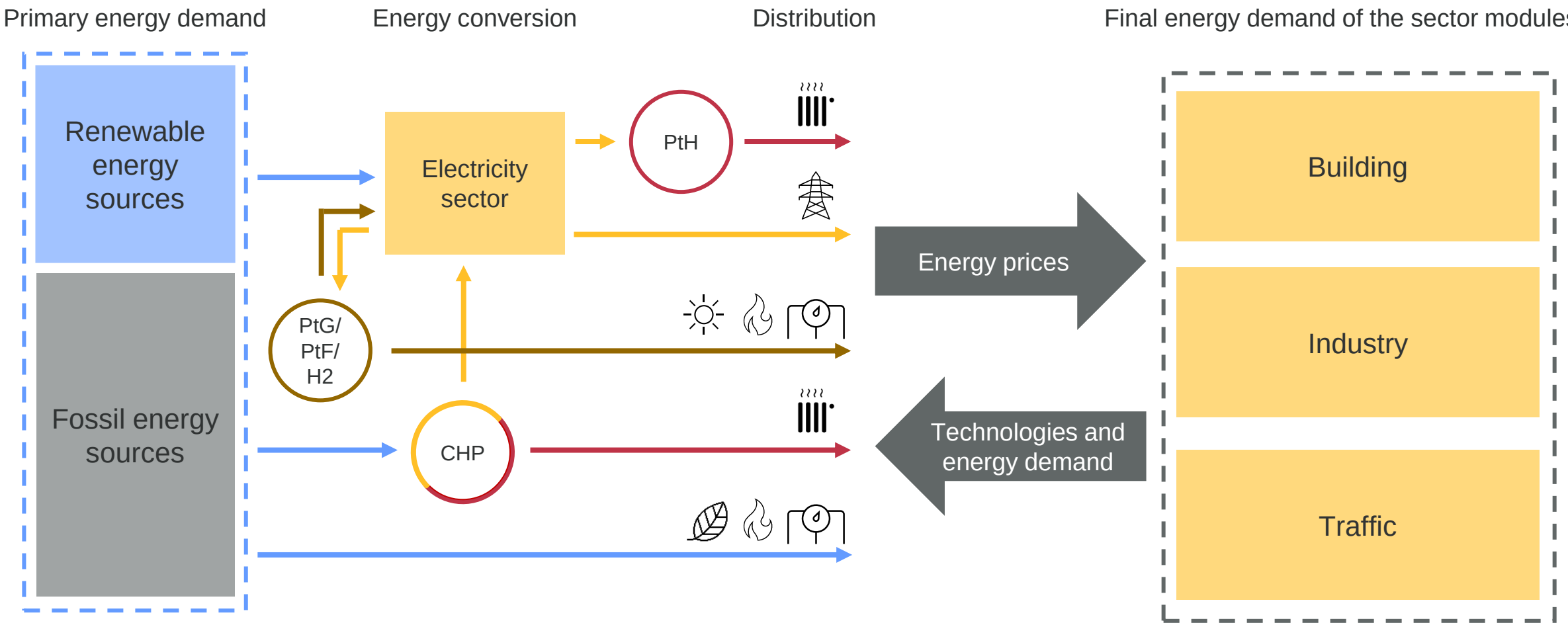


- The figure above shows the hourly feed-in of renewable energies, the power plant deployment decision and the net import balance for one week in February 2023.
- The week is initially characterised by significant power generation from onshore wind. During these hours, electricity is exported and the storage facilities are charged. At the end of the week, the wind decreases and the storage facilities are discharged. Electricity imports from abroad are necessary, as well as the use of oil-fired power plants.
- The lower figure shows the delta in the electricity mix as a deviation from the upper figure. With a higher availability of French nuclear power plants, the situations with electricity imports would increase. In addition, the use of oil-fired power plants could be dispensed with in individual hours.

3

Appendix: Model description and sources

DIMENSION enables an integrated view of several sectors



DIMENSION DISPATCH - Model overview

Input

Model parameters

- Hourly demand profiles per country (EU27+GB+CH+NO)
- Demand Side Management
- Technical and economic power plant parameters
- European power plant park
- Trade capacities between countries
- Regional feed-in profiles RE

Vote

- Total electricity demand DE
- Gas capacities and fuel prices
- RE capacities DE

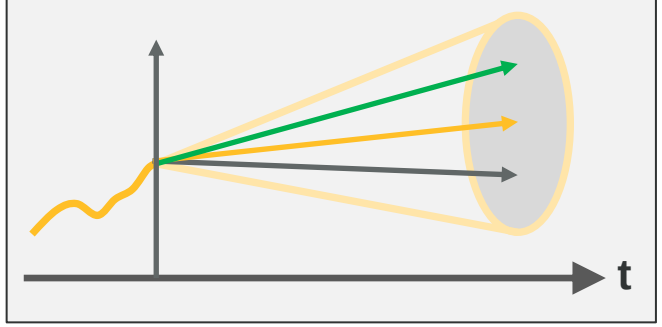
Political framework

DIMENSION DISPATCH

Cost-minimising power plant deployment modelling

Key years: **2022 and 2023**

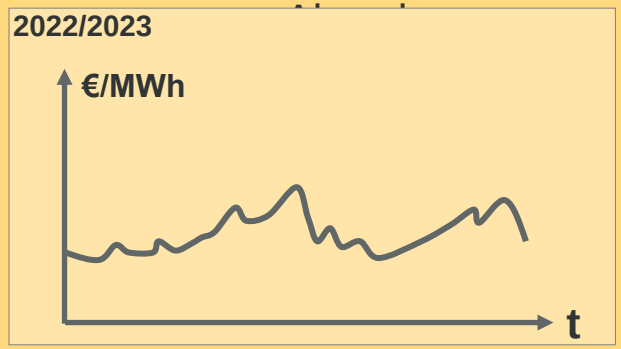
Sensitivities



Output

- Hourly power plant input, feed-in and cut-off RE
- Fuel consumption
- CO_2 emissions
- Imports and exports
- Losses

Electricity price time series Day



Sources

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BNetzA (2022a)	List of power plants of the Federal Network Agency, as of 31 May 2022. Link: https://www.bundesnetzagentur.de/DE/Fachthemen/ElektrizitaetundGas/Versorgungssicherheit/Erzeugungskapazitaeten/Kraftwerksliste/start.html
BNetzA (2022b)	Call for tenders under the KVBG. Link: https://www.bundesnetzagentur.de/DE/Fachthemen/ElektrizitaetundGas/Kohleausstieg/GebotsterminAugust2022/artikel.html
CME (2022)	CME Group. Coal (API2) CIF ARA (ARGUS-McCloskey), URL: https://www.cmegroup.com/markets/energy/coal/coal-api-2-cif-ara-argus-mccloskey.html
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RTE (2022)	Réseau de Transport d'Electricité. Perspectives pour le système électrique pour l'automne et l'hiver 2022-2023. URL: https://assets.rte-france.com/prod/public/2022-09/Analyse%20passage%20hiver%202022-2023.pdf
THE (2022)	Trading Hub Europe. Dutch TTF Gas Futures. URL: https://www.theice.com/products/27996665/Dutch-TTF-Gas-Futures/data?marketId=5132979&span=3

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