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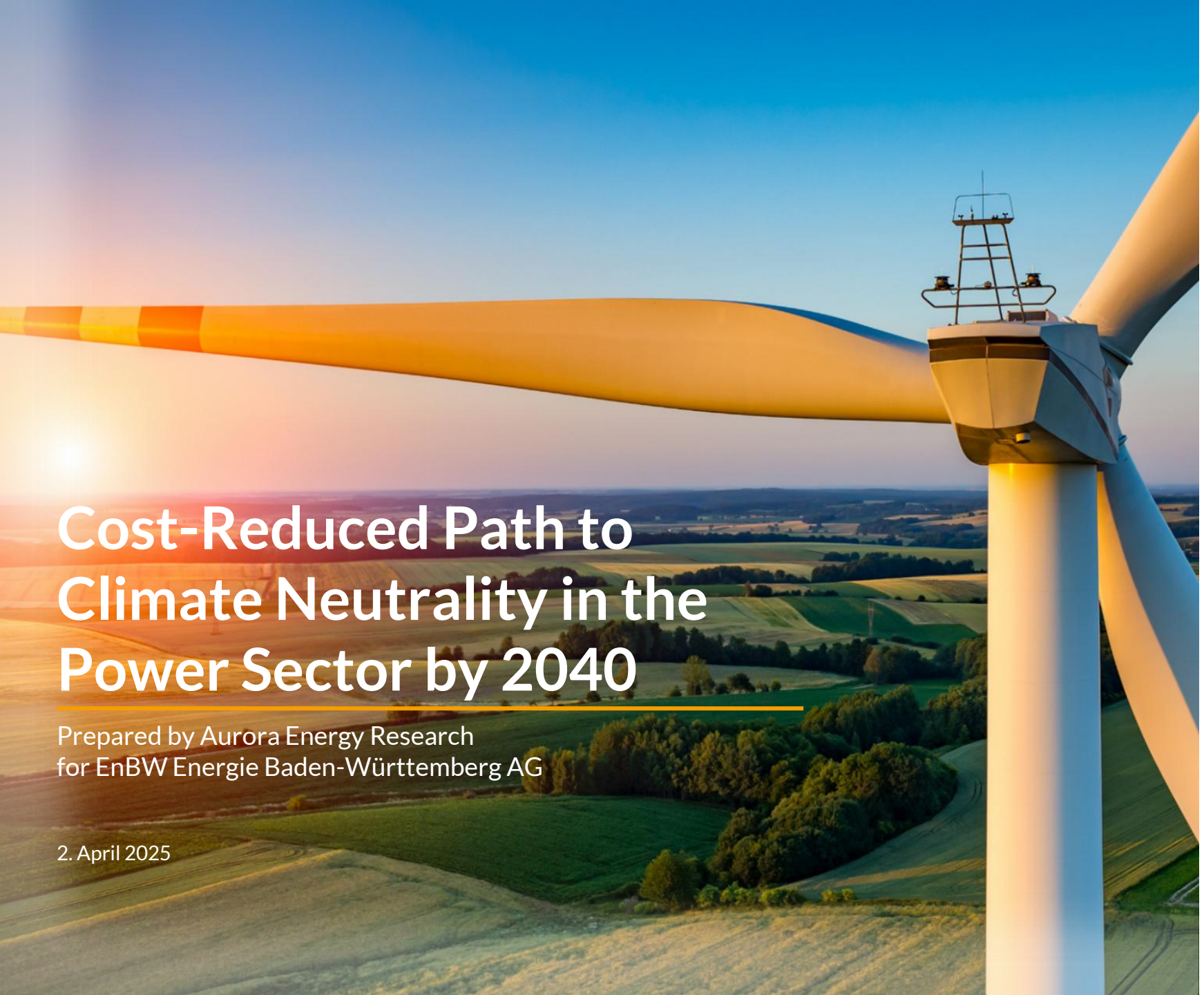
Study

Cost-Reduced Path to Climate Neutrality in the Power Sector by 2040



Cost-Reduced Path to Climate Neutrality in the Power Sector by 2040

Prepared by Aurora Energy Research
for EnBW Energie Baden-Württemberg AG

2. April 2025

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A system-wide cost reduction of the power sector can benefit the economy as whole

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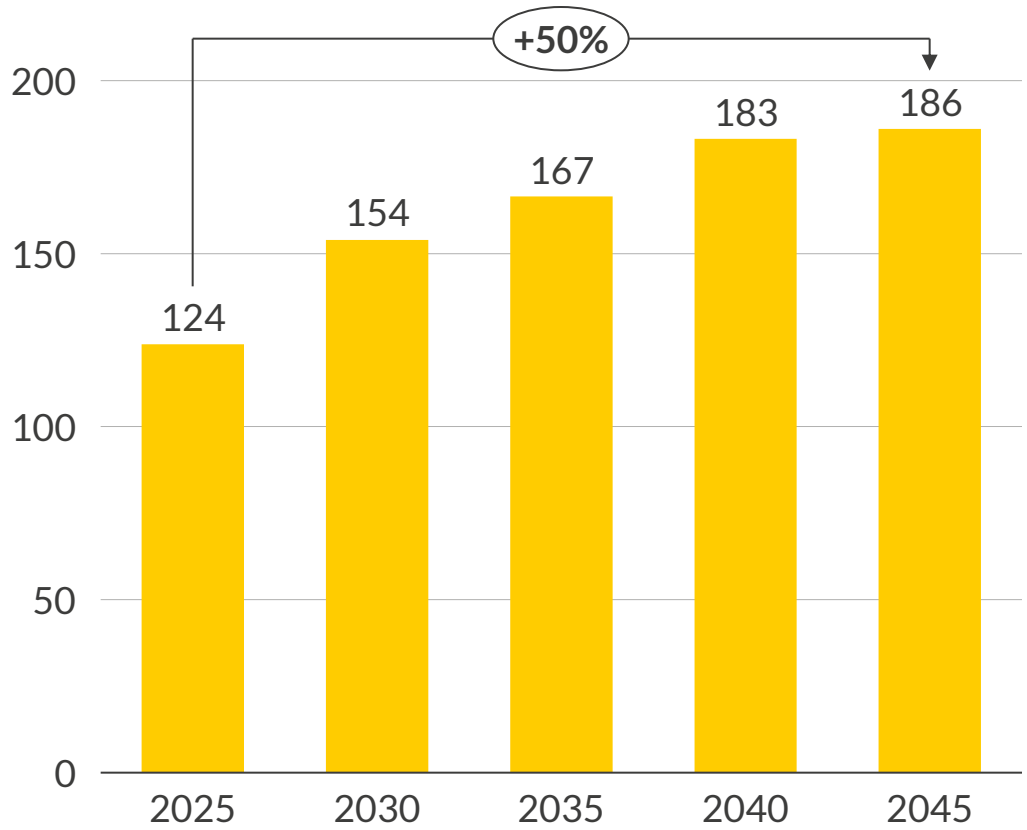
Initial Situation

- The decarbonisation of the electricity sector is a major challenge for politics, private businesses and consumers.
- The target of a **fully decarbonised electricity sector by 2040** has so far mainly been optimised with regards to **climate protection and security of energy supply.**
- A focus on affordability and cost efficiency is a necessary next step. As currently planned, the **annual system costs will increase by 50% by 2045** compared to today.
- A **holistic cost reduction** is indispensable to reduce the burden on the German economy, increase competitiveness, ensure public acceptance and accelerate the electrification across all key sectors of the economy.

System costs per year, NEP-System[1]

€ Bn., real 2023



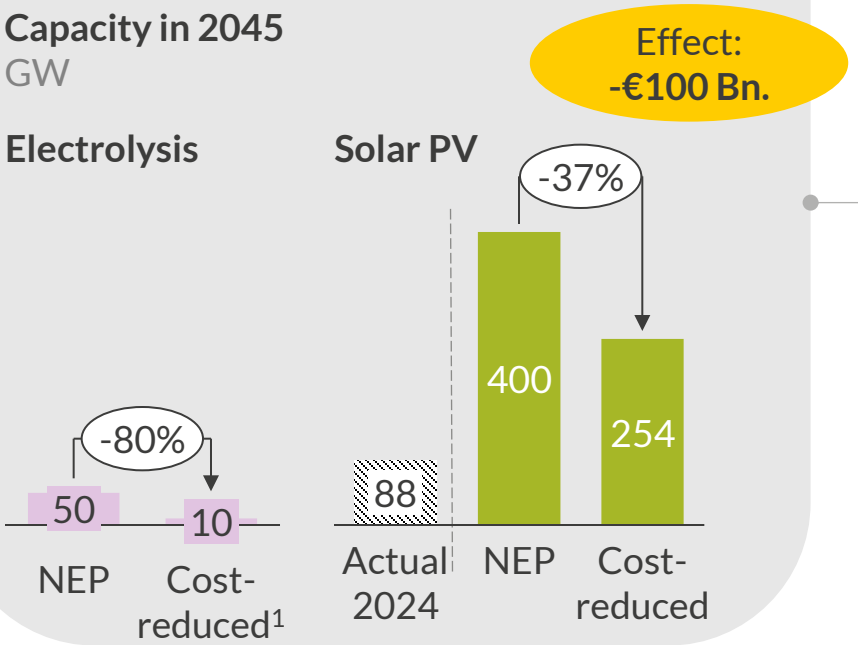
1) Corresponds to the Network Development Scenario NEP 2023 B

Source: Aurora Energy Research

Measure:
Reduce H_2-Electrolysis target and associated solar PV capacity

Results

- Reduction in the expansion of electrolysers and associated solar generation



Explanation

- The ambitious electrolyser capacity targets of 50 GW would increase system costs significantly.
- Imported green hydrogen remains lower cost than domestically produced hydrogen.
- Reducing electrolyser capacities allows for a reduction of solar PV expansion targets and associated grid investments.
- Reducing solar PV capacity is more efficient than onshore wind as wind availability is better synchronised with demand.

Insight

- Domestic production of H_2 at a scale foreseen in the NEP results in high system cost. A reduction in electrolyser capacity to 10 GW and the associated reduction in PV capacity **reduces system costs in the energy sector by around € 100 billion.**

1) Corresponds to the 'final scenario' in the study report

Source: Aurora Energy Research

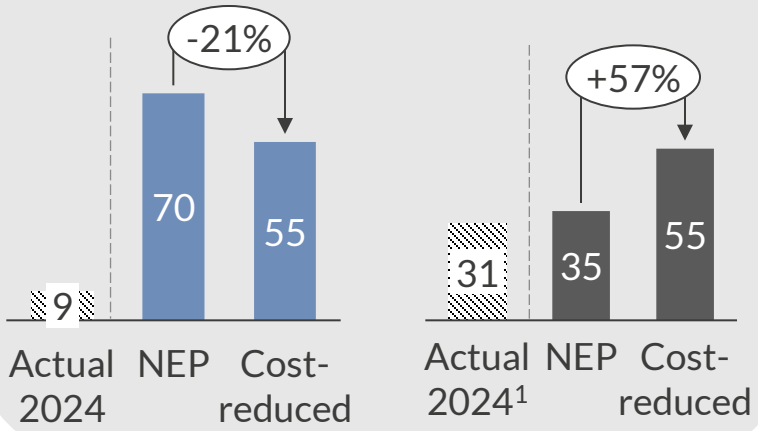
Measure:
Reduce offshore expansion target and increase gas/H2 capacity

Results

- Reduction of offshore wind target by 21% and increase in the capacity of gas/H_2 power plants

Effect: **-€80 Bn.**

Capacity in 2045
GW



Explanation

- Connection costs for offshore wind plants rise exponentially from a capacity of 55 GW onwards. This is due to the requirements of grid connection points that lie further inland.[2]
- The expansion of a further 20 GW of gas/H_2 power plant capacity can compensate for the offshore reduction while increasing security of supply.
- The power plants can also bridge 'Dunkelflaute' periods when both solar and wind generation is far too low to service demand.

Insight

Adjusting the offshore expansion target from 70 GW to 55 GW **results in a cost reduction of approx. €80 billion.**

1) OCGTs and CCGTs 2) The decrease in specific yields due to increasing wake effects is not yet taken into account here.

Source: Aurora Energy Research

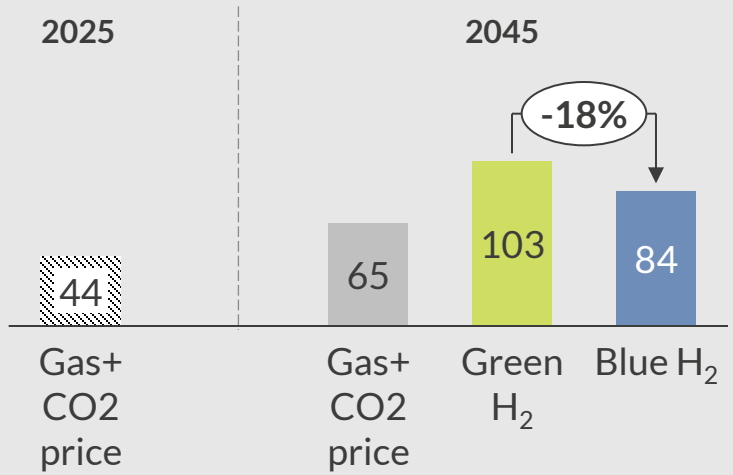
Measure:
Adjust the location of gas/H_2 power plants and enable blue H_2

Results

- Usage of blue H_2 instead of green H_2

Effect: **-€40 Bn.**

Gas and hydrogen import prices
€/MWh, real 2023



Explanation

- The usage of blue H_2 instead of green H_2 saves fuel costs.
- Locating gas/ H_2 power plants in the southern locations on the grid utilises existing grid and gas infrastructure and reduces grid bottlenecks.
- Optimised ratio of OCGTs und CCGTs further reduces system costs.

Insights

- A technologically and regionally adjusted **expansion of gas/H_2 power plants** combined with a switch to blue hydrogen reduces the system costs by **approx. €40 billion.**

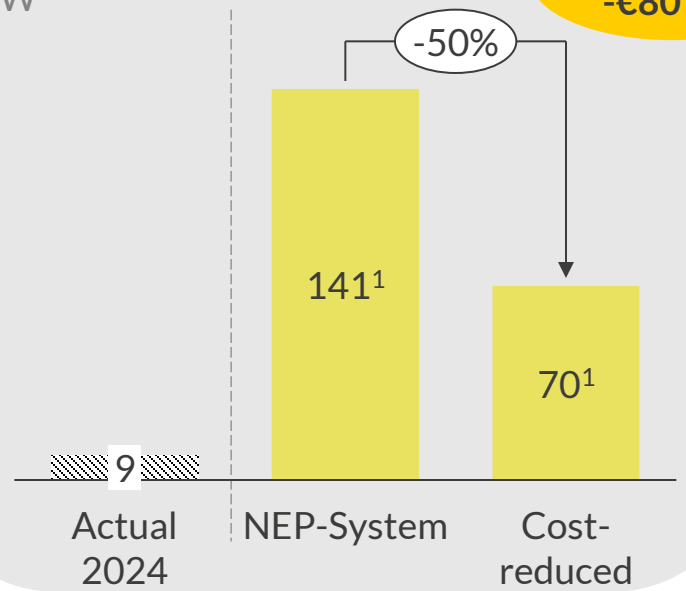
Source: Aurora Energy Research

Measure:
Reduce battery storage expansion target

Results

- Reduction of the expansion targets for battery storage by 50%

Battery storage capacity in 2045[1]
GW



Explanation

- The expansion of battery storage according to the network development plan is very high. In addition, battery storage systems are only suitable to a limited extent for providing capacity over longer periods of time.
- Gas/H_2 power plants fulfil this task more cost-efficiently and flexibly.
- The addition of gas/H_2 power plants means that less batteries are needed in the system while avoiding loss of load, and dependency on high-cost imports.
- Ultimately, the development of batteries will be market-driven however.

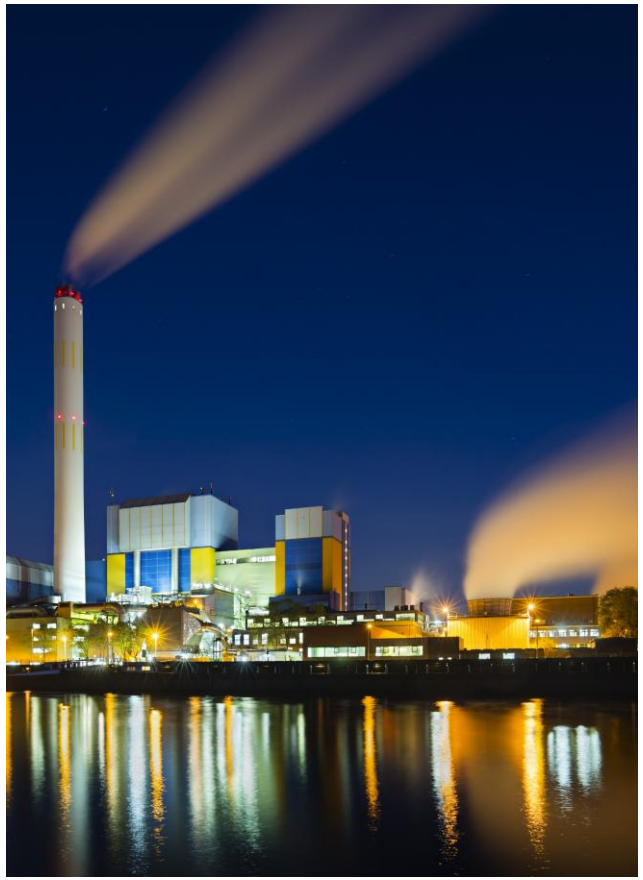
Insight

- Battery storage and gas/H_2 power plants complement each other well technologically. An adjusted ratio of the two leads to a cost reduction of **approx. € 80 billion.**

1)This corresponds to the connection capacity of batteries. The capacity in the NEP system corresponds to 850 GWh and in the cost-optimised system to approx. 420 GWh.

Source: Aurora Energy Research

Sensitivity:
Adjust system sizing for adapted demand expectations



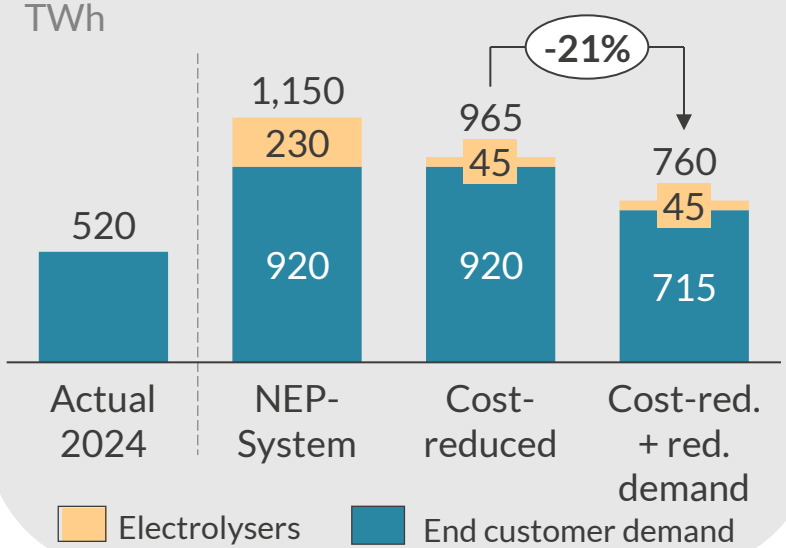
Results

- Adjusted dimensioning of the energy system in line with lower demand expectations

Effect: up to **-€400 Bn.**

Electricity demand in 2045[1]

TWh



Explanation

- If base demand is reduced compared to the network development plan, capacities can be further adjusted.
- Expectations for future end customer demand have fallen since the 2023 NEP was drafted. We tested a a reduction of 20-25% by 2045. The sensitivity shows that this would reduce total system cost significantly.
- This illustrates the importance of demand projection for system planning purposes. This is to prevent over-dimensioning of capacities and grids

Insight

- The system cost are highly dependent on underlying electricity demand assumptions. In addition to techno-economic improvements, adapting the dimensioning of the electricity sector system can **save approx. €400 Billion.**

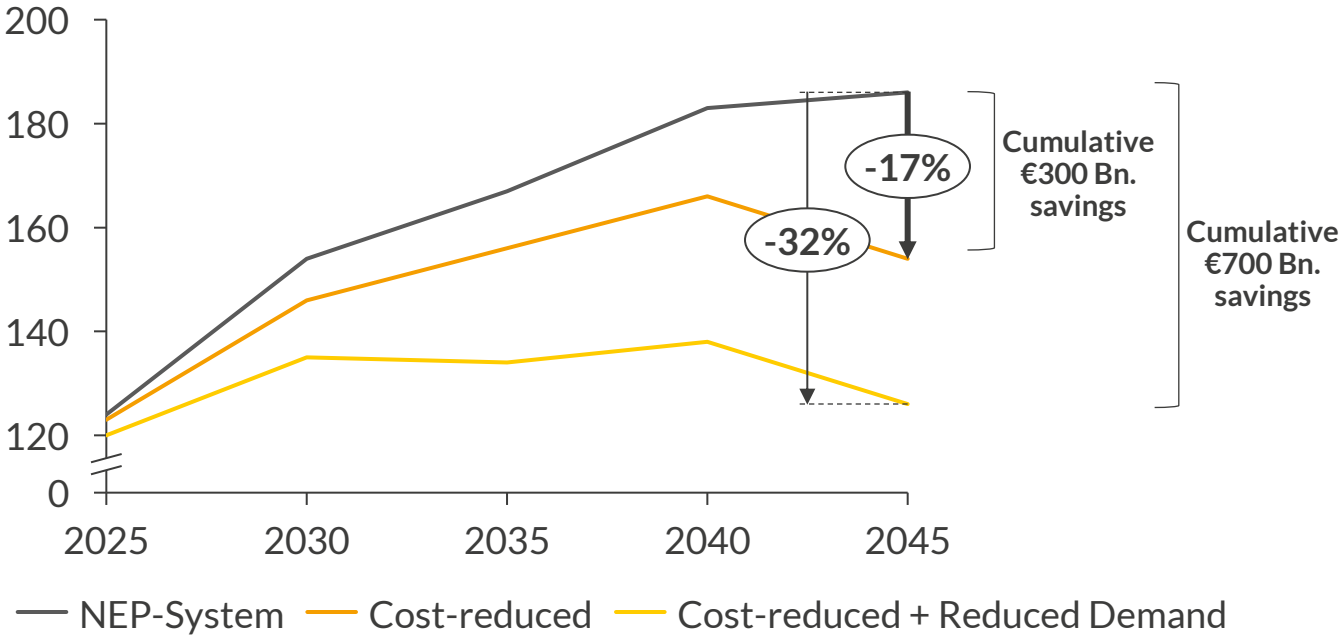
1) Including self-consumption

Source: Aurora Energy Research

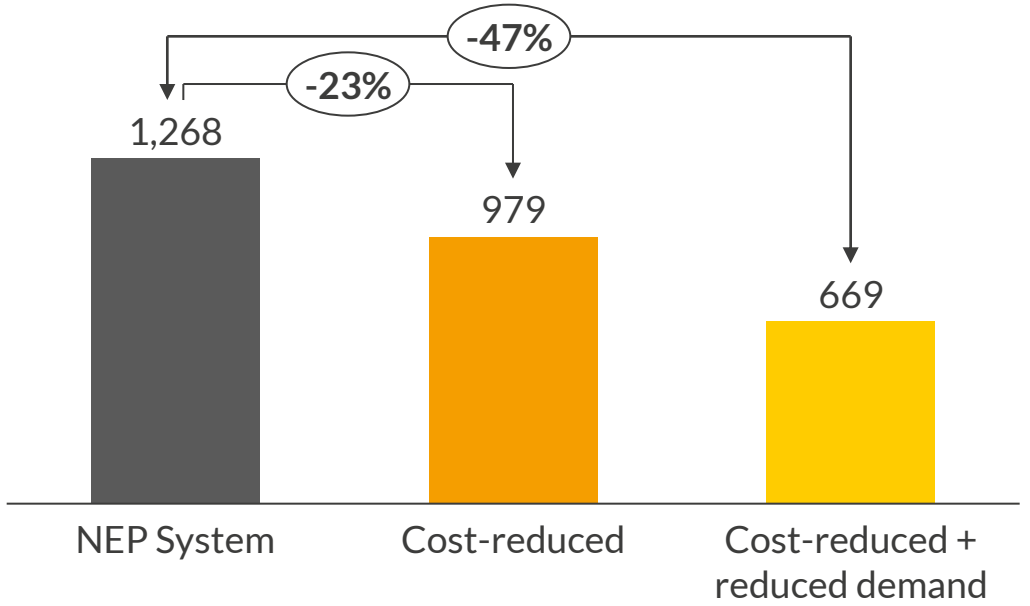
Through the outlined measures restructuring the total power system costs can be reduced significantly

Key study results

Annualised system costs
€ Bn., real 2023



Total investment costs 2025-2045
€ Bn., real 2023



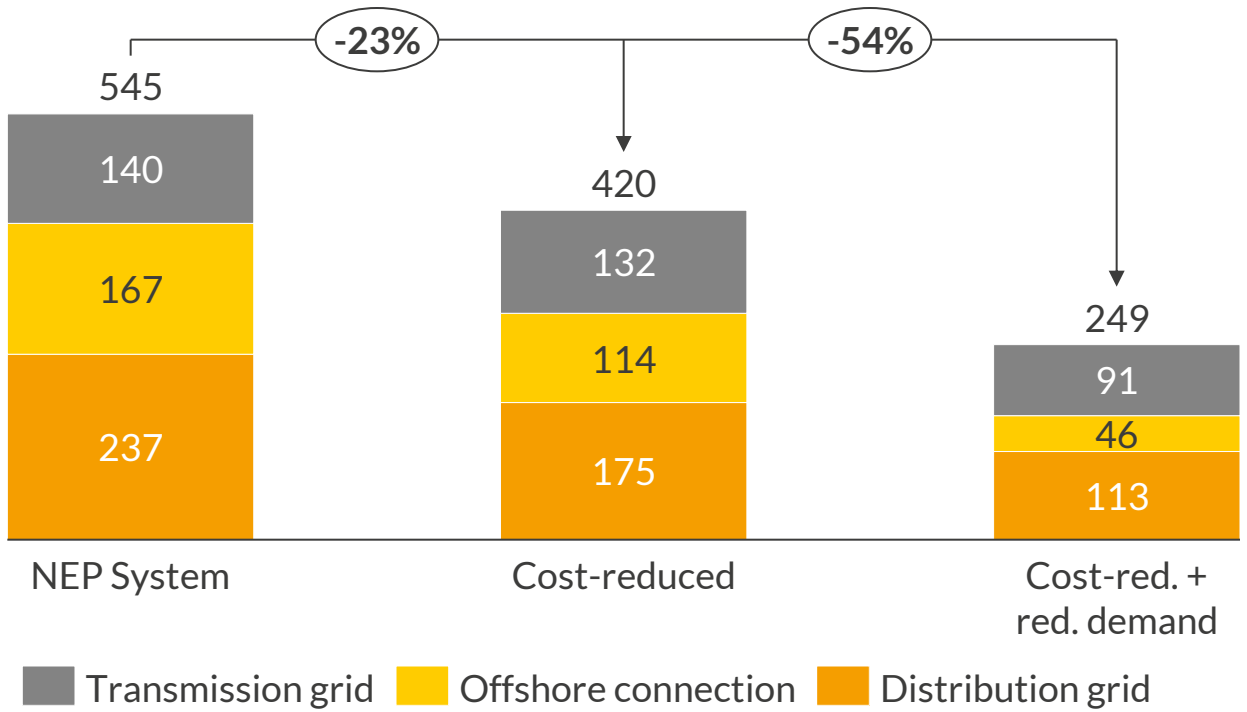
Insight

Without adjusting German climate target and even improving security supply of, **annual system costs in the power sector can be reduced by up to 17% and investments by 23% by 2045.** In case of reduced demand expectations cost reductions can reach 32% and 46% respectively.

Source: Aurora Energy Research

The reduction in investment is mainly driven by the reduction in grid investment

Development of grid investment costs 2025-2045
€ Bn., real 2023



Explanation

- The greatest saving in the cost-reduced system results from the reduction in solar PV capacity in the distribution grid.
- Additionally, offshore wind capacity reductions and associated connection costs, reduce grid costs significantly.
- In the cost-reduced system with lower demand expectations, there is a reduction in load-related grid expansion as well as a reduction in renewables-related grid expansion.

Insight

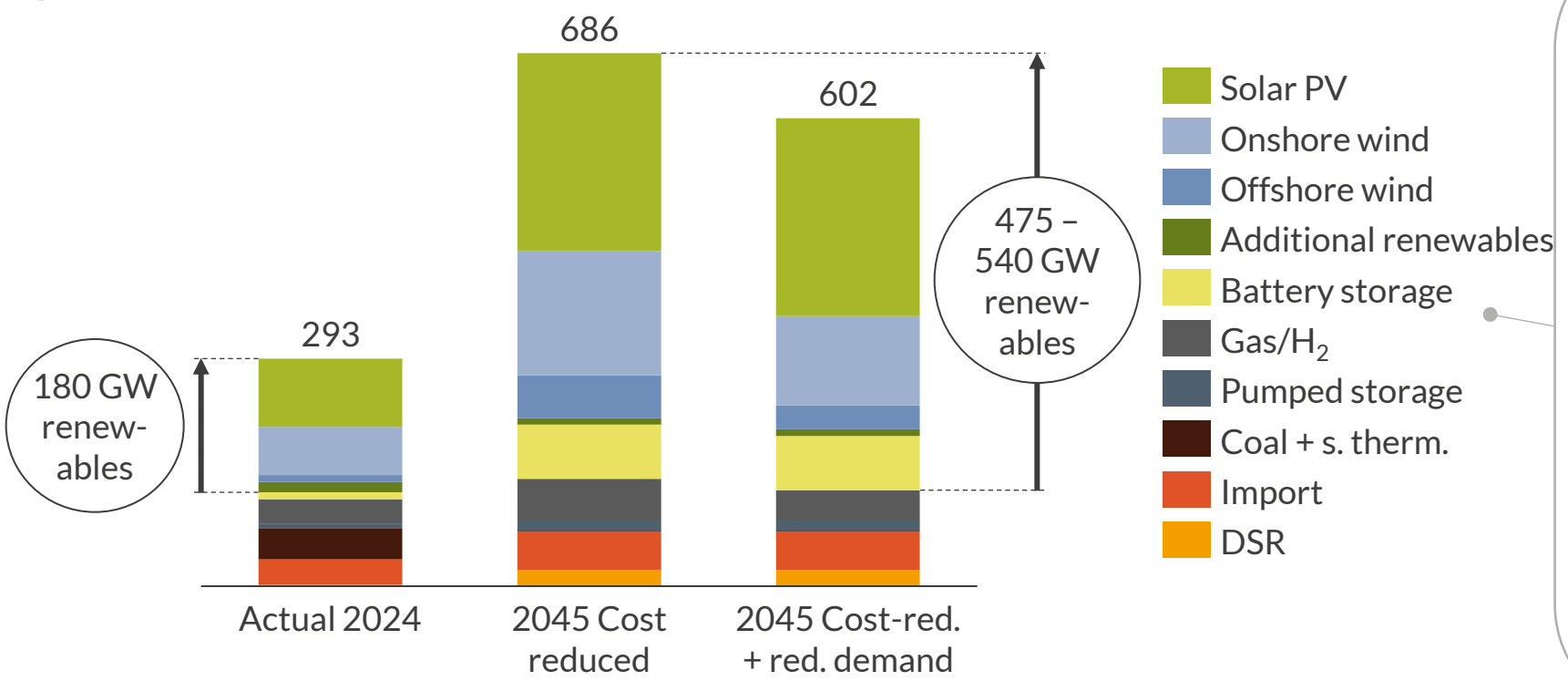
In the **cost-reduced system** grid investments can be reduced by approx. **€125 Billion.** In the **cost-reduced system with reduced demand,** investment costs decrease by an **additional €171 Billion.**

Source: Aurora Energy Research

The adjusted transformation remains ambitious and relies on renewables

Development of the generation mix

GW



Explanation

- Renewable capacity would still more than double by 2045 to achieve the capacity mix in a cost reduced system. This makes renewables and batteries indispensable for this scenario.
- For the 2045 generation mix with reduced demand, there are several equivalent options with regard to the capacities of offshore and gas/ H_2 power plants. The system cost savings remain constant, but the investment and operating cost shares shift. In particular a balance between thermal and offshore wind capacity will need to be found.

Insight

Even with the implementation of the cost-educed measures the **basic principles of the energy transition remain unchanged:** accelerated expansion of wind, PV and battery storage, while bridging 'Dunkelfaute' moment and grid bottlenecks via H_2 power plants.

Source: Aurora Energy Research

Climate targets can be achieved at significantly lower costs in the power sector

The **climate target** can be achieved at **lower system costs in the power sector with savings of €300 to €700 billion.**

The **savings** are particularly reflected in the **required investments**, which can be reduced by a quarter to a half.

The greatest absolute savings of up to €700 Bn. are achieved when the **system is also appropriately dimensioned.** A **demand-adjusted** and economically reduced power system helps **stabilise end-customer prices.**

The **expansion of renewables, hydorgen power plants and grids** must **continue at a high pace** to meet Germany's climate targets. A cost reduction promotes public acceptance, accelerates electrification and relieves the national economy.

The urgency of climate targets and long lead times for some investment, mean that it is important **to set the course for a low cost energy transition now.**

Source: Aurora Energy Research