EU COAL PHASE-OUT 2030
FINAL RESULTS

Agora Energiewende

16.09.2021

Agenda

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EXECUTIVE SUMMARY

Methodology & scenarios

SCENARIO DESIGN
- Definition of political scenarios
- Basis for power market modeling

ASSUMPTIONS
- Techno-economical parameters
- RES, coal trajectories
- CO_2 prices

MODELING
- Power plant dispatch & investment up to 2030
- Development of capacity and generation mix

RESULTS
- Incremental generation costs* (ICG)
- Investment volumes
- CO_2- and other emissions

MODELING APPROACH

EU-27 countries aggregated and major coal-countries as focus group („Coal-6“): BG, CZ, DE, PL, RO, SI**

REGIONAL SCOPE

40 % reduction scenario

40 % Policy mix (40 % PM)

Policy mix – “40 % Scenario” implies the former EU 2030 carbon mitigation ambition level. No significant market based coal exit or RES expansion. CO_2 price based on EC Reference 2016 sc. (35 €/t in 2030).

55 % reduction scenarios

55 % Policy mix (55 % PM)

Policy mix - complete **coal exit until end of 2030** and increased, policy-driven RES expansion as well as elevated CO_2 prices (54 €/t in 2030 based on TYNDP2020).

55 % Market based coal exit (55 % MCE)

Market based coal exit - coal exit trajectory resulting from relying on an economic decommissioning of all coal plants driven by the CO_2 price. RES expansion remains policy-driven.

55 % market based coal-to-clean (55 % MCTC)

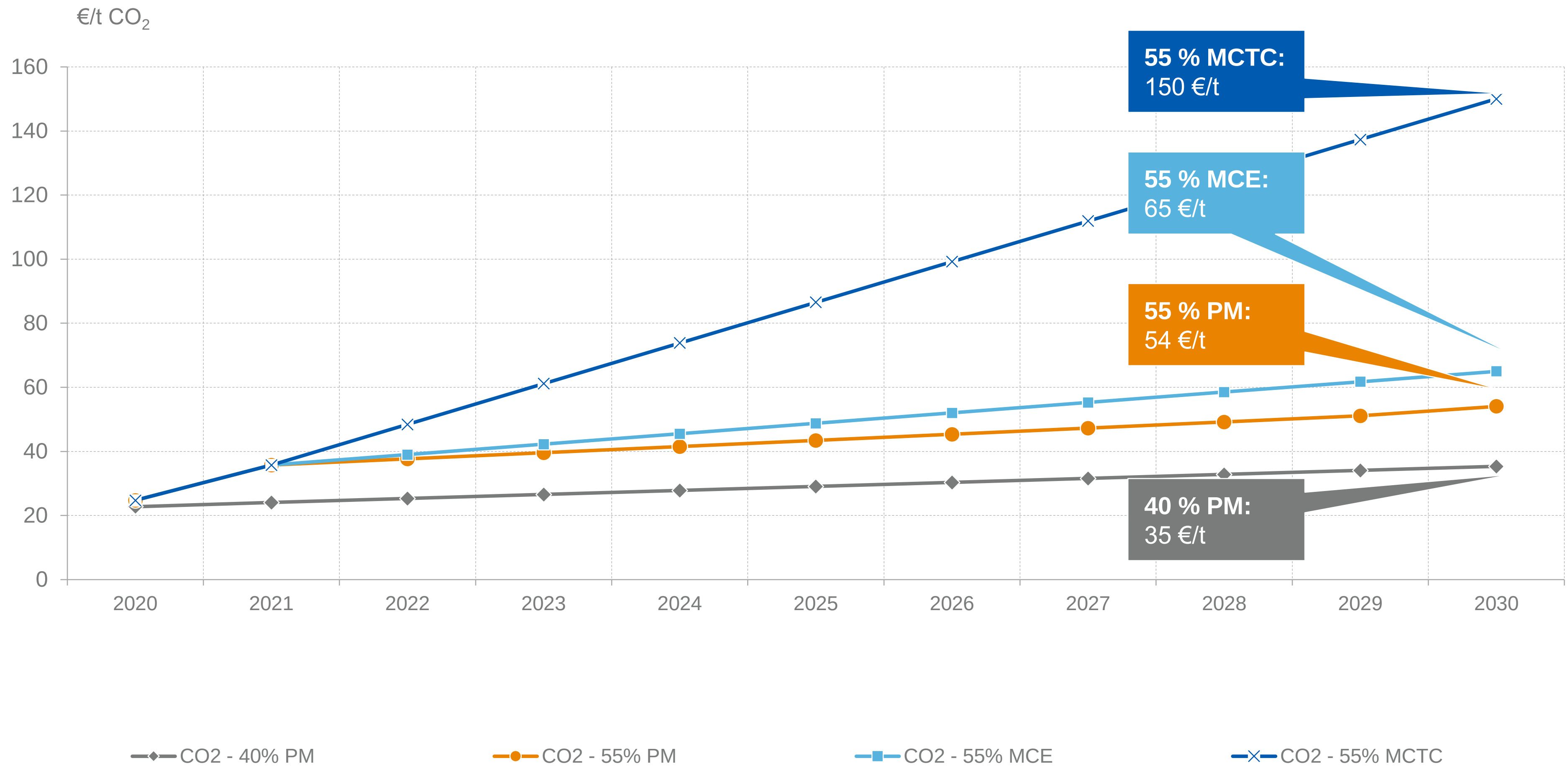
Market based coal exit and RES expansion - further explores the requirements and implications of a CO_2 price-driven coal-to-clean transformation.

SCENARIOS

* For an economic comparison of scenarios the differences in generation cost are of main relevance. This study looks at an indicator called “Incremental generation costs”. For a detailed explanation see methodology section. ** excl. island markets of Malta, Cyprus.

CO_2 price* trajectories

40 % and 55 % PM scenario trajectories based on projections in reference sources (EC2016 Ref / TYNDP DE sc.). 55 % MCE & 55 % MCTC trajectories result from heuristically iterations as described in the methodology section.

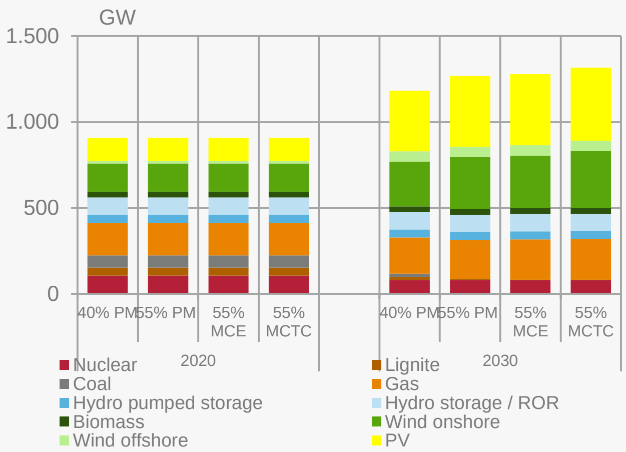


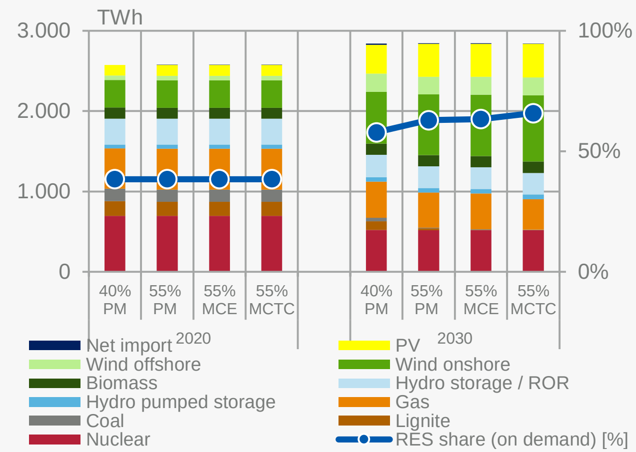
* real 2021 prices

Key results – EU

Capacities

- Phase out of remaining 38 GW of coal capacities in 55 % scenarios
- Substitution with 100 GW mix of wind onshore, PV & minor flexible gas capacity



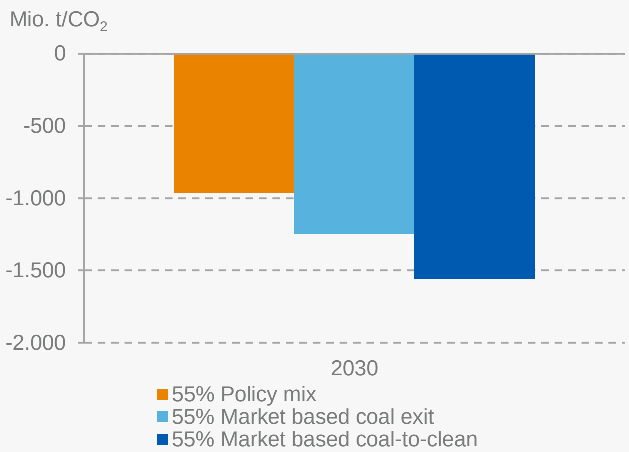


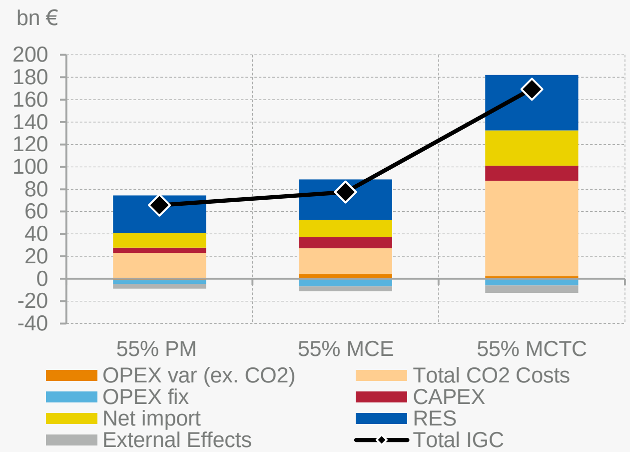
Generation

- Less carbon-intensive EU generation mix in the 55 % scenarios
- RES shares increase by over 5 percentage points compared to 40 % PM

Total CO_2 emission deltas

- Significant CO_2 savings in 55 % scenarios over the decade
- Incremental effects of higher EU ETS prices are limited by reduced coal-capacity over time





Total IGC deltas

- IGC in a similar range in the 55 % PM and 55 % MCE scenarios
- Much higher CO_2 price in 55 % MCTC drives IGC up. However, related costs do create additional public income

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Conclusions

A clear pathway to „-55 % in 2030“	The trajectory to reach the 2030 target is clear: A phase-out of the remaining 38 GW (in 2030) coal capacities in the EU countries in 2030 is met with 100 GW additional wind and PV. Additional costs to the consumer versus the baseline remain limited in the range of 3-7 €/MWh with an average of 5 €/MWh.
A coal exit until 2030 is feasible	Modelling indicates that a full coal exit until 2030 is possible with additional market based deployment of gas of around 15 GW and overall investment volumes of 82 bn €. Additional reserves would be necessary to cover national peak loads nationally or secure non-standard weather years. This would imply building on average two additional gas-based power plants per year in between 2024 and 2030 in the EU, which seems feasible but given the timeline would need a fast decision on governance and incentive structures.
A strong ETS price leads the way	Three core policy approaches are available to incentivize necessary developments: increased ETS-carbon pricing, national policies to govern coal phase-outs and support of renewable expansion. The higher the European ambition in regards to ETS pricing, the fewer national policies are necessary to reach the target. The currently assumed ambition to increase the reduction target and reform the ETS* already significantly reduces the need for additional national incentives, but not completely.
Market-driven coal exit on the doorstep	The modelling indicates that sustained prices above 65 €/t alongside the necessary RE expansion could lead to a full and market-driven coal phase-out. Any national regulation on coal phase-out should therefore take care not overcompensate plant closures to even slow down this development.
Renewable support likely to remain until 2030	With increasing renewable penetration, the ability to integrate additional renewable volumes decreases. Therefore, to fully phase out support mechanisms for renewables a much higher CO_2 price, in the range of up to 150 €/t, would be necessary. This would lead to major distributional challenges (increasing power prices vs. increasing revenues from CO_2 auctions), which would be difficult to resolve.

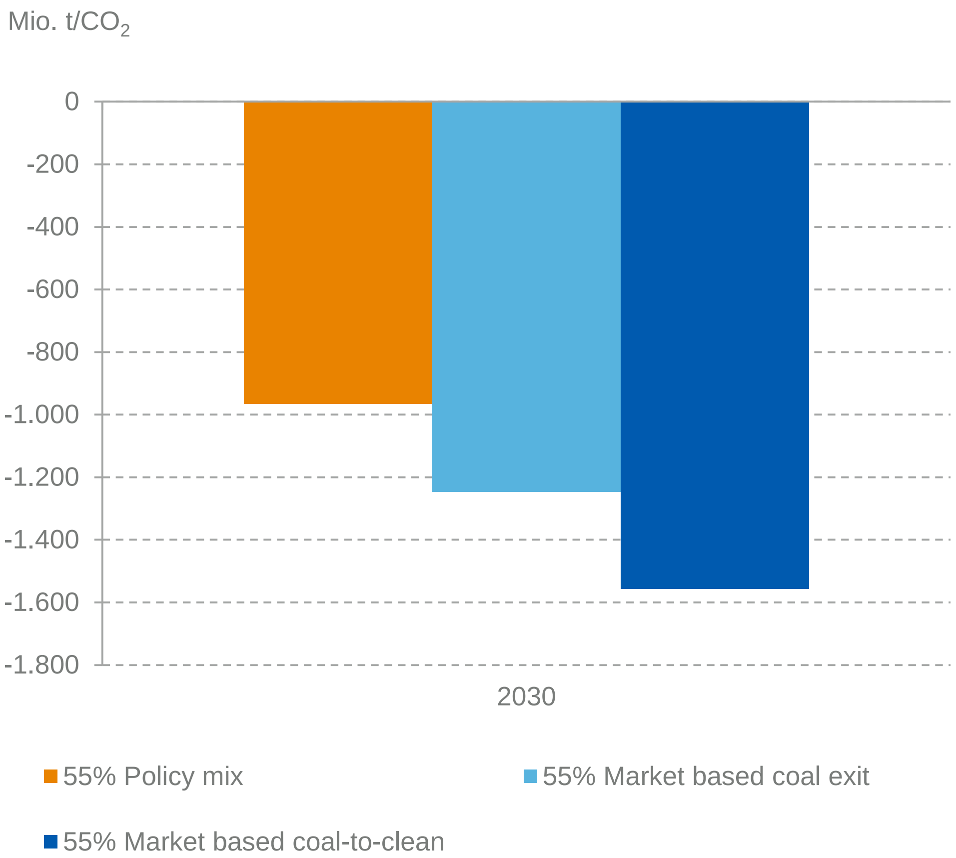
* Projections ranging from ~54 €/t (entso-e TYNDP2020 Distributed Energy Scenario) to ~70-80 €/t (EC ETS amendment proposal annex, COM(2021) 551 final) in 2030.

RESULTS FOR EU

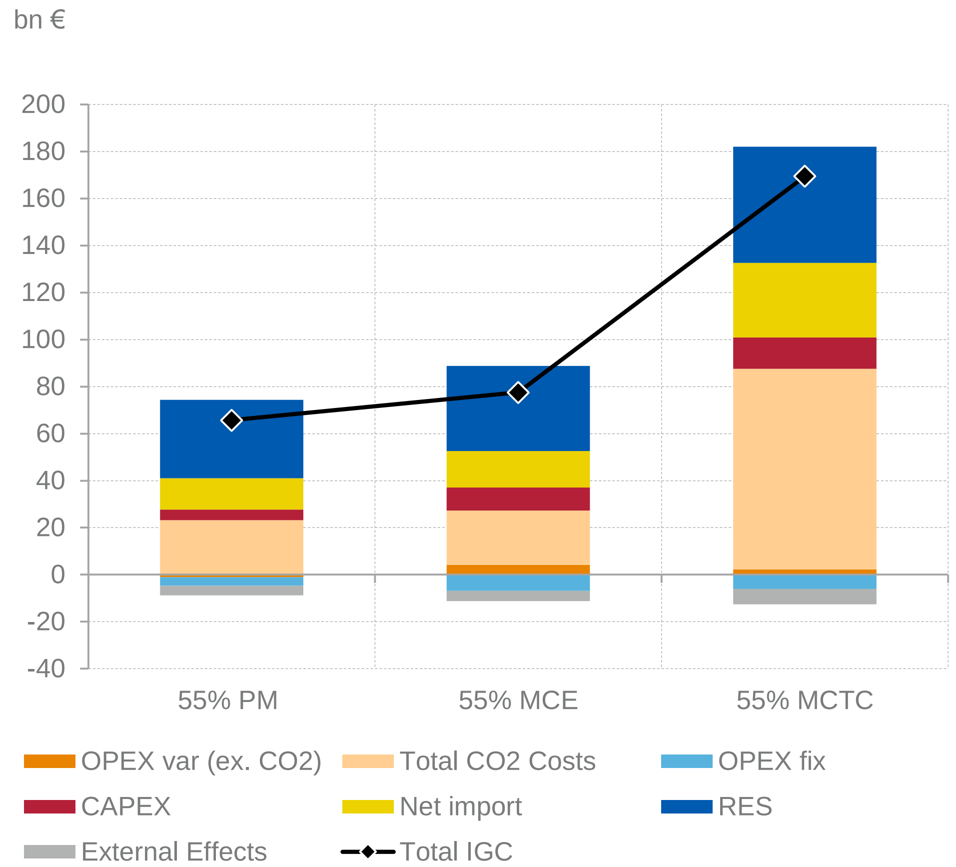
Total emissions & system costs – EU

All coal-exit scenarios result in significant reduction of CO_2. Incremental effects of higher CO_2 prices are diminishing as coal capacity is decreasing. Additional IGC are in a similar range in the 55 % PM and 55 % MCE scenarios, while higher CO_2 price in 55 % MCTC drives IGC up significantly at EU level as it affects markets without potential for coal substitution.

Total CO_2 emissions (2020-2030)
Deltas minus 40 % PM



Total IGC (2020-2030)
Deltas minus 40 % PM

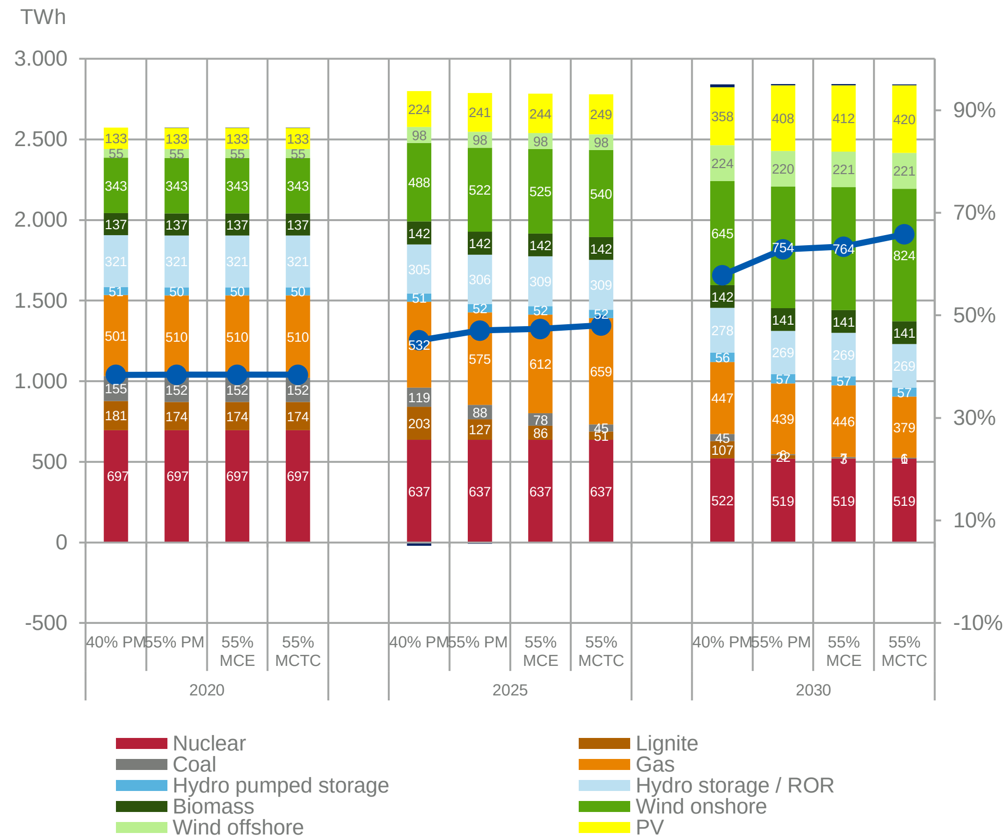


Capacity & generation - EU

Compared to the 40 % PM scenario, the 55 % scenarios see an accelerated reduction of remaining coal capacities, which are substituted with a mix of wind onshore, PV & gas units (flexibility demand). The EU generation mix becomes less carbon-intensive in the 55 % scenarios and RES shares increase by over 5 percentage points by 2030, and more in MCTC due to additional market based expansion.

Capacities

Generation



Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM).

PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

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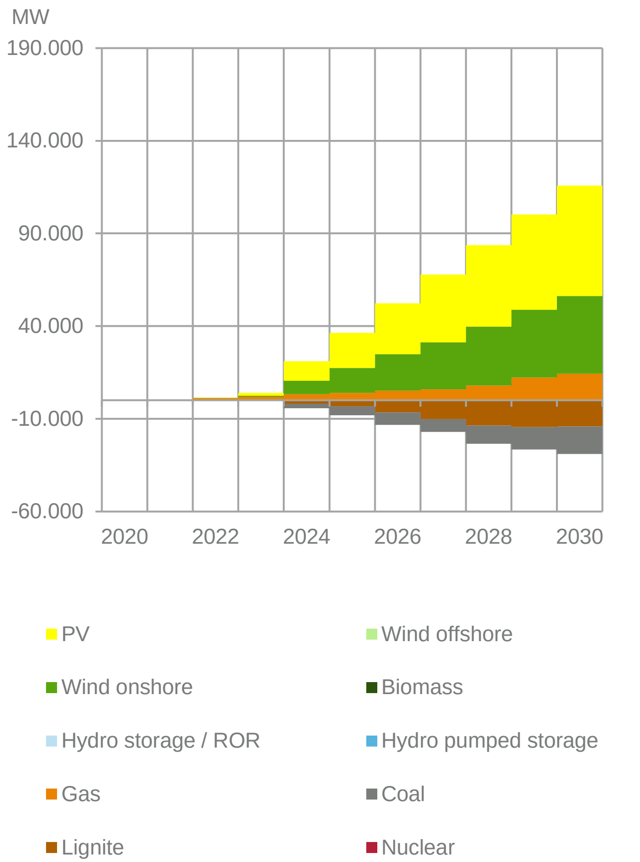
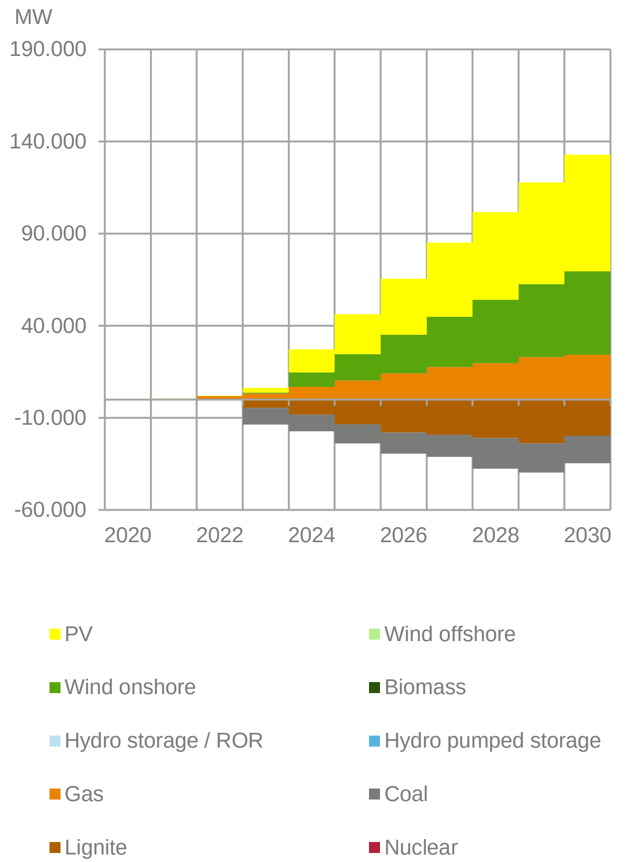
Scenario differences: Installed capacities at EU level

In all 55 % scenarios, the remaining coal capacities are substituted with a mix of wind onshore, PV and gas. Compared to the 55 % PM, the 55 % Market based scenarios see an earlier and steeper capacity reduction of coal units driven by higher CO_2 price trajectories. Higher CO_2 prices also trigger additional market based RES expansion, especially in the 55 % Market based coal-to-clean scenario.

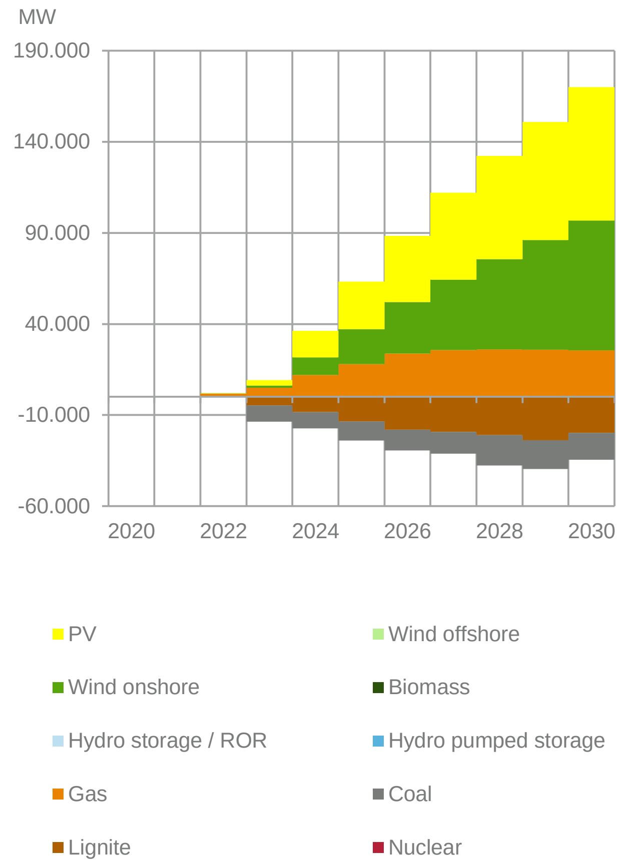
55 % PM



55 % MCE



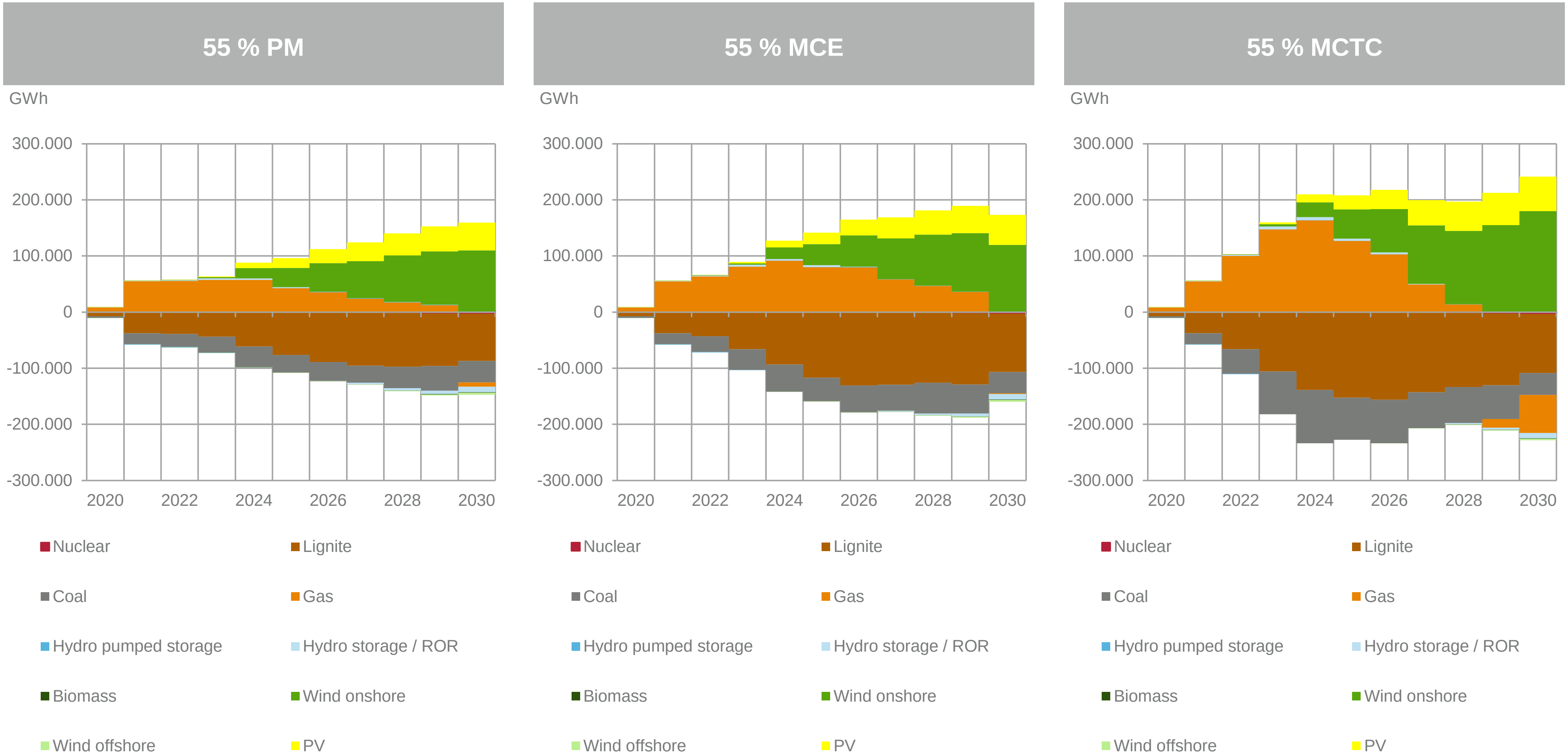
55 % MCTC



Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Scenario differences: Power generation at EU level

Earlier decommissioning and lower utilization of the remaining coal-fired units trigger temporary increased gas-based generation (mid-term), especially in both 55 % Market based scenarios. In the long run, coal-based generation is compensated by PV, wind onshore and some gas-based generation. All scenarios lead to an increase in renewable energy generation of over 150 TWh by 2030.

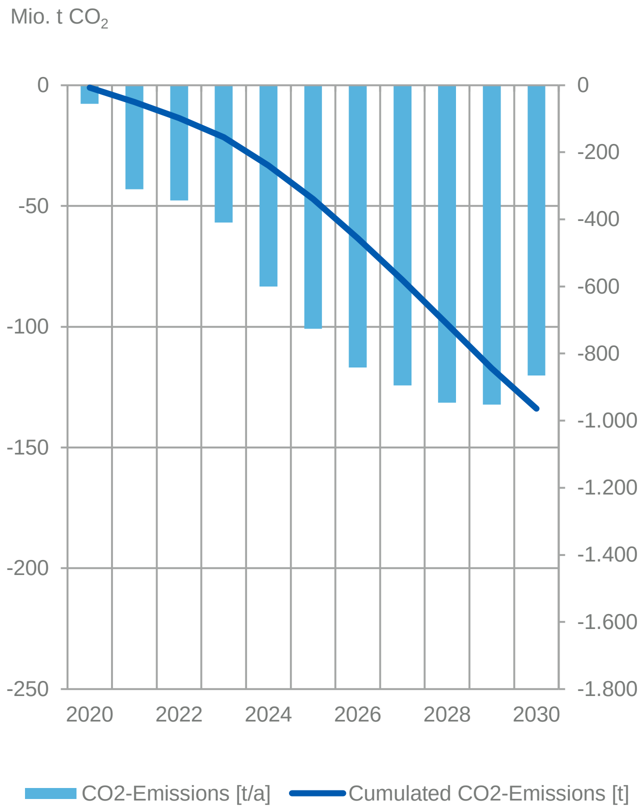


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

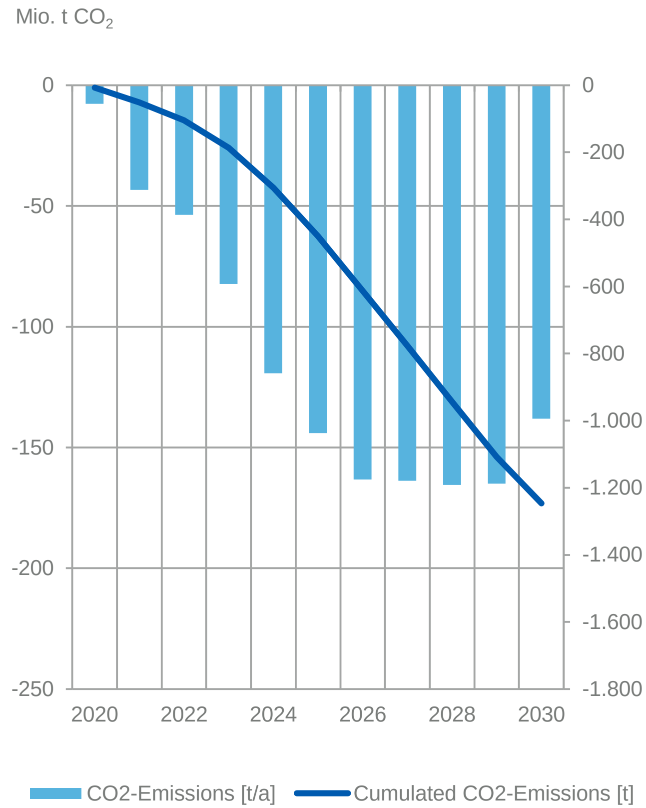
Scenario differences: CO_2 emissions at EU level

All 55 % scenarios lead to significant CO_2 savings compared to the 40 % PM scenario. Until 2024, the additional reduction is driven only by the CO_2 price. In total, the 55 % PM results in CO_2 reduction of 964 Mio. t by 2030, the 55 % MCE by an additional 282 Mio. t of this reduction. In the 55 % MCTC scenario a larger (compared to 55% PM) reduction 594 Mio. t CO_2.

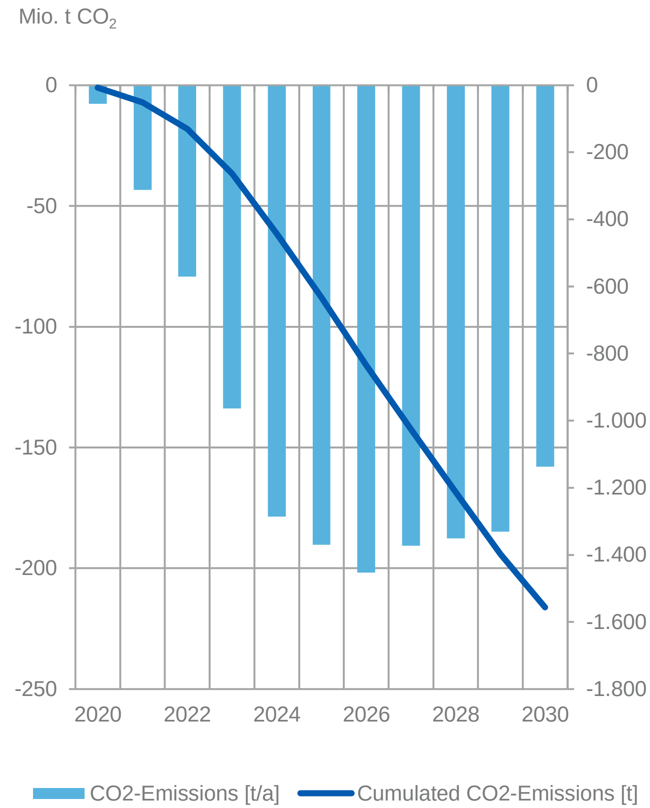
55 % PM



55 % MCE



55 % MCTC

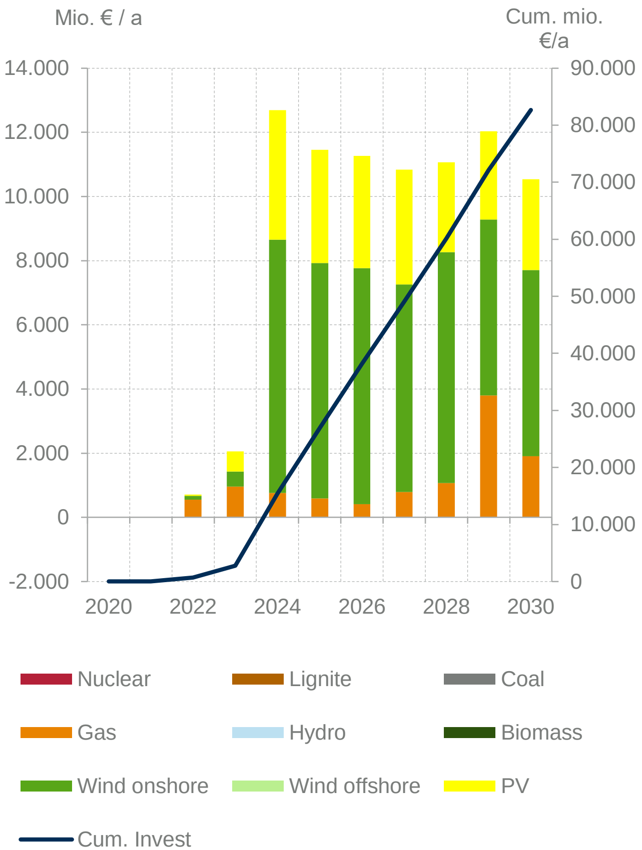


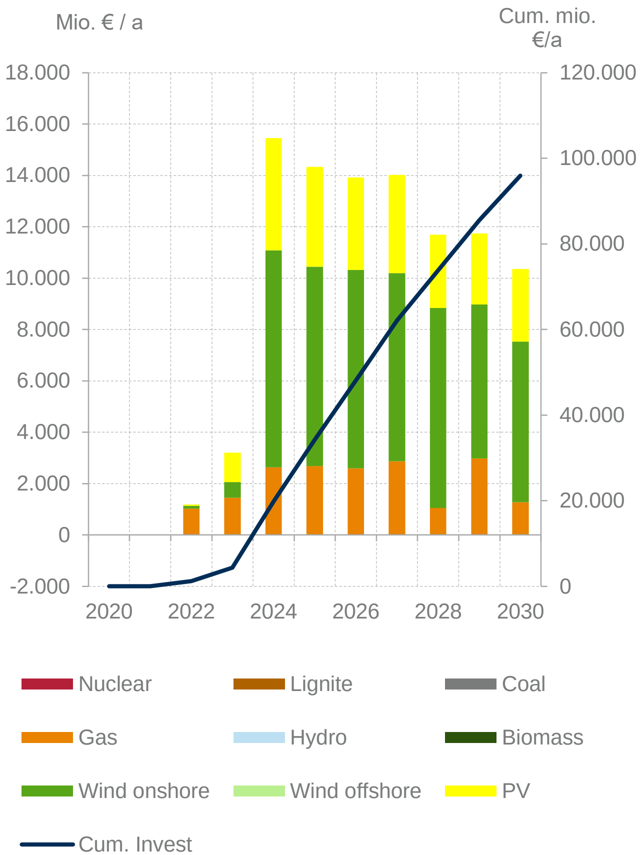
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

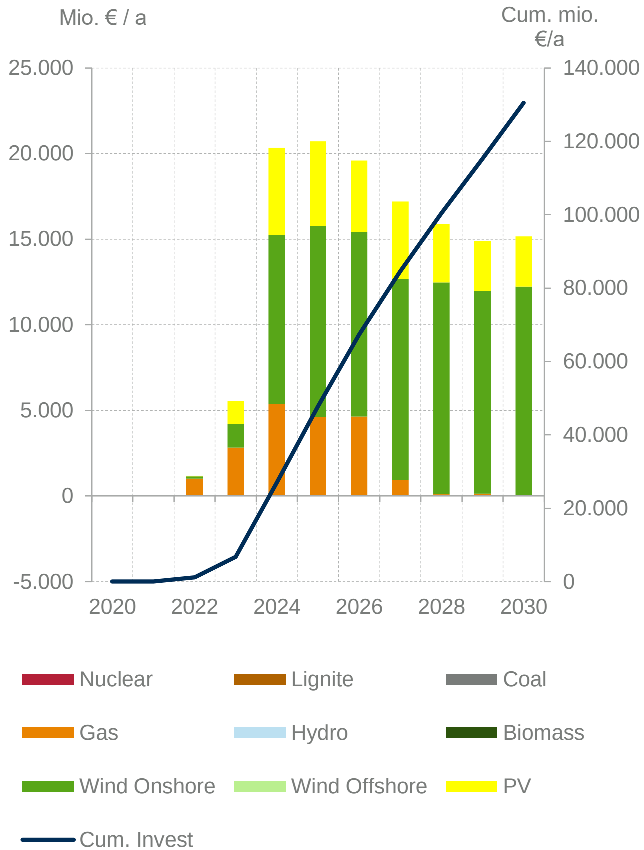
Scenario differences: Investment volumes at EU level

Required additional investments into the power-generating infrastructure of the EU accumulate to 83 bn € (55 % PM), 96 bn € (55 % Market based coal exit) and 131 bn € (55 % Market based coal-to-clean) until 2030. Additional investments are mainly channelled towards onshore wind and PV assets and, to a lesser extent, into gas-based capacities.

55 % PM	55 % MCE	55 % MCTC





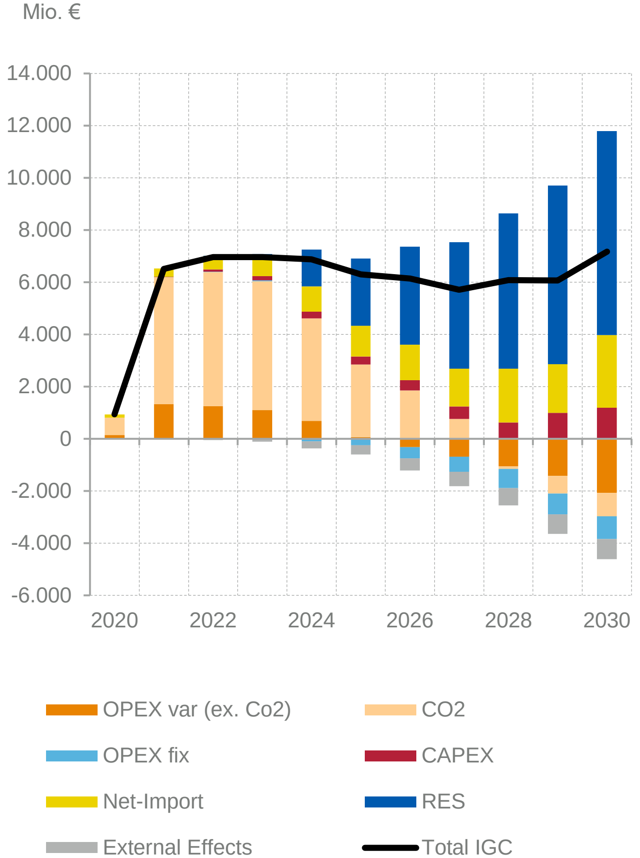


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

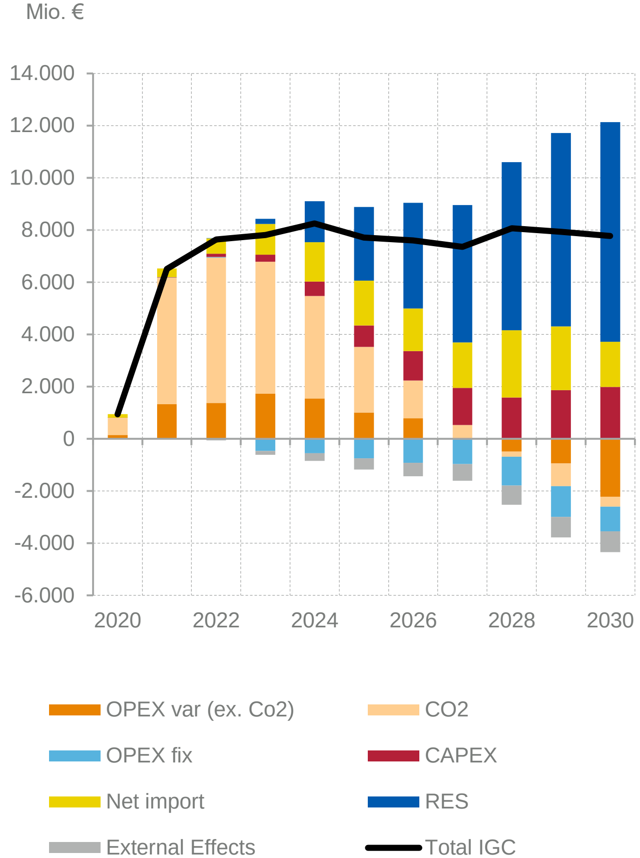
Scenario differences: Incremental generation costs at EU level

Annual incremental generation costs are higher in all 55 % scenarios. Main drivers are higher CO_2 costs (mid-term), and (long-term) RES & import costs which dominate diverse savings in OPEX and external effects by the end of the decade. Note: Revenues from auctioned CO_2 certificates can also be seen as a source of income.

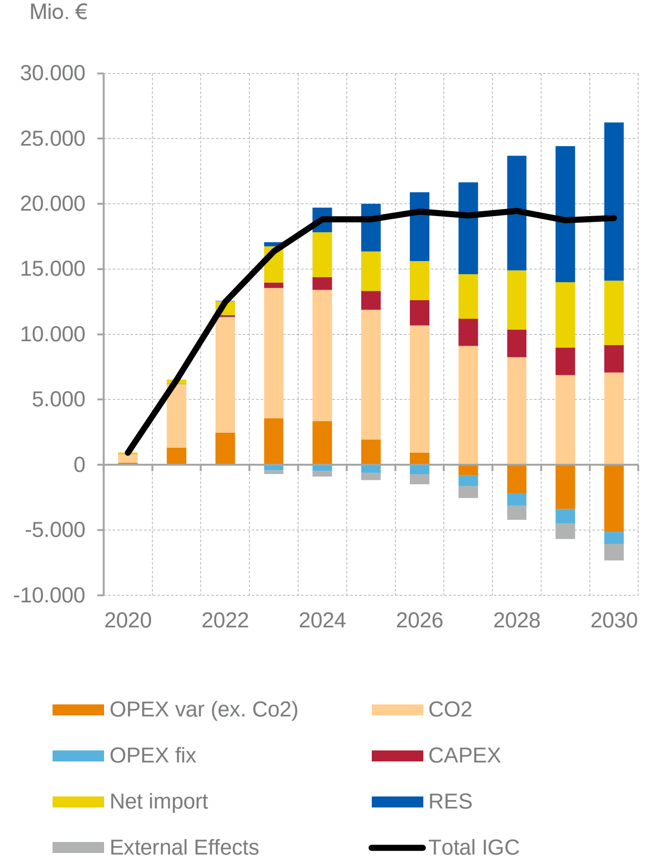
55 % PM



55 % MCE



55 % MCTC

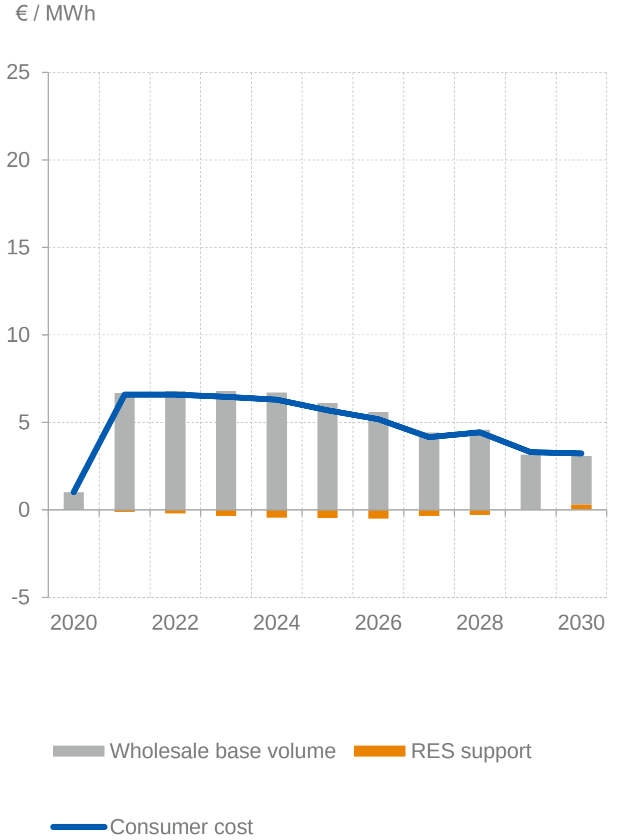


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

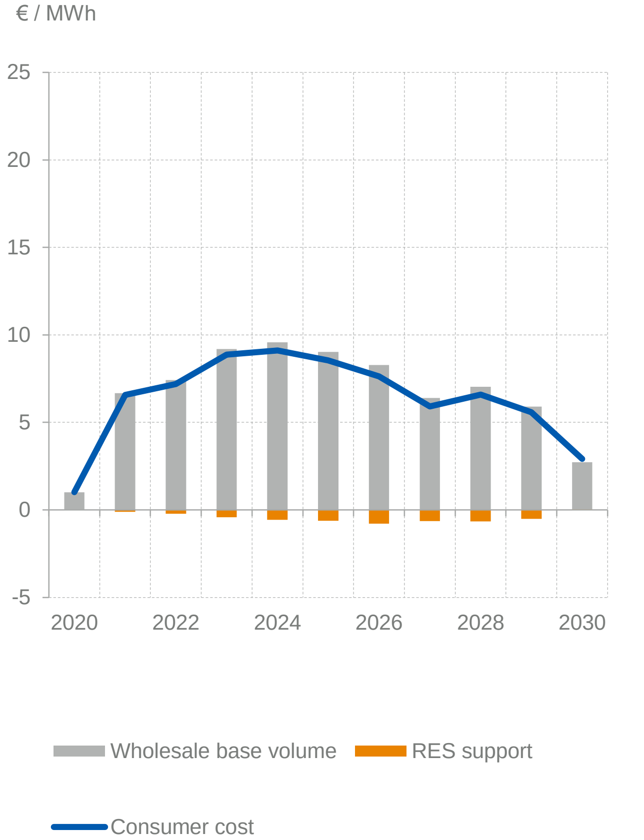
Scenario differences: Consumer costs at EU level

Costs to consumers increase in all 55 % scenarios due to higher wholesale price levels (approx. 5 €/MWh in the 55% PM scenario), partly driven by higher CO_2 prices and net-imports. The effect is mitigated with increased availability of carbon-free renewable generation towards 2030.

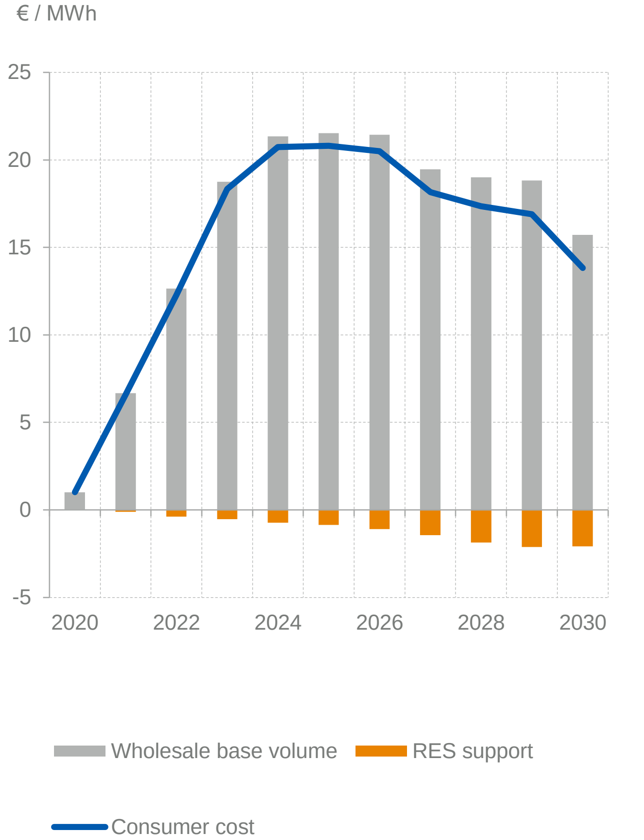
55 % PM



55 % MCE



55 % MCTC

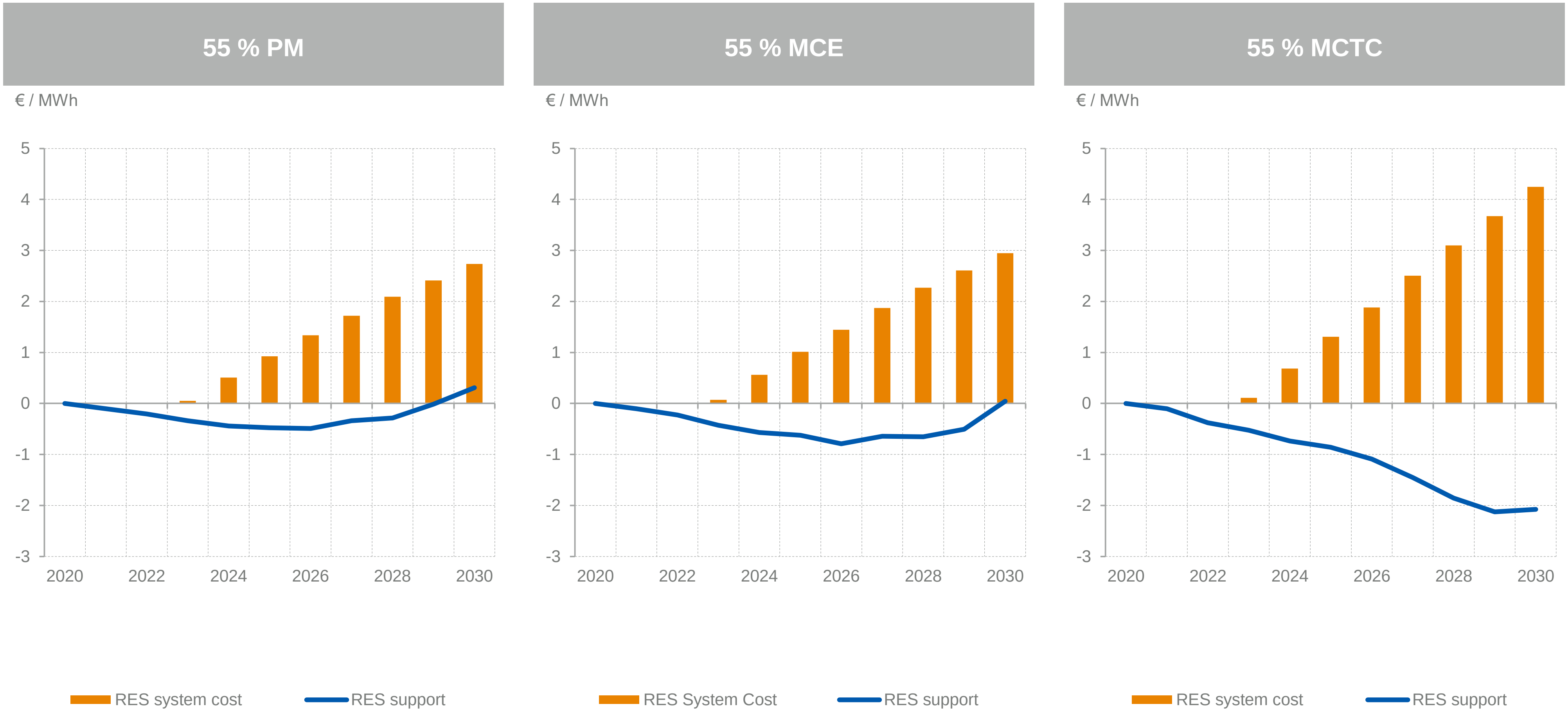


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM).

PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Scenario differences: RES re-financing at EU level

The deployment of significant additional RES capacities increases RES system costs in the 55 % scenarios. Higher wholesale prices imply higher market revenues of RES generation and thus decrease support needs, especially in the 55 % Market based coal-to-clean scenario.

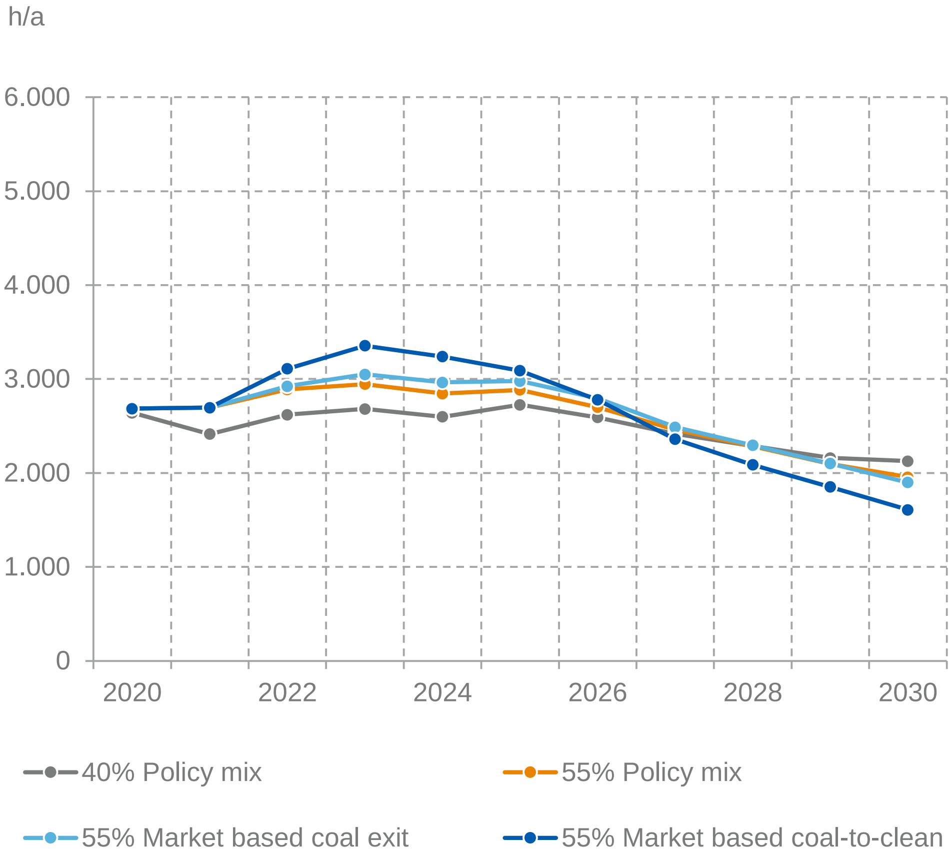


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM).

PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Utilization of gas capacities - EU

Full-load hours (FLH)



Comments

- **In the short-term, utilization of (existing) gas capacities increases in the 55 % scenarios due to**
  - CO_2 price driven fuel switch from coal to gas
  - Reduction of coal capacities
- **As the expansion of replacement RES capacities increases towards 2030, the full load hours of the gas portfolio decreases to a lower level than in the 40 % scenarios**
- **Thus gas capacities increasingly provide capacity to the market while generation plays a decreasing role**

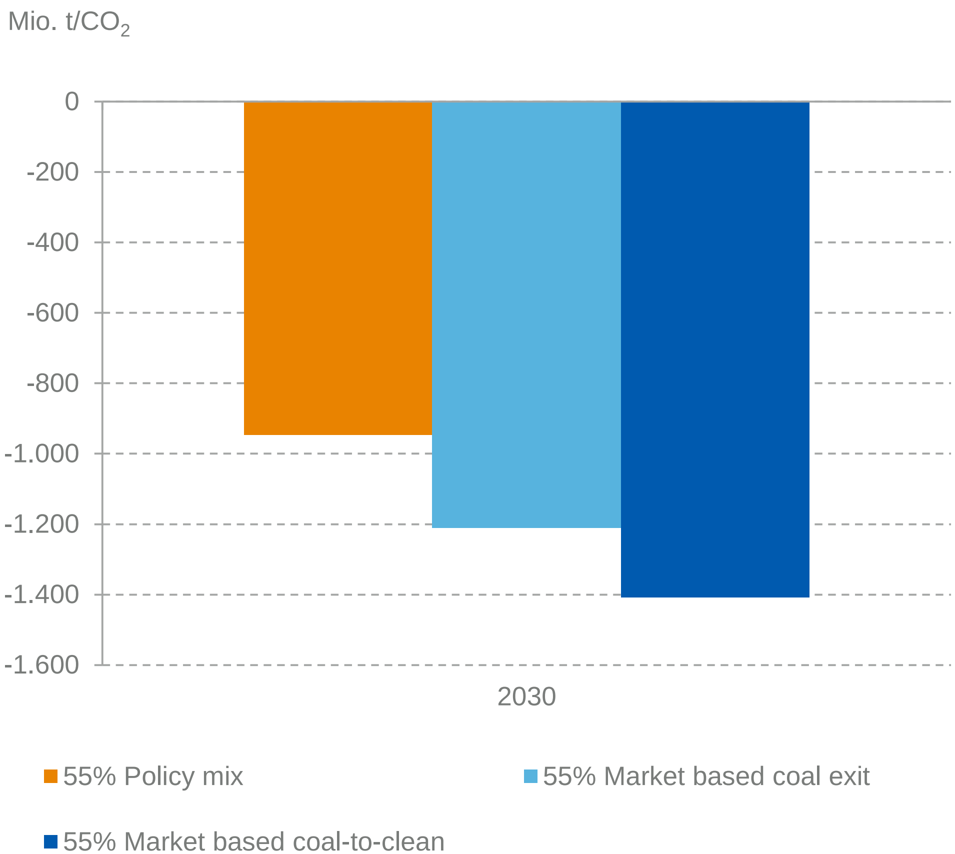
PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

RESULTS FOR COAL-6

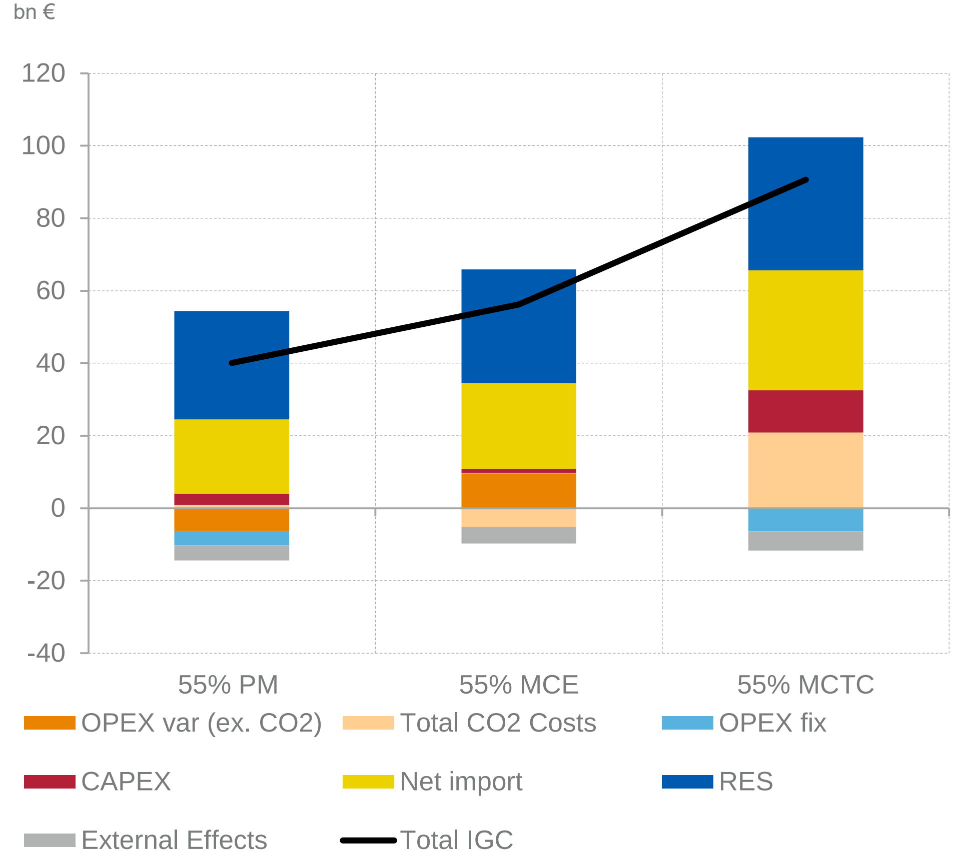
Total emissions & system costs – Coal-6

All coal-exit scenarios result in significant reduction of CO_2. Incremental effects of higher CO_2 prices are diminishing as coal capacity is decreasing. Additional IGC are in a similar range in the 55 % PM and 55 % MCE scenarios, while higher CO_2 price in 55 % MCTC drives IGC up significantly at EU level as it affects markets without potential for coal substitution.

Total CO_2 emissions (2020-2030)
Deltas minus 40 % PM



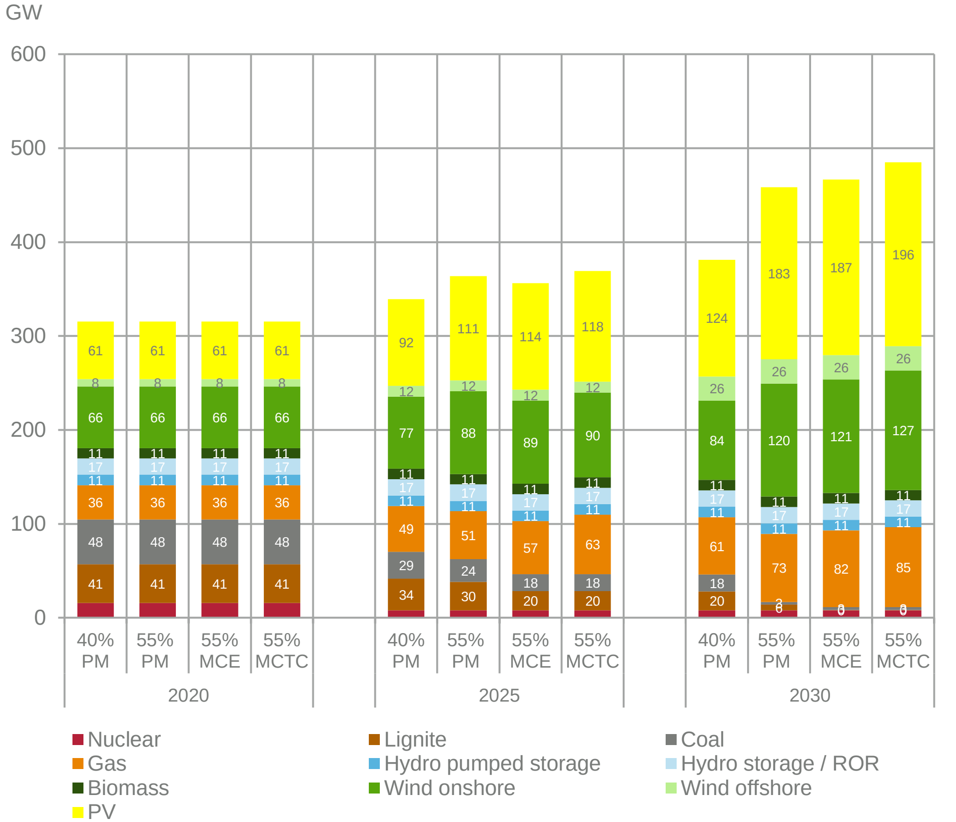
Total IGC (2020-2030)
Delta minus 40 % PM



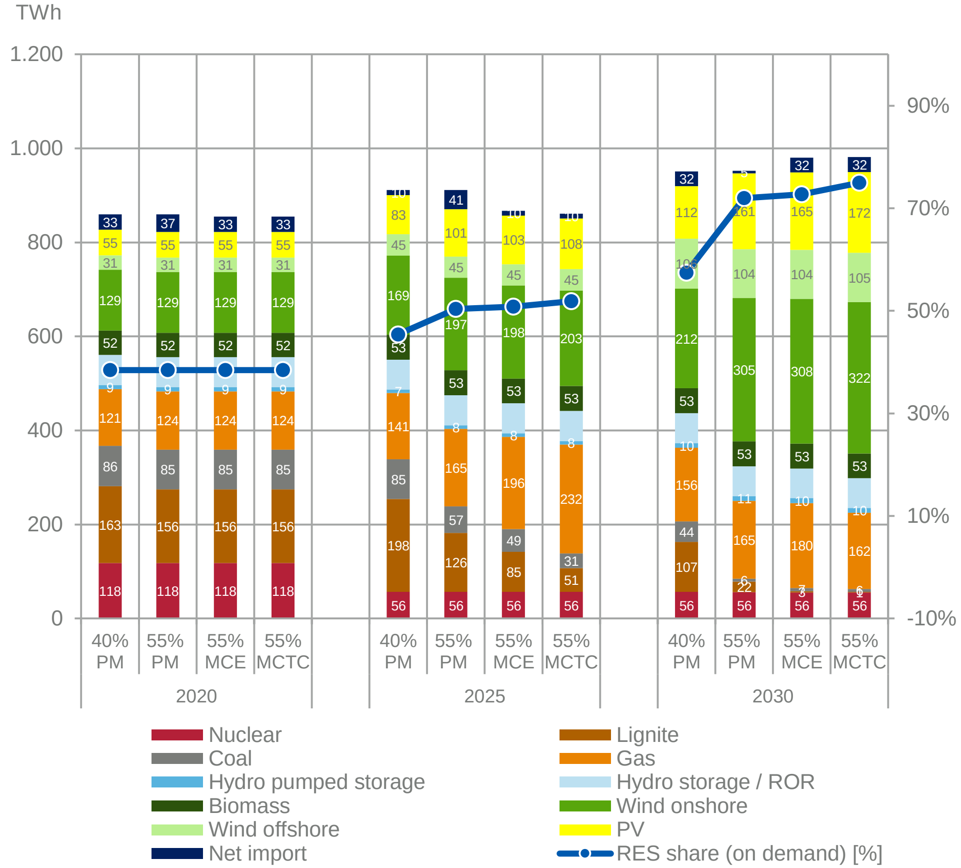
Capacity & generation – Coal-6

Compared to the 40 % PM scenario, the 55 % scenarios see an earlier decommissioning & accelerated reduction of remaining coal capacities which are substituted over time with a mix of wind onshore, PV & gas units (flexibility demand). The generation mix of the Coal-6 cluster becomes less carbon-intensive & RES shares increase by over 15 percentage points compared to 40 % PM in 2030.

Capacities



Generation

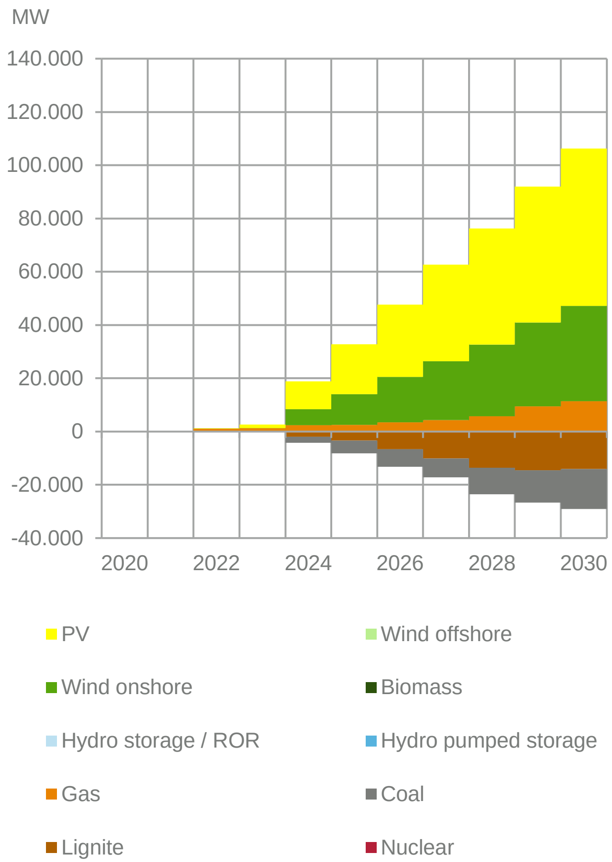


PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

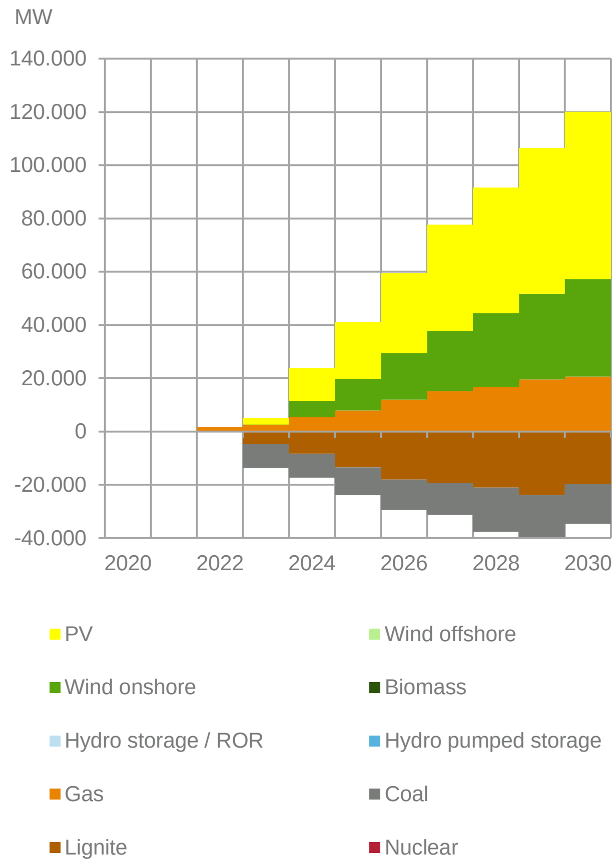
Scenario differences: Installed capacities at Coal-6 level

In the 55 % scenarios, the remaining coal capacities are substituted with a mix of wind onshore, PV and gas. Compared to the 55 % PM, the 55 % Market based scenarios see an earlier and steeper capacity reduction of coal driven by higher CO_2 price trajectories. Higher CO_2 prices also trigger additional market based RES expansion, especially in the 55 % Market based coal-to-clean scenario.

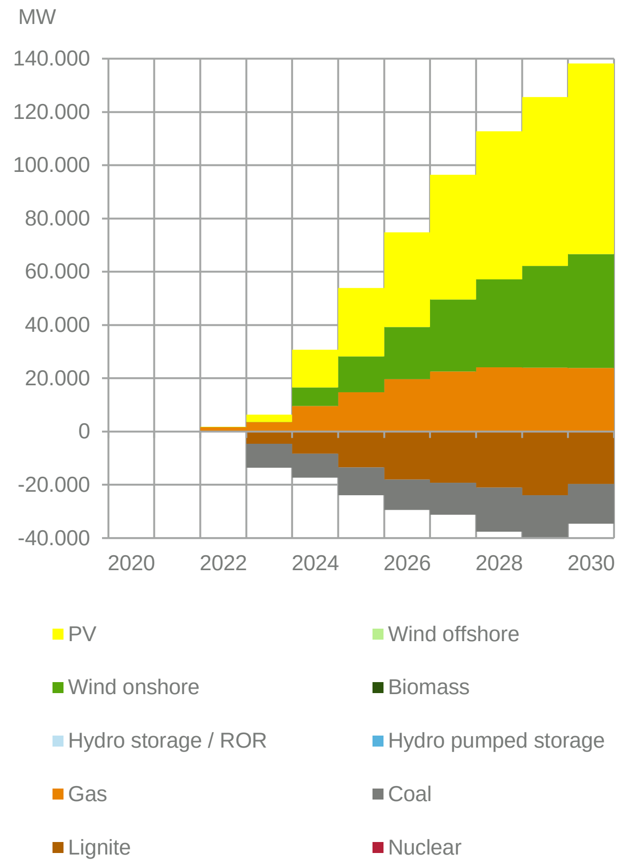
55 % PM



55 % MCE



55 % MCTC

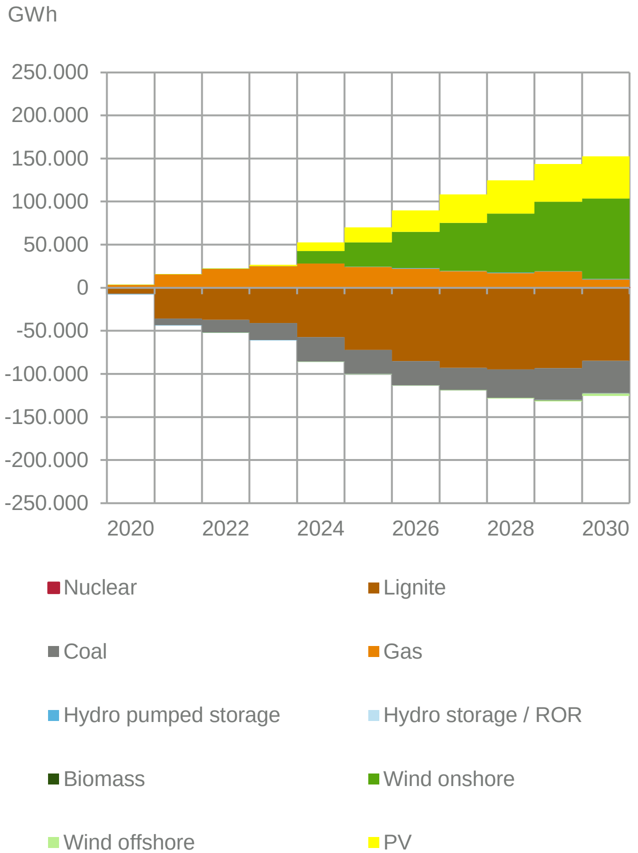


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

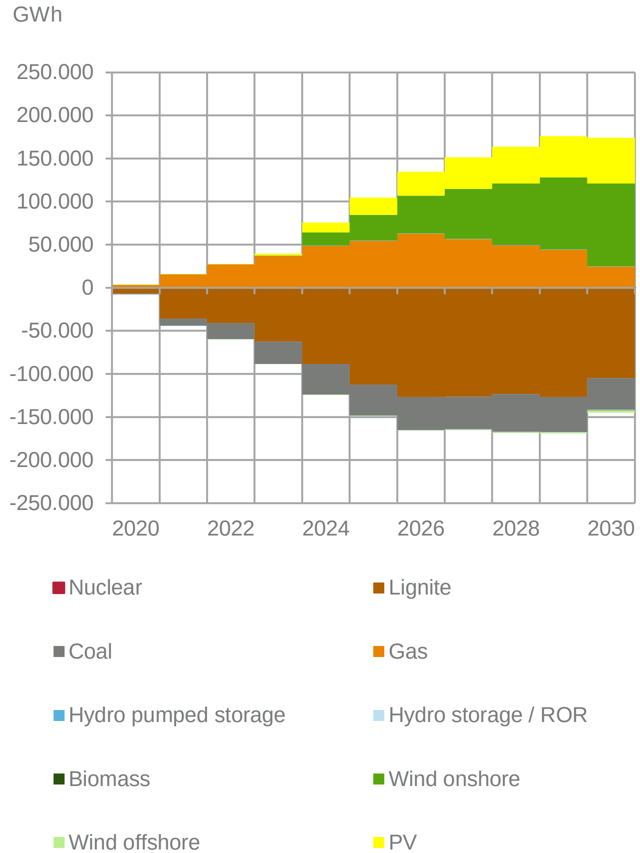
Scenario differences: Power generation at Coal-6 level

Earlier decommissioning and lower utilization of the remaining coal-fired units trigger temporary increased gas-based generation (mid-term), especially in both 55 % Market based scenarios. In the long run, coal-based generation is compensated by PV, wind onshore and some gas-based generation. All scenarios lead to an increase in renewable energy generation of over 140 TWh by 2030.

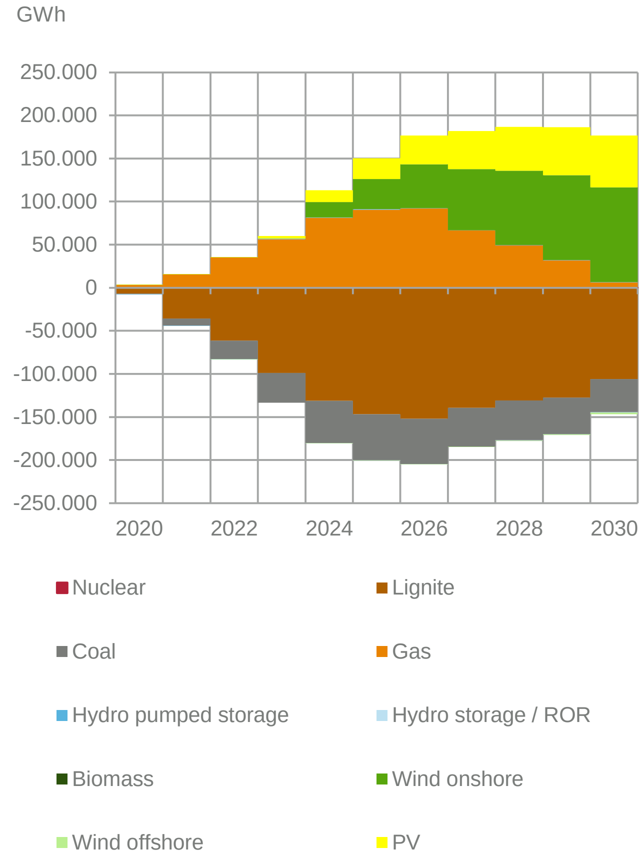
55 % PM



55 % MCE



55 % MCTC

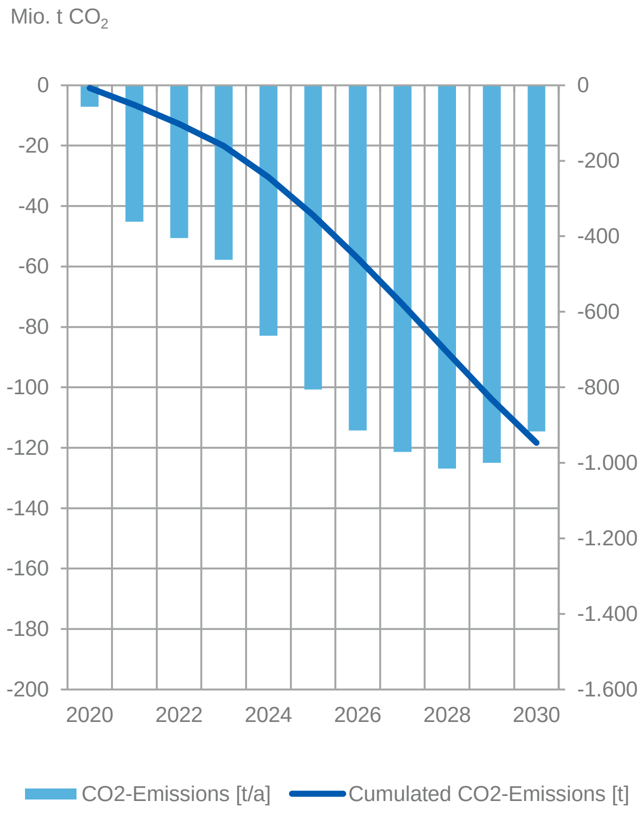


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

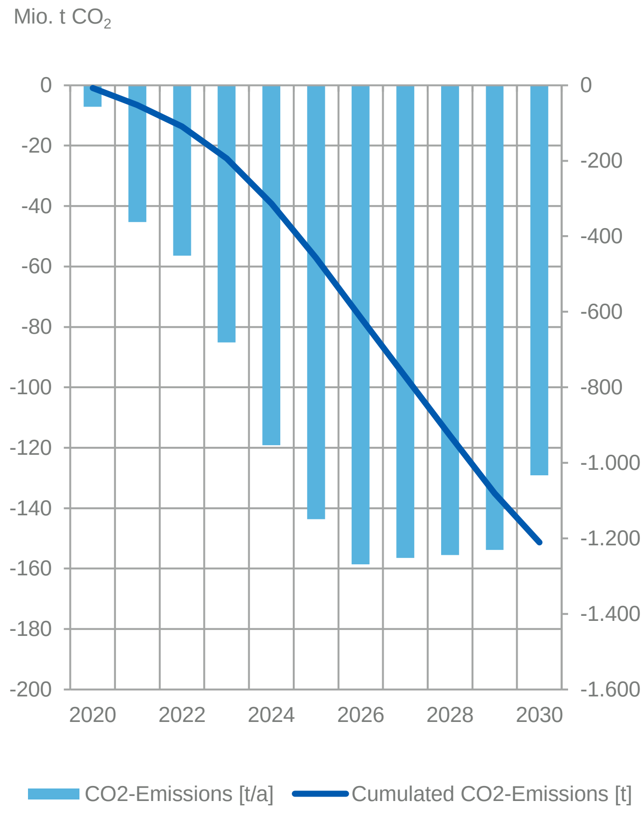
Scenario differences: CO_2 emissions at Coal-6 level

All 55 % scenarios lead to significant CO_2 savings for the Coal-6 cluster compared to the 40 % PM scenario. Until 2024, the additional reduction is driven only by the CO_2 price. In total, the market based coal exit scenario results in a cumulated reduction of 26 %, the market-based coal-to-clean scenario in a cumulative reduction of 47 % until 2030 compared to the 55 % PM scenario.

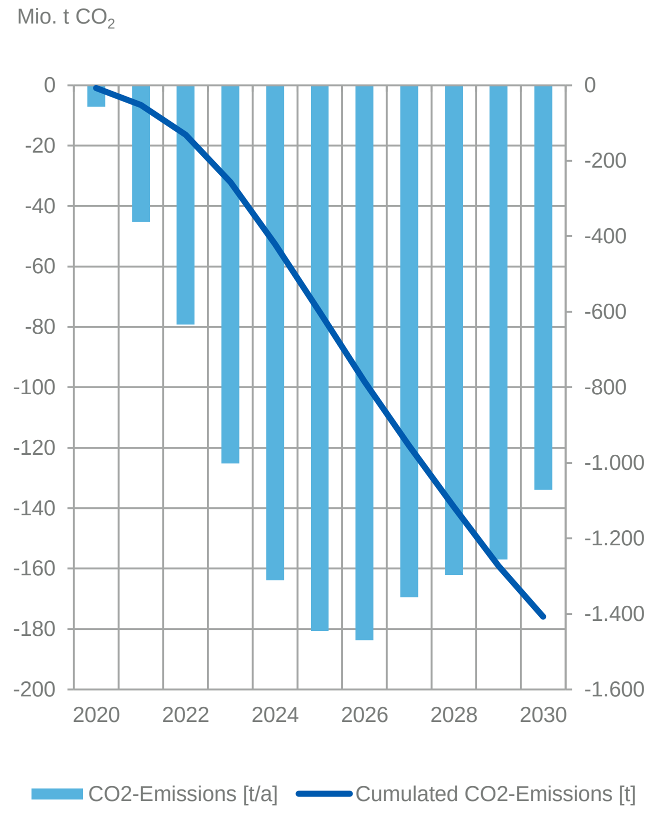
55 % PM



55 % MCE



55 % MCTC



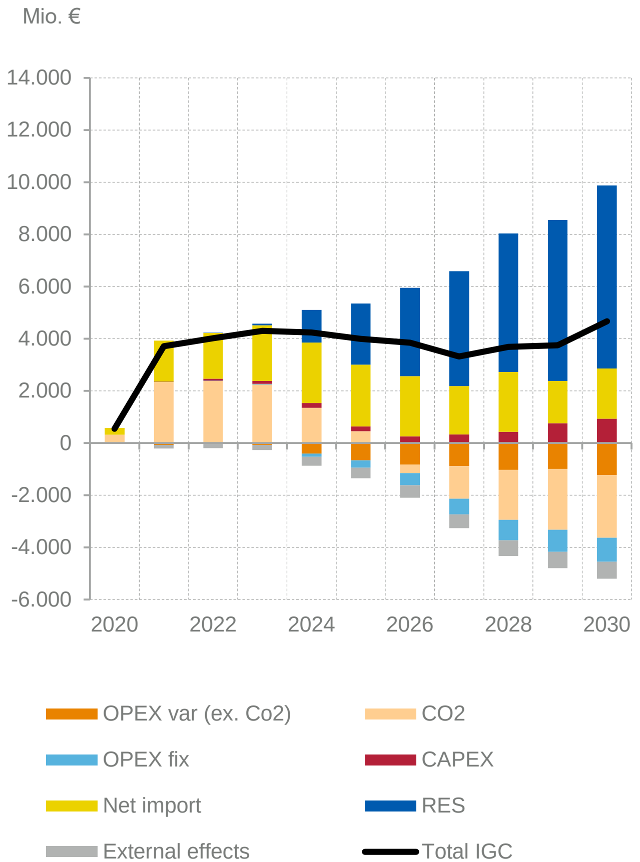
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Scenario differences: Incremental generation costs at Coal-6 level

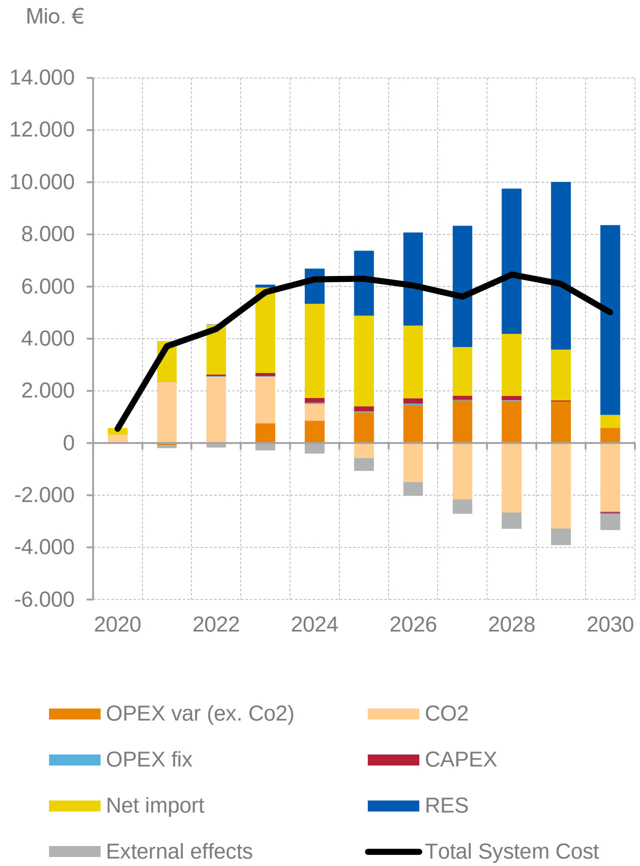
Annual incremental generation costs for the Coal-6 cluster are higher in the 55 % scenarios. Main drivers are add. CO_2 costs (mid-term), and RES & import costs (long-term), which dominate diverse savings in OPEX and external effects by the end of the decade.

Note: Revenues from auctioned CO_2 certificates can also be seen as a source of income.

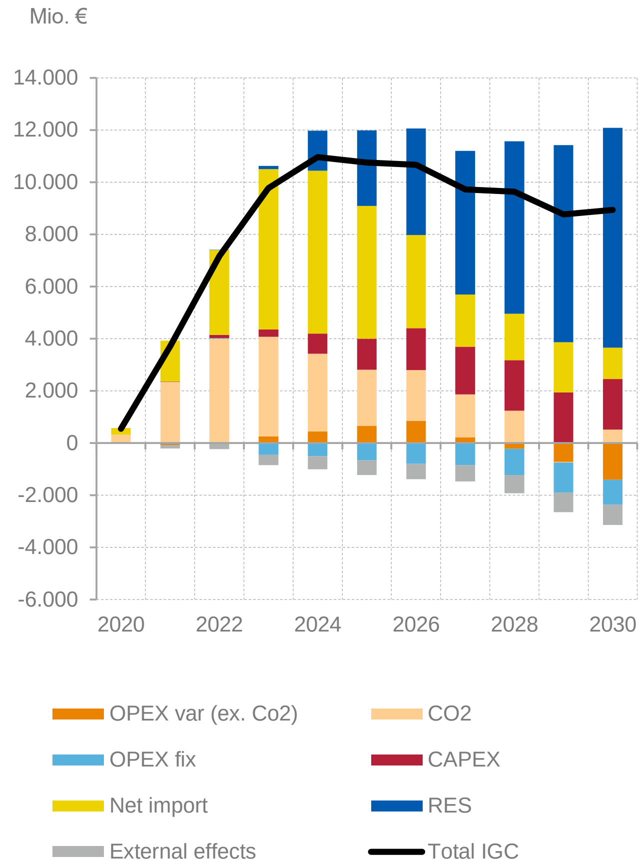
55 % PM



55 % MCE



55 % MCTC

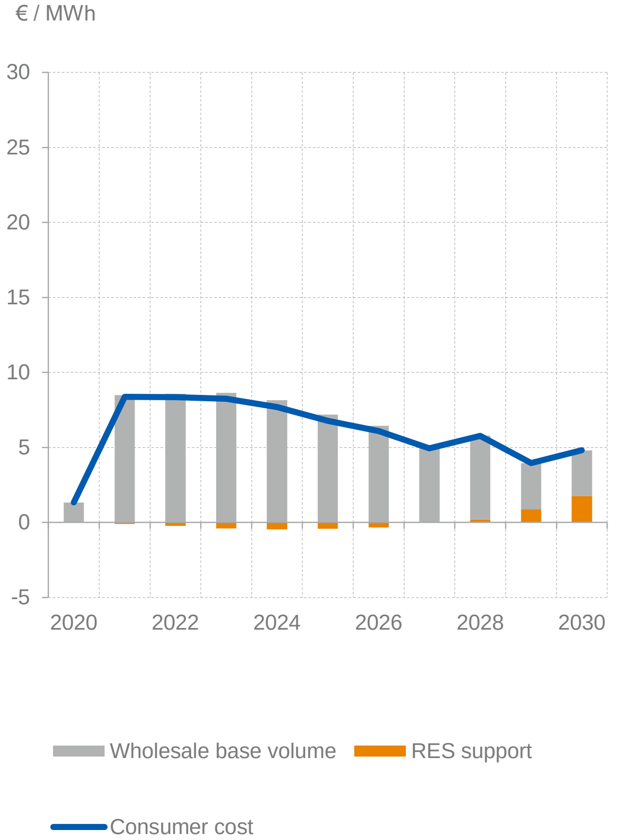


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

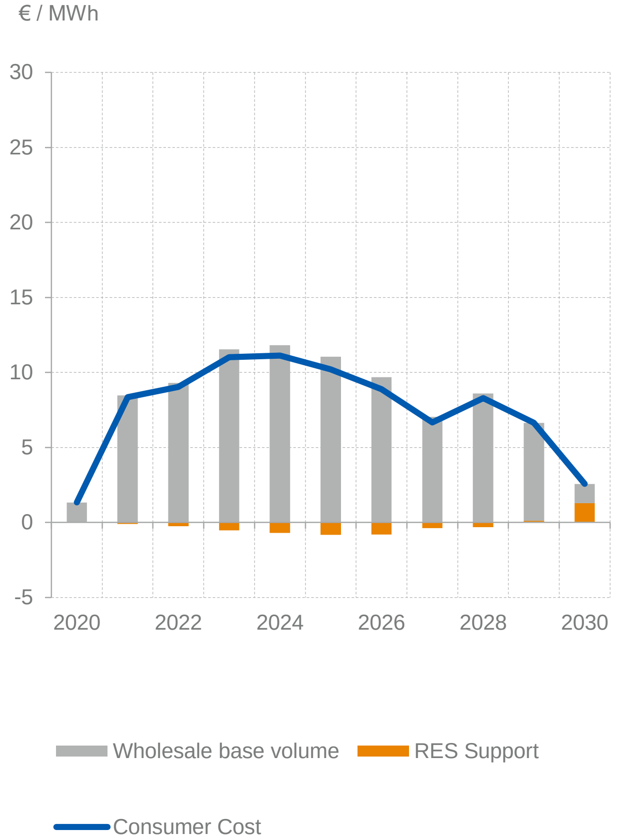
Scenario differences: Consumer costs at Coal-6 level

Costs to consumers increase in all 55 % scenarios for the Coal-6 cluster due to higher wholesale price levels, partly driven by higher CO_2 prices and net-imports. The effect is mitigated with increased availability of carbon-free renewable generation towards 2030.

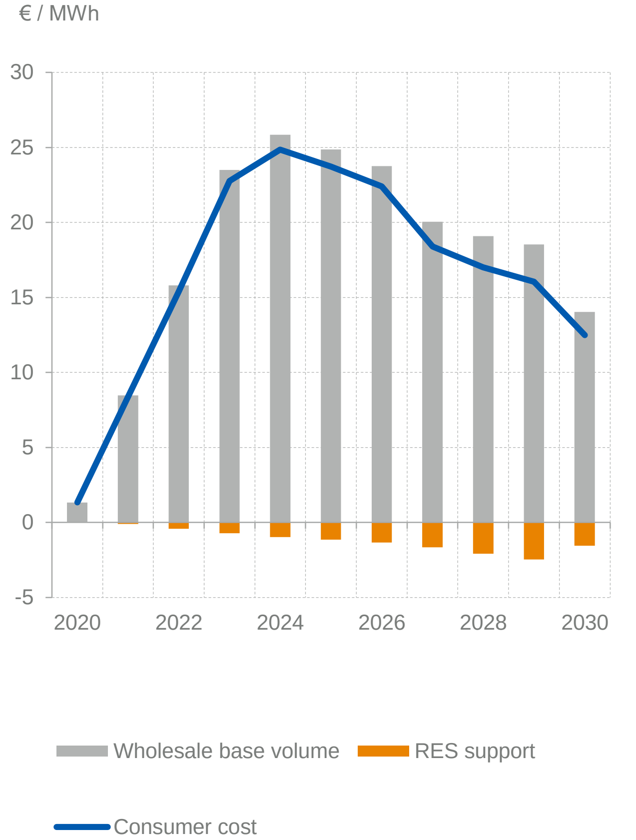
55 % PM



55 % MCE



55 % MCTC

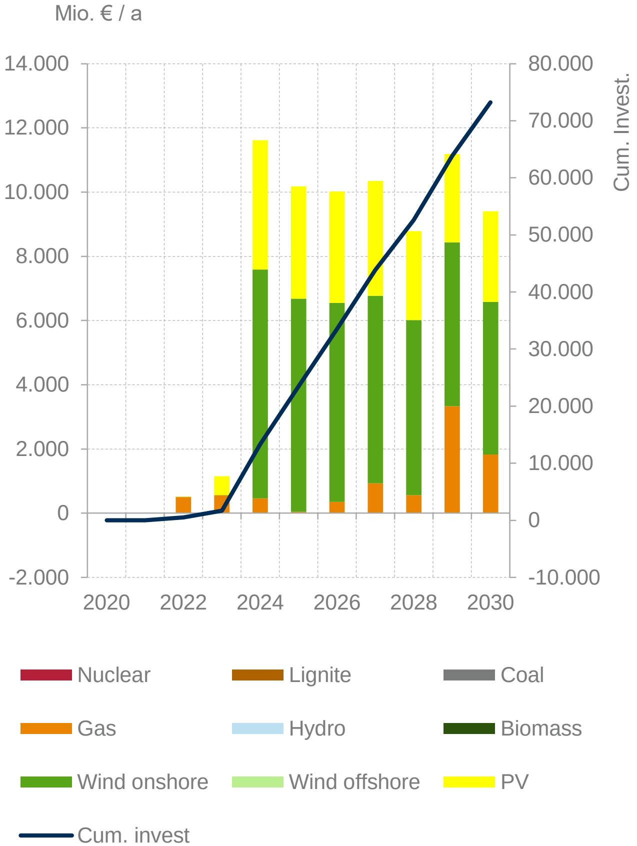


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

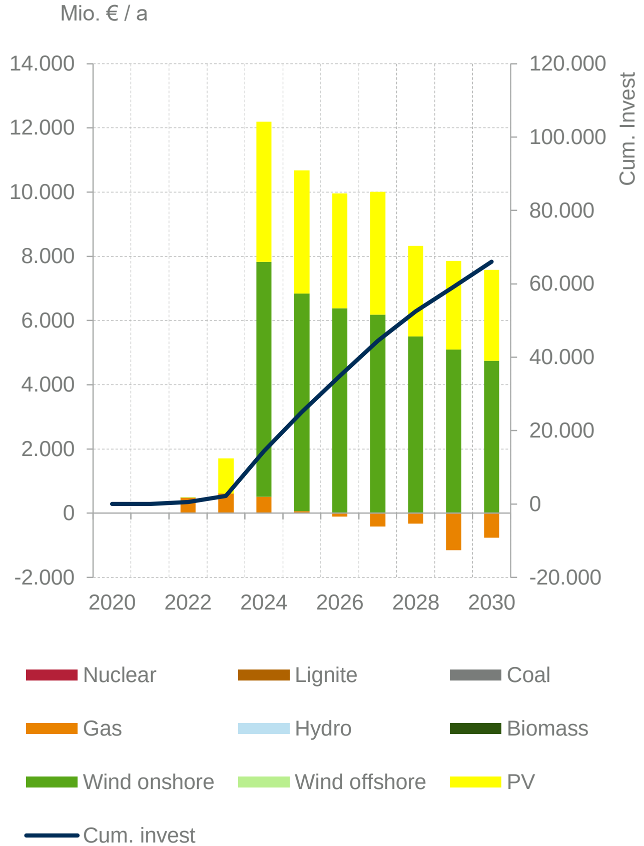
Scenario differences: Investment volumes at Coal-6 level

Required additional investments into the power-generating infrastructure (Coal-6) accumulate to 73 bn € (55 % PM), 66 bn € (55 % Market based coal exit) and 96 bn € (55 % Market based coal-to-clean) until 2030. Additional investments are mainly channelled towards onshore wind and PV assets and, to a lesser extent, into gas-based capacities.

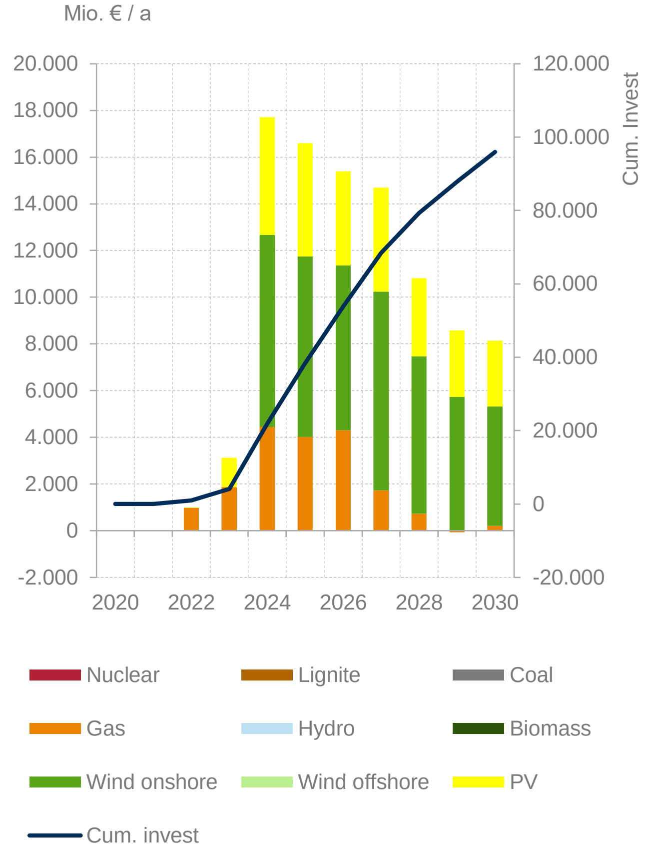
55 % PM



55 % MCE



55 % MCTC

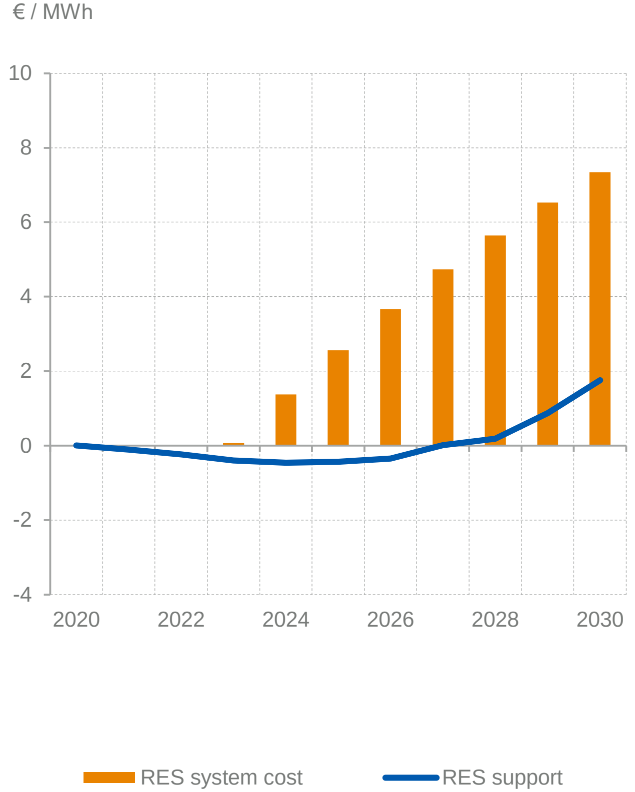


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

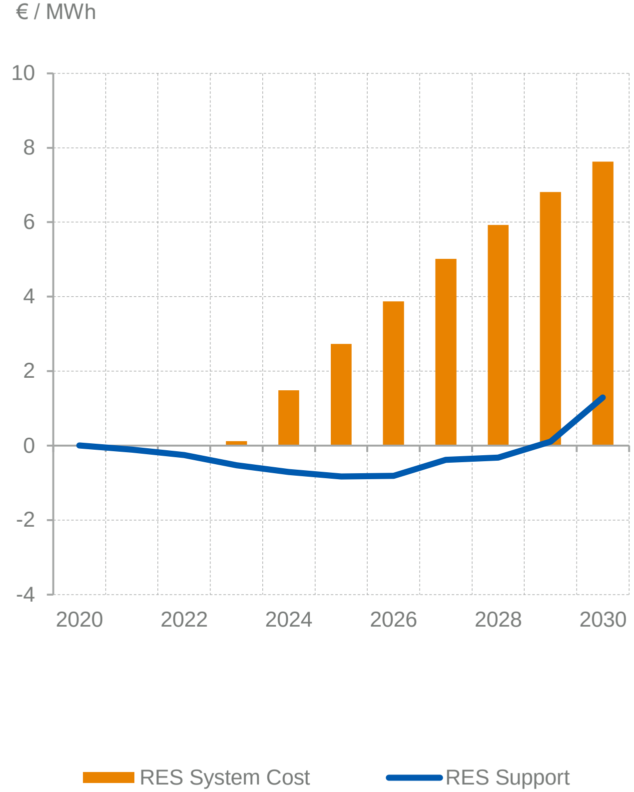
Scenario differences: RES re-financing at Coal-6 level

The deployment of significant additional RES capacities increases RES system costs in the 55 % scenarios. Higher wholesale prices imply higher market revenues of RES generation and thus decrease support needs. The additional required RES support decreases especially in the 55 % Market based coal-to-clean scenario.

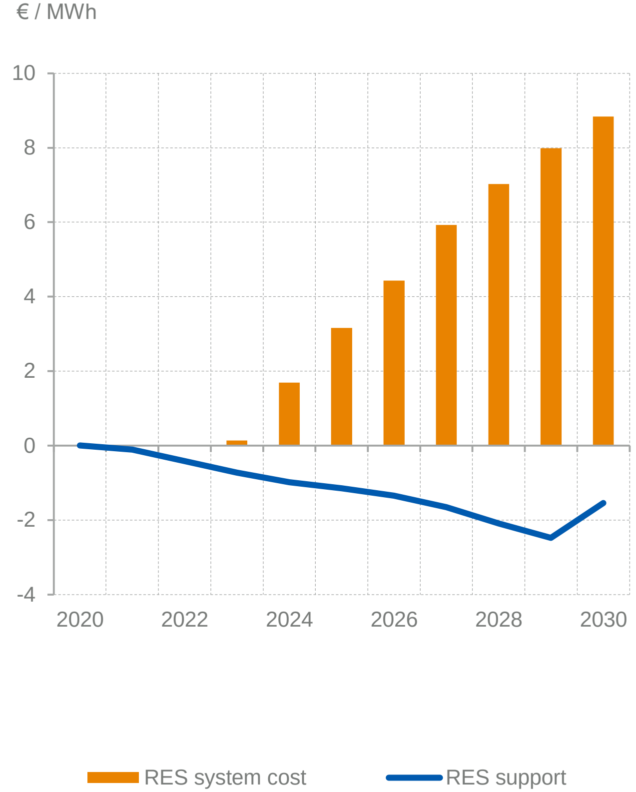
55 % PM



55 % MCE



55 % MCTC

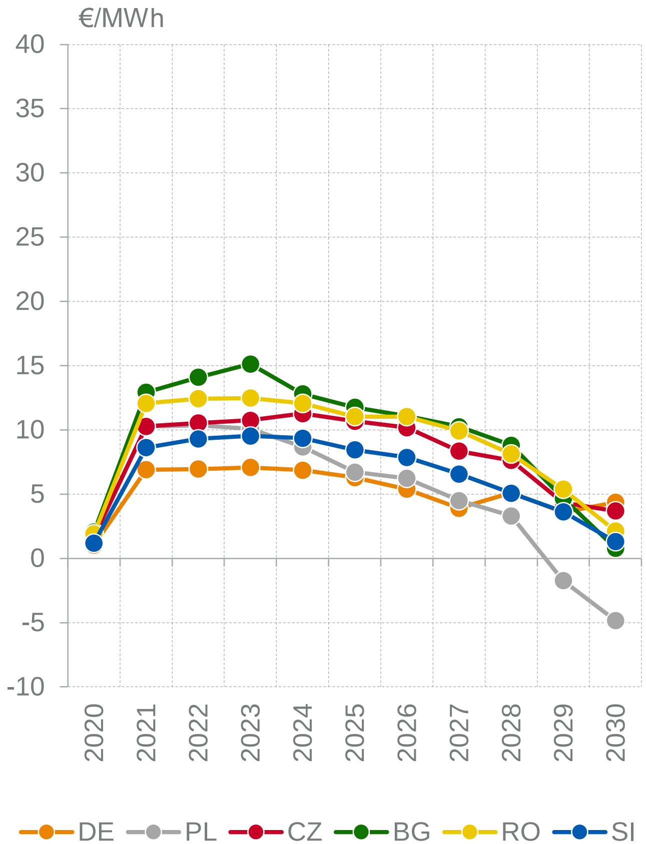


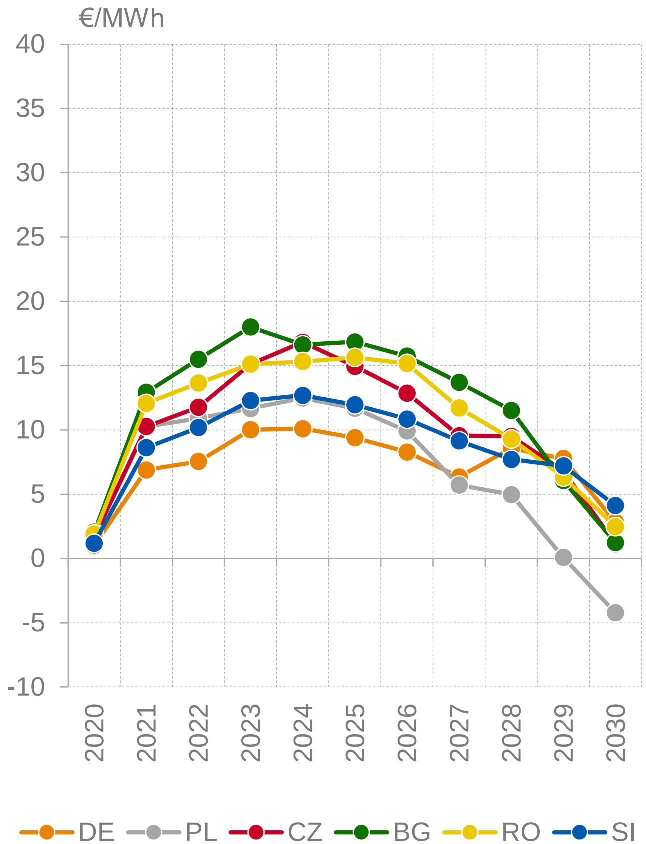
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

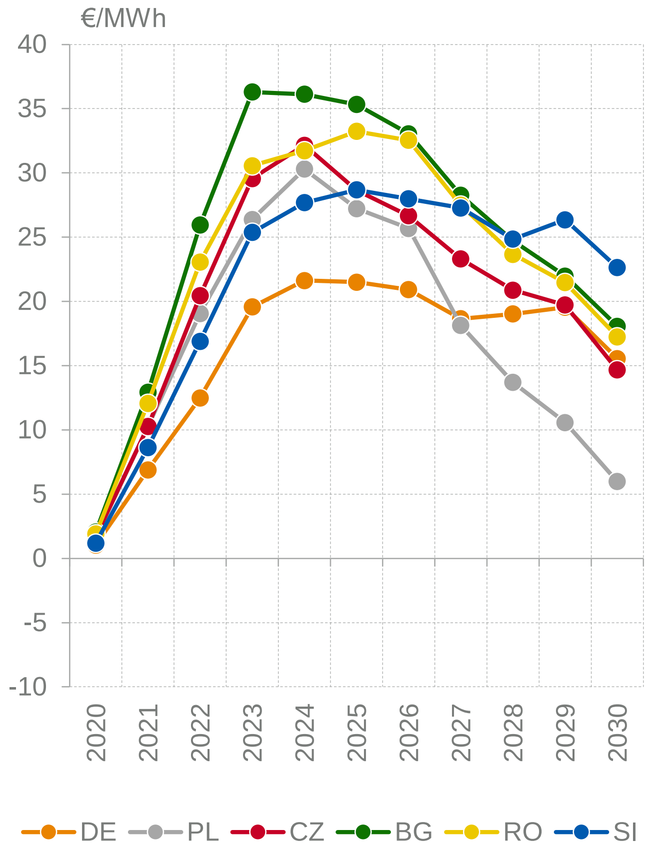
Wholesale base prices deltas – Coal-6

A strong initial impact on wholesale prices can be observed in all 55 % scenarios, which is reduced towards 2030 as the generation-mix becomes less carbon-intensive. The increase levels out at below 5 €/MWh in the 55 % PM & 55 % Market based coal exit scenario. In the case of PL, prices even decrease. 55 % PM has the lowest impact on price levels, due to the lower assumed CO_2 prices.

55 % PM	55 % MCE	55 % MCTC



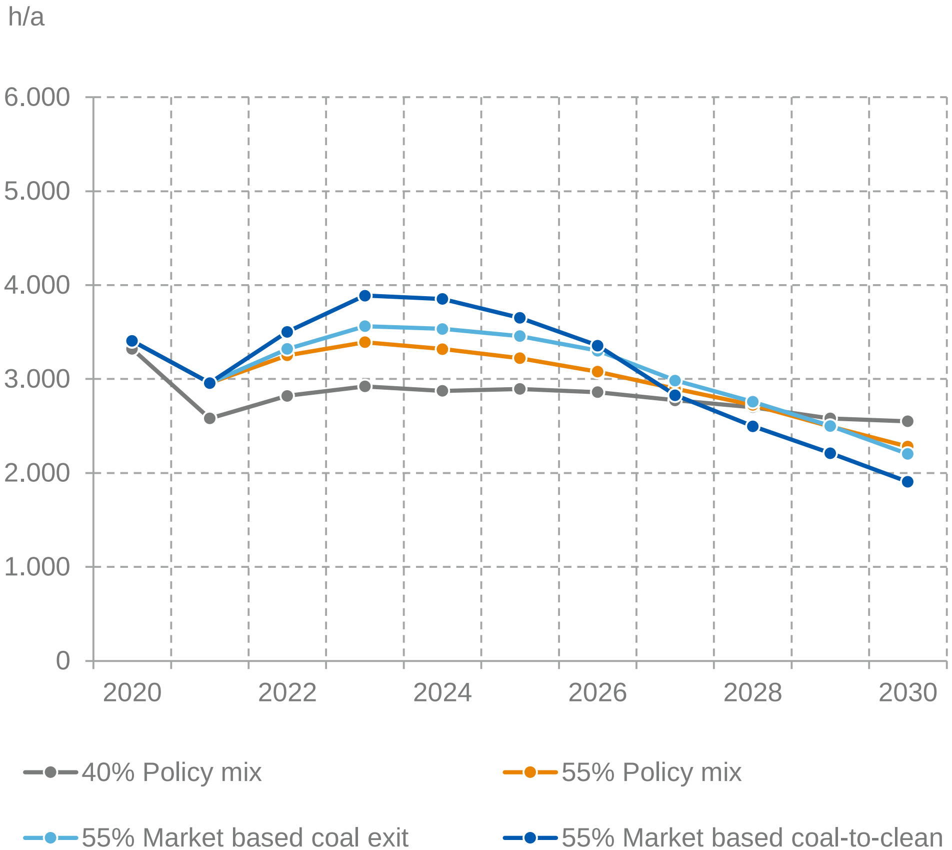




Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Utilization of gas capacities – Coal-6

Full load hours (FLH)



Comments

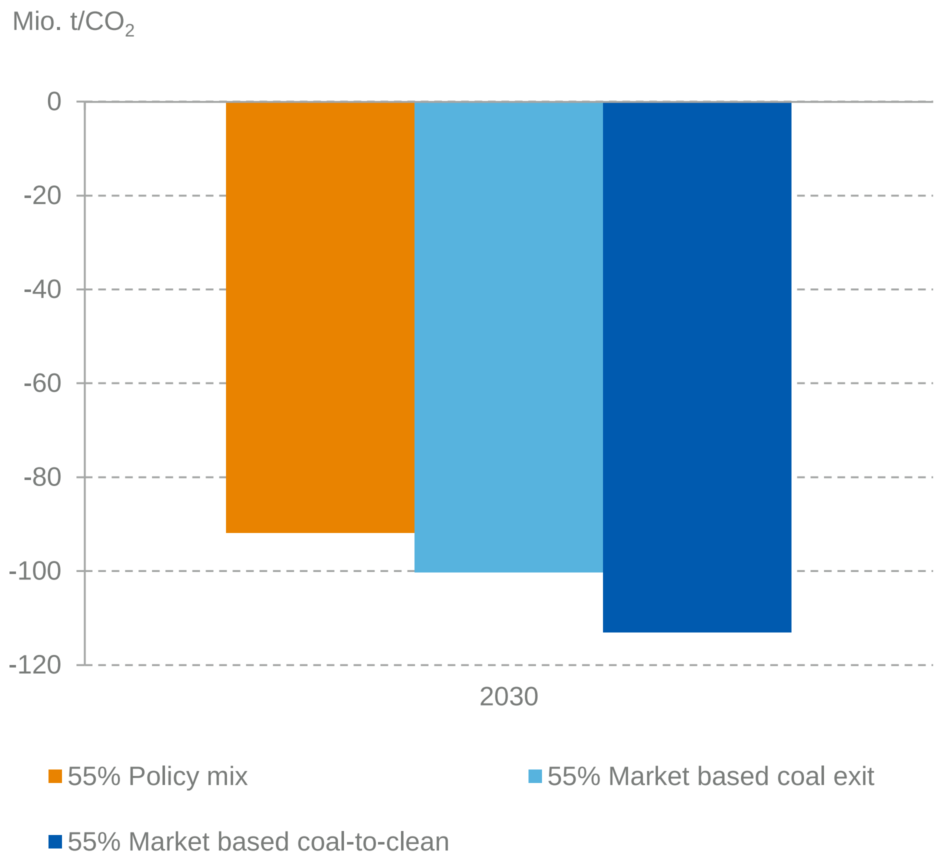
- **In the short-term, utilisation of (existing) gas capacities increases in the 55 % scenarios due to**
  - CO_2 price driven fuel switch from coal to gas
  - Reduction of coal capacities
- **As the expansion of replacement RES capacities increases towards 2030, the full load hours of the gas portfolio decreases to a lower level than in the 40 % scenarios**
- **Thus gas capacities increasingly provide capacity to the market while generation plays a decreasing role**

RESULTS ON COUNTRY LEVEL

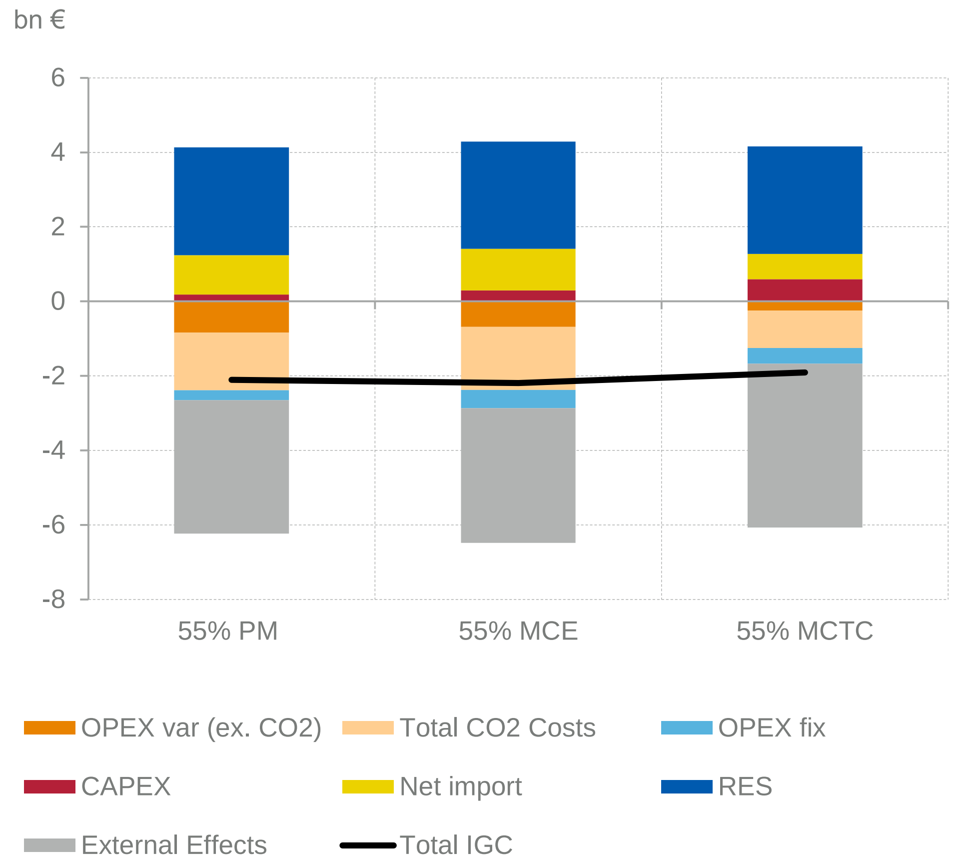
BG

Total emissions & system costs – BG

Total CO_2 emissions (2020-2030)
Deltas minus 40 % PM



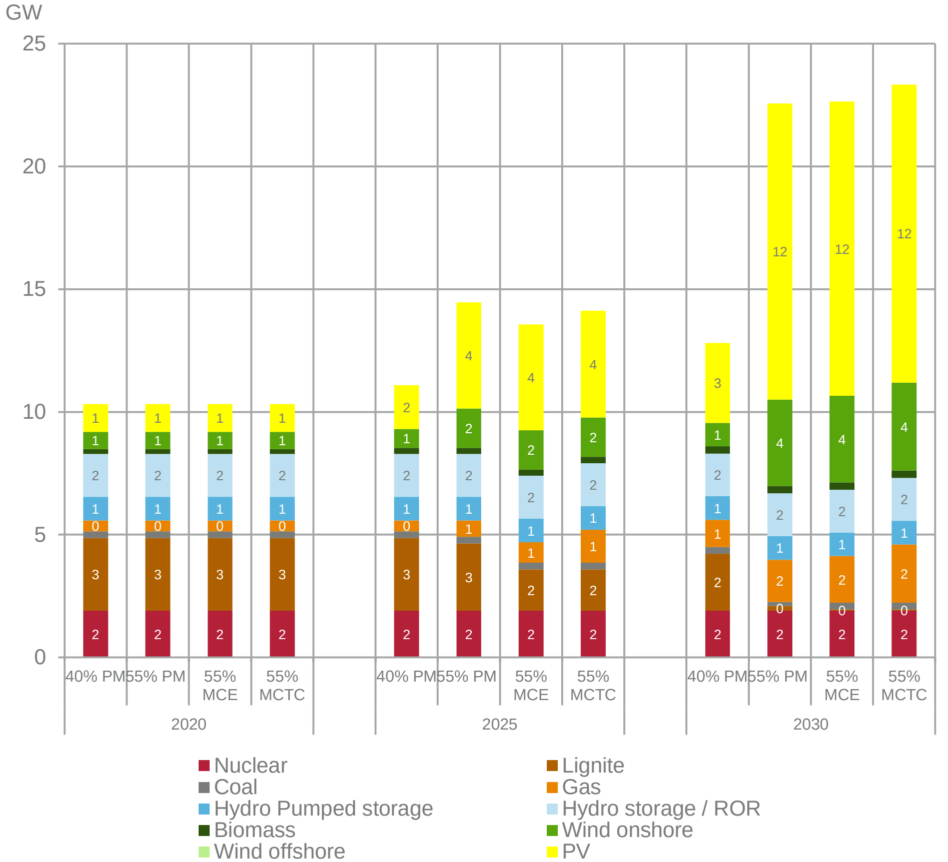
Total IGC (2020-2030)
Deltas minus 40 % PM



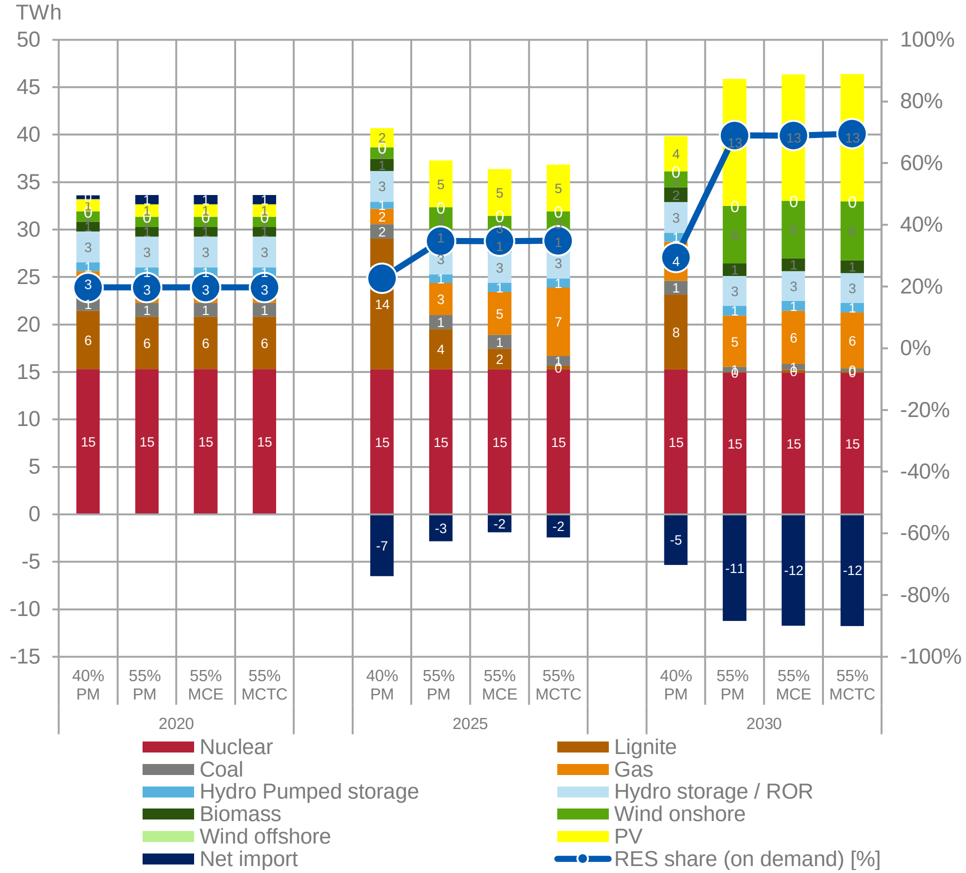
Capacity & generation – BG

Compared to the 40 % PM scenario, the 55 % scenarios lead to an earlier decommissioning & accelerated reduction of remaining coal capacities in Bulgaria, which are substituted over time with a mix of wind onshore, PV & gas units (flexibility demand). The generation mix becomes less carbon-intensive and RES shares (on demand) increase by over 40 percentage points by 2030 in the 55 % scenarios.

Capacities



Generation

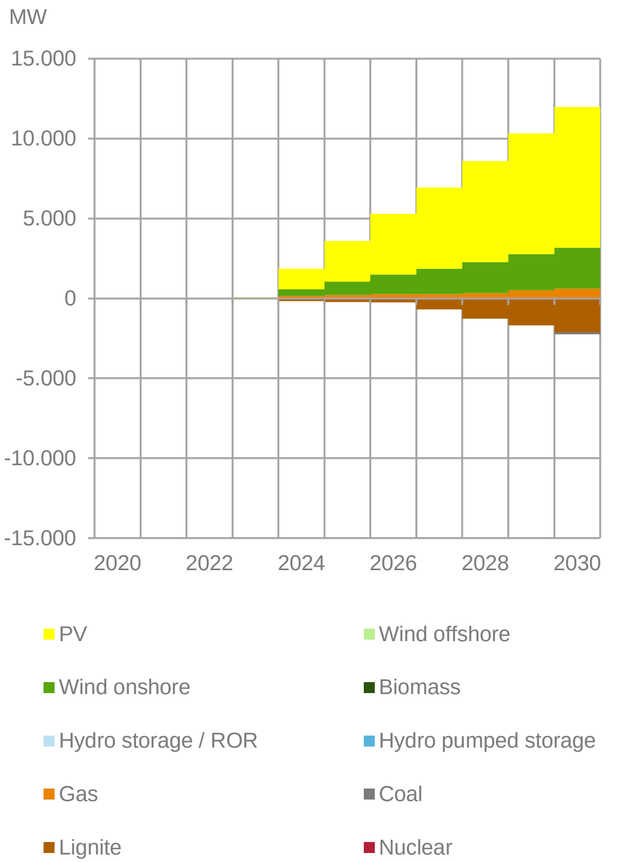


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

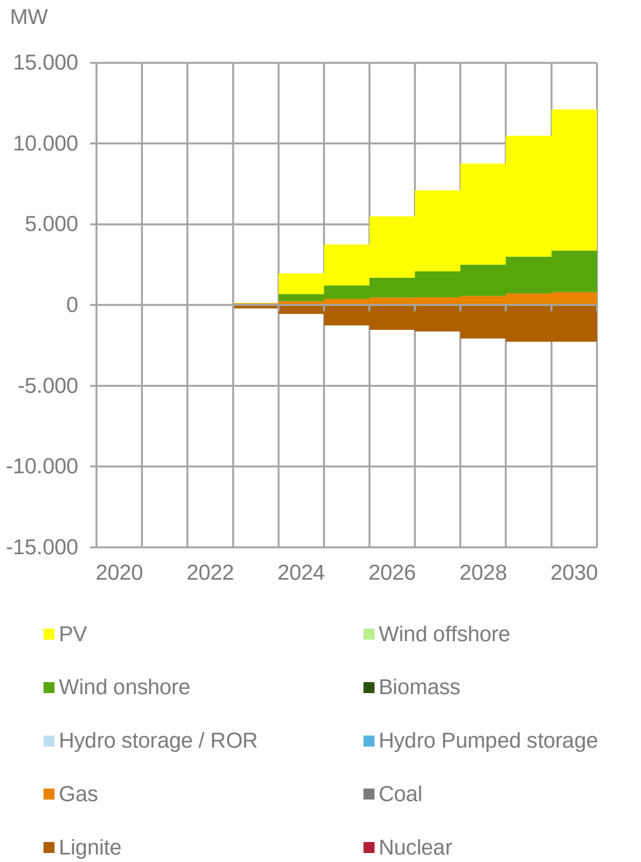
Scenario differences: Installed capacities in BG

In the 55 % scenarios, the remaining coal capacities are substituted with a mix of PV, wind onshore and gas. Compared to the 55 % PM, the 55 % Market based scenarios see an earlier and steeper capacity reduction of coal units driven by higher CO_2-price trajectories. The higher CO_2-prices also trigger additional market based RES expansion, especially in the 55 % Market based coal-to-clean scenario.

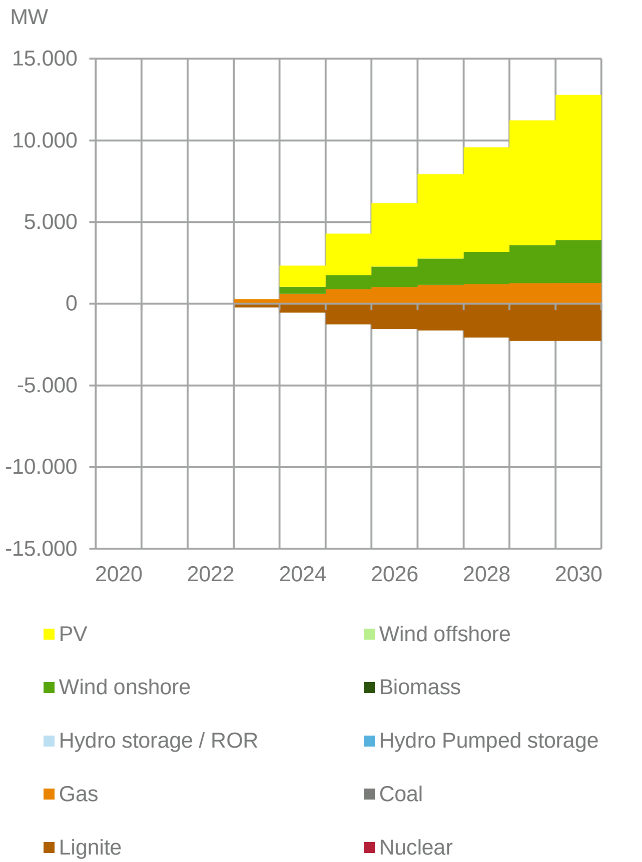
55 % PM



55 % MCE



55 % MCTC



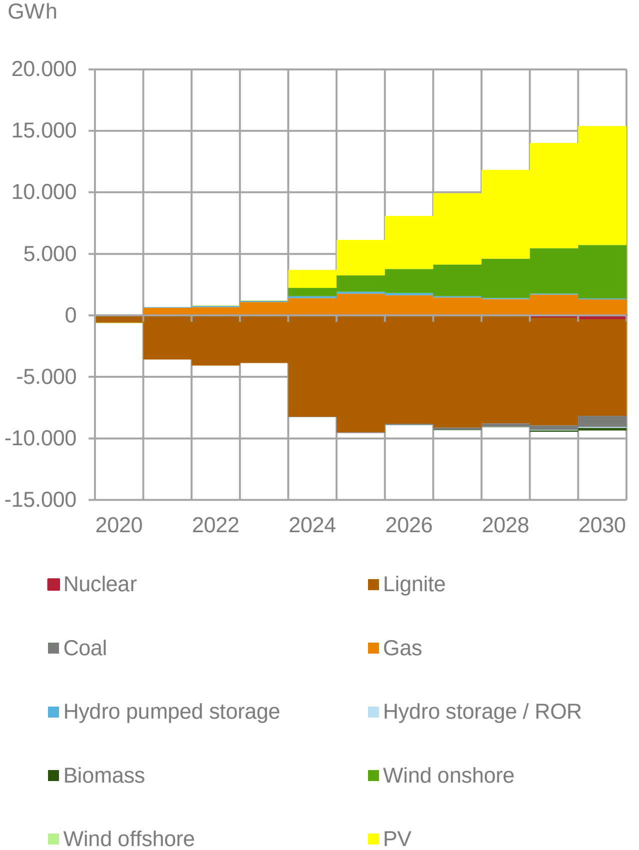
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM).

PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

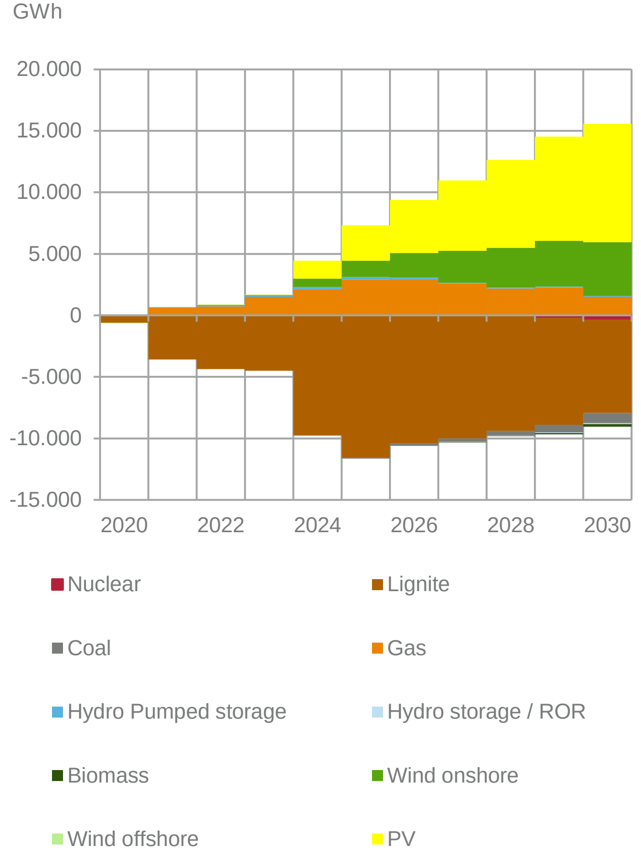
Scenario differences: Power generation in BG

Earlier decommissioning and lower utilization of the remaining coal-fired units in Bulgaria trigger temporary increased gas-based generation (mid-term), especially in both 55 % Market based scenarios. In the long run, coal-based generation is compensated by PV, wind onshore and some gas-based generation.

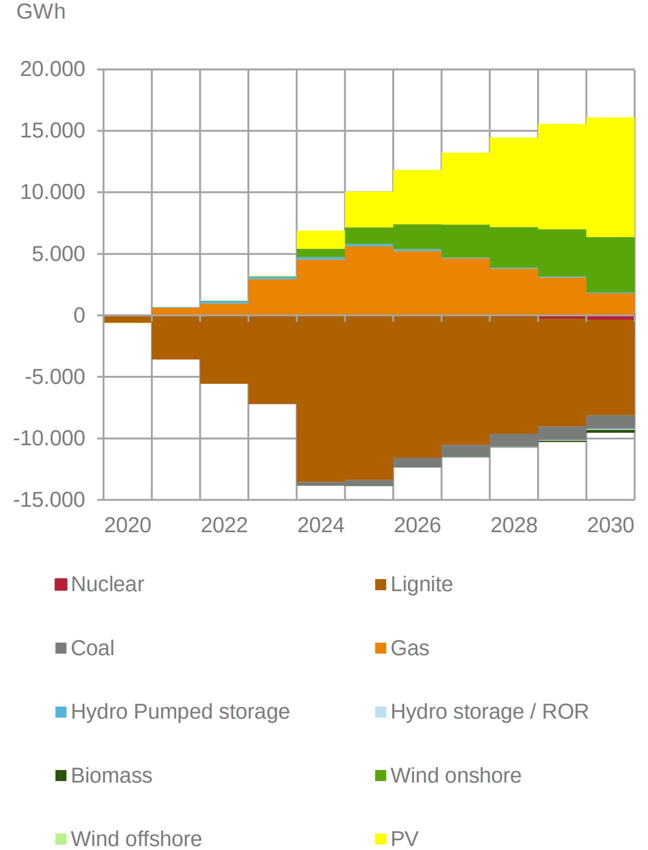
55 % PM



55 % MCE



55 % MCTC

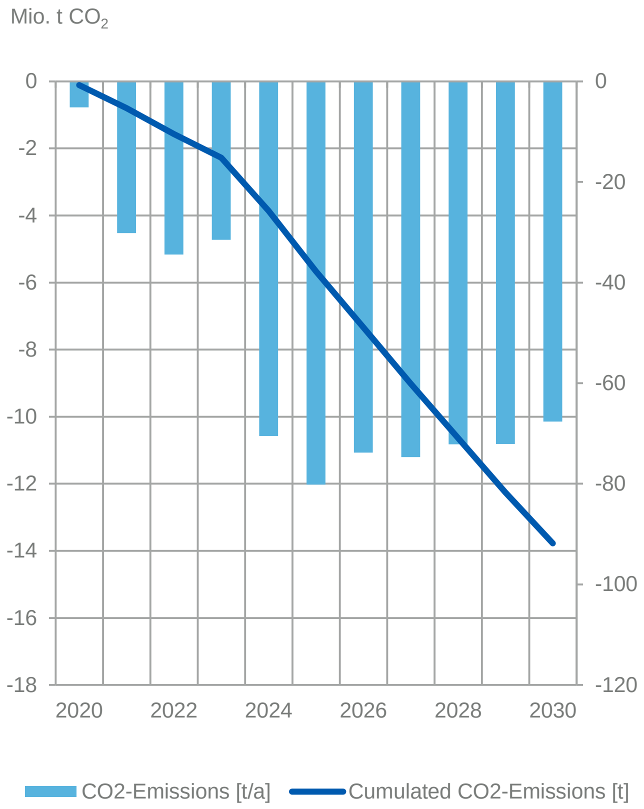


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

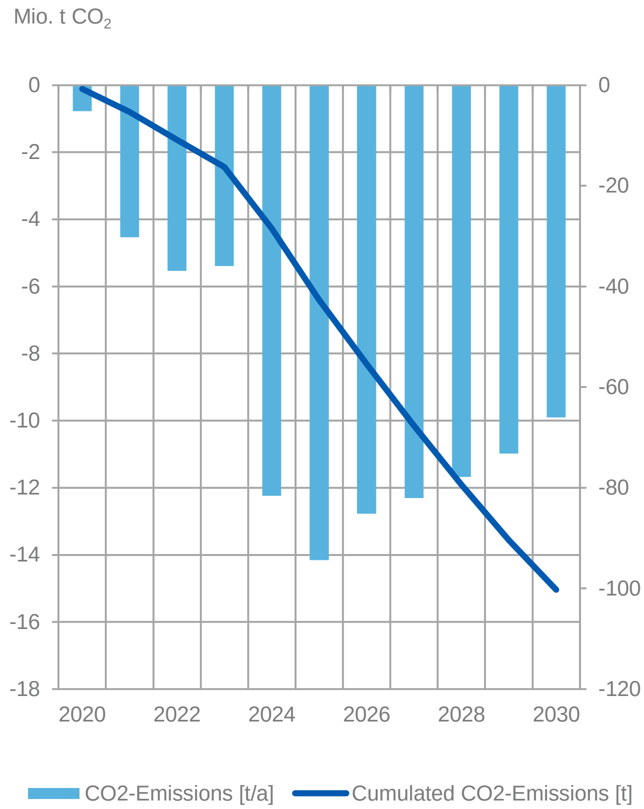
Scenario differences: CO_2 emissions in BG

All 55 % scenarios lead to significant CO_2 savings in Bulgaria compared to the 40 % PM scenario. Until 2024, the additional reduction is driven only by the CO_2 price. In total, the 55 % PM scenario results in a cumulative reduction of 92 Mio.t. of CO_2 (market based coal exit: 100 Mio.t.; market-based coal-to-clean: 113 Mio.t.) until 2030 compared to the 55 % PM scenario.

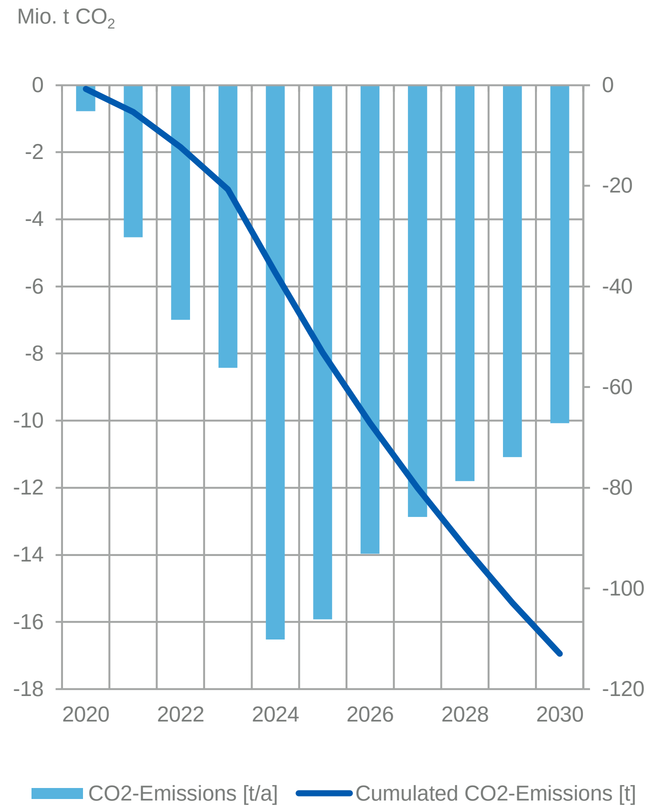
55 % PM



55 % MCE



55 % MCTC

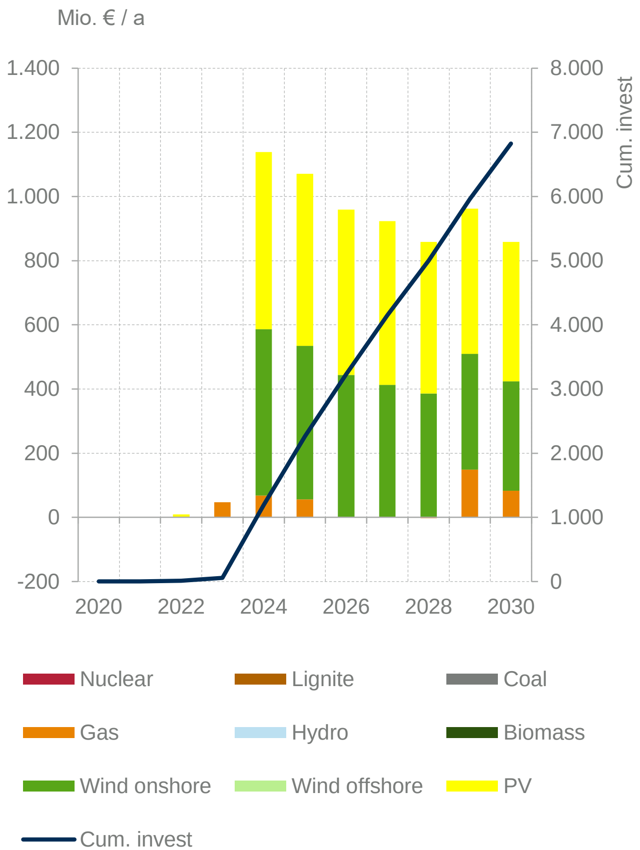


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

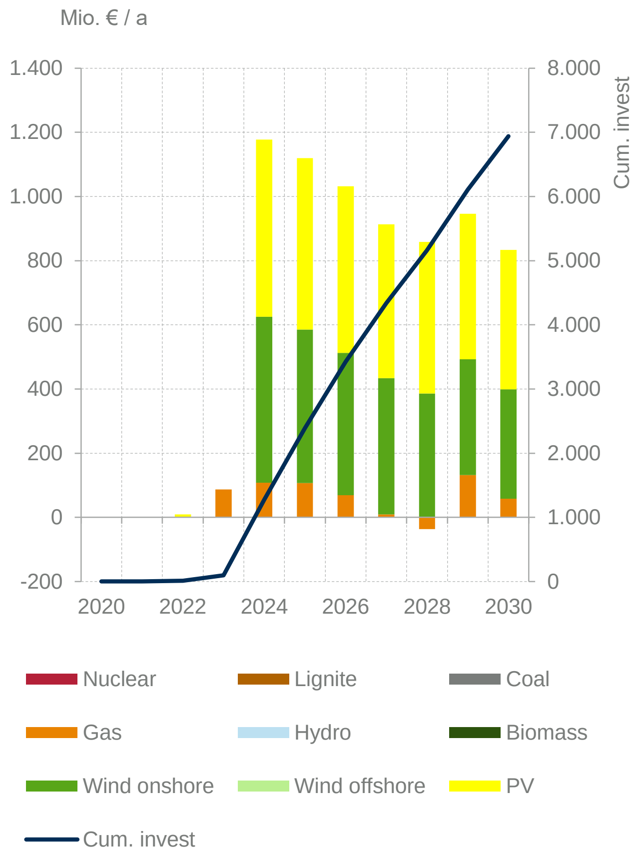
Scenario differences: Investment volumes in BG

Required additional investments into Bulgaria's power-generating infrastructure accumulate to 6.8 bn € (55 % PM), 6.9 bn € (55 % Market based coal exit) and 7.3 bn € (55 % Market based coal-to-clean) until 2030. Additional investments are mainly channelled towards onshore wind and PV assets and, to a lesser extent, into gas-based capacities.

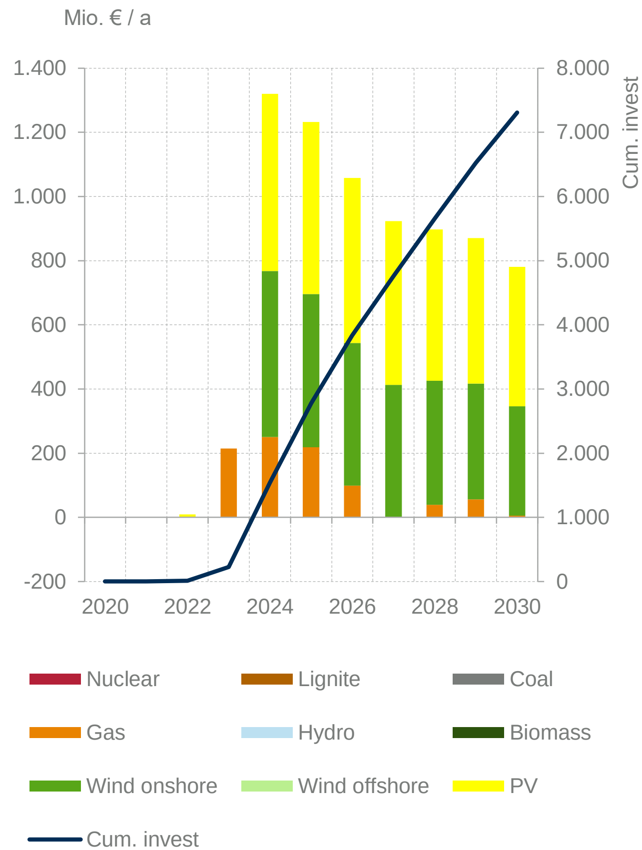
55 % PM



55 % MCE



55 % MCTC

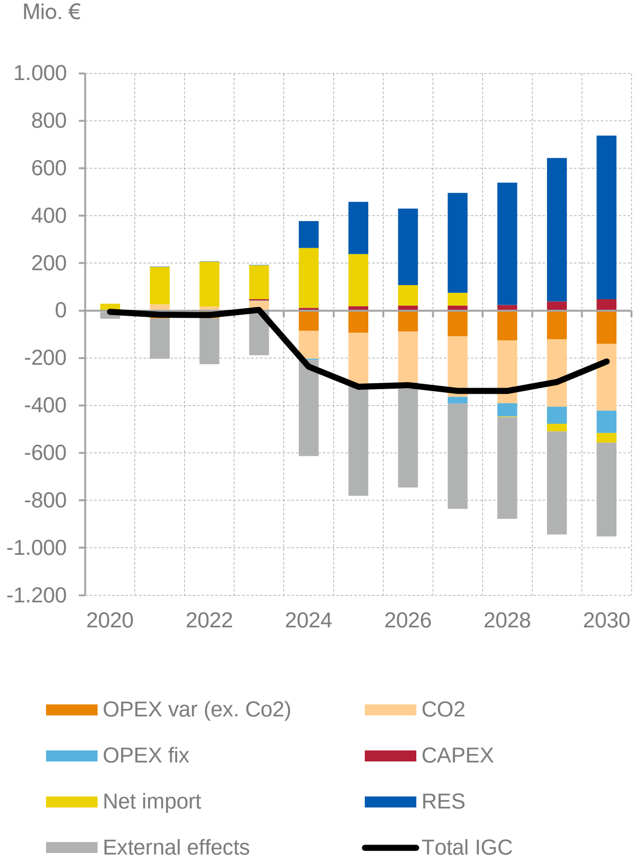


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

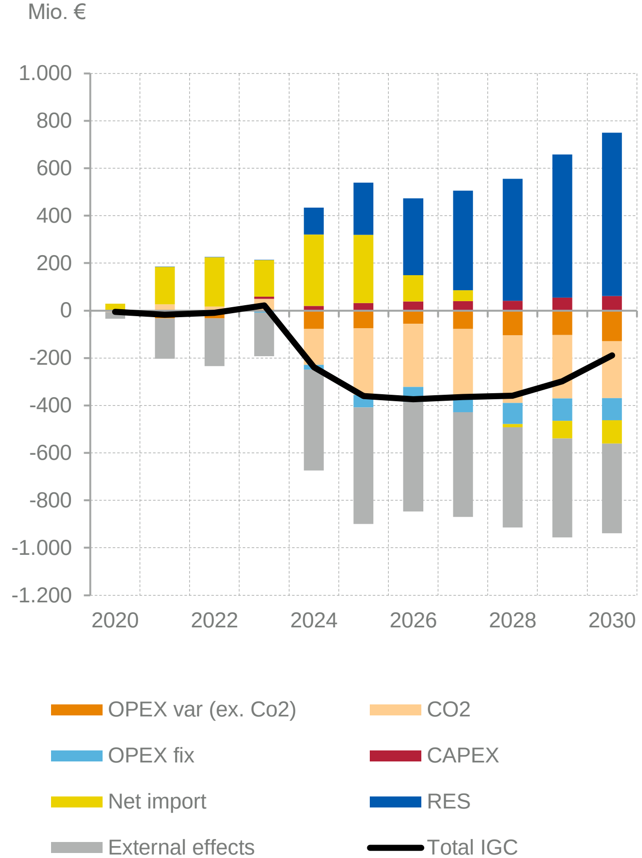
Scenario differences: Incremental generation costs in BG

Annual incremental generation costs are <u>lower</u> in Bulgaria in all 55 % scenarios. Main drivers are lower OPEX and costs related to external effects, which overcompensated RES & import costs. Note: Revenues from auctioned CO_2 certificates can also be seen as a source of income.

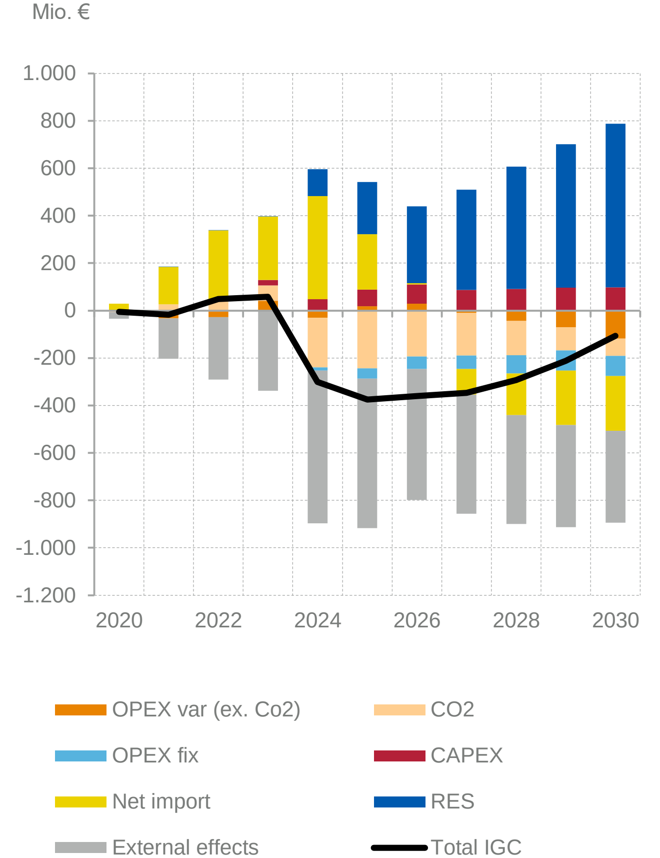
55 % PM



55 % MCE



55 % MCTC

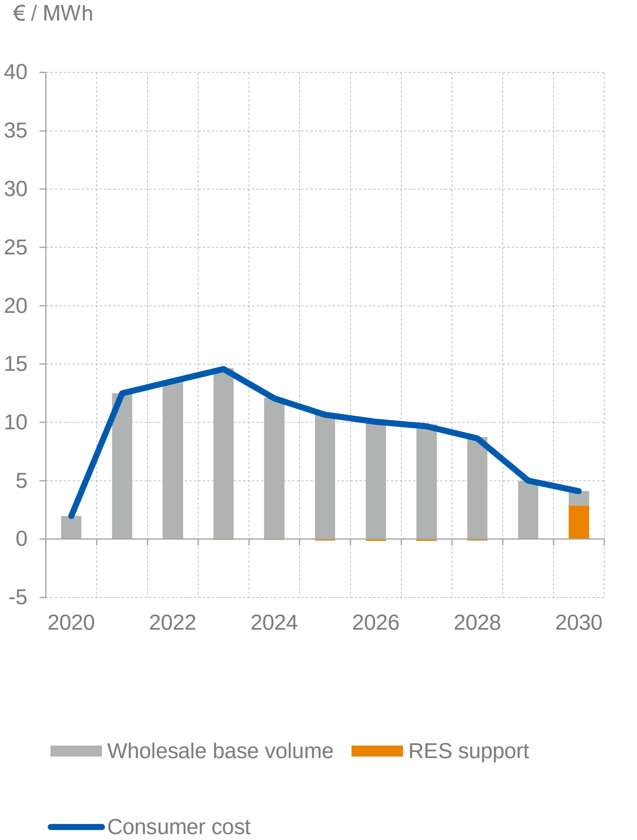


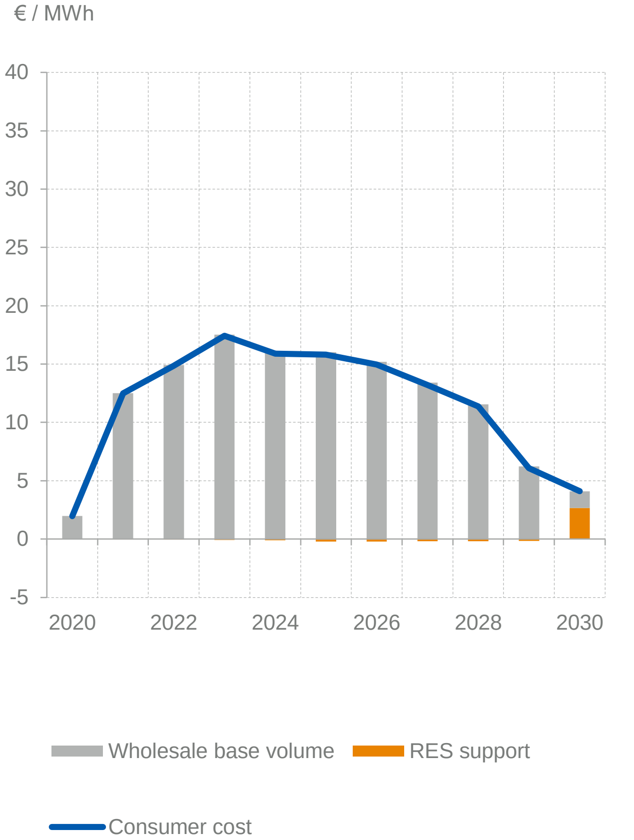
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

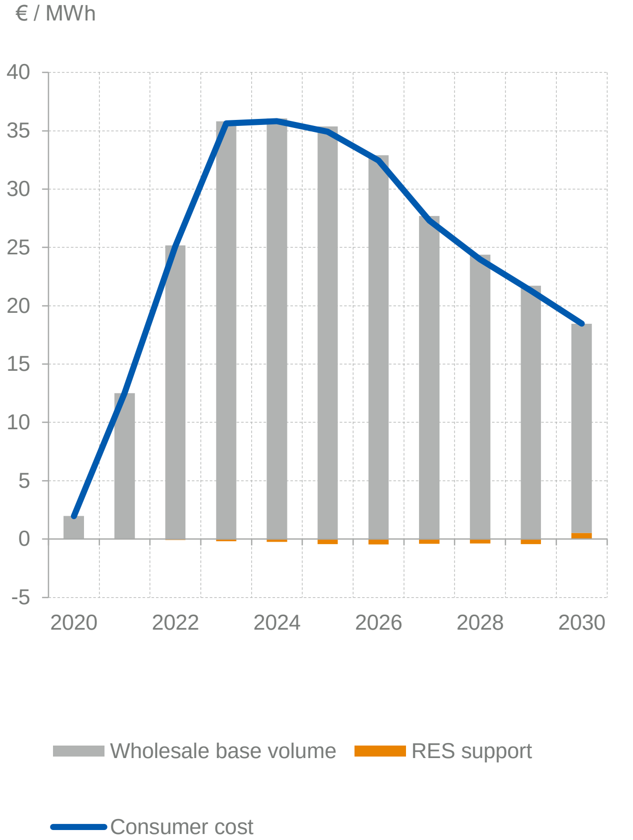
Scenario differences: Consumer costs in BG

Costs to consumers increase in all 55 % scenarios in Bulgaria (in comparison with the 40 % PM scenario) due to higher wholesale price levels, partly driven by higher CO_2 prices and net-imports. The effect is mitigated with increased availability of carbon-free renewable generation towards 2030.

55 % PM	55 % MCE	55 % MCTC





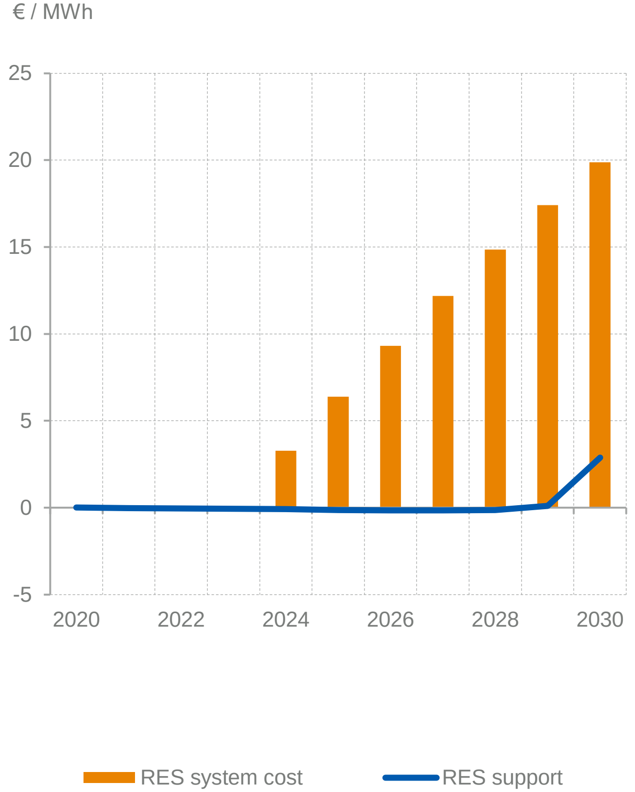


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

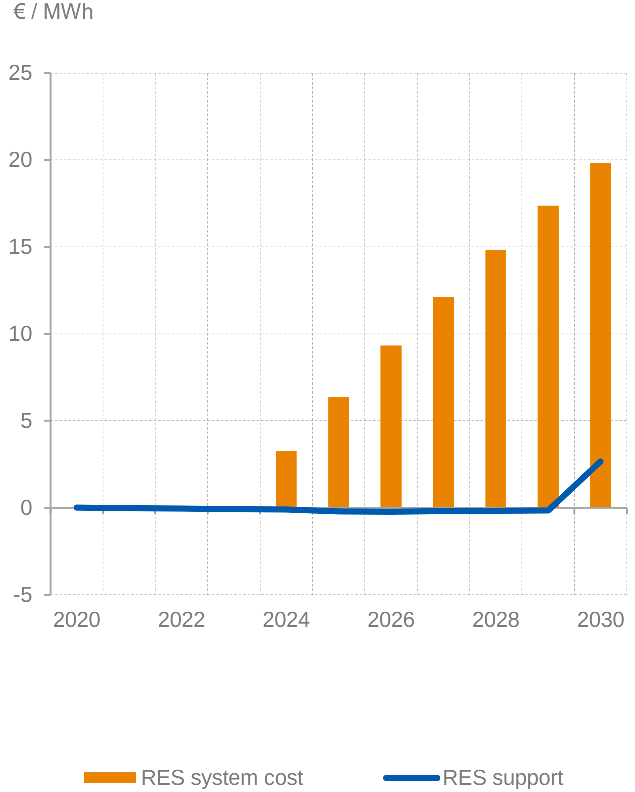
Scenario differences: RES re-financing in BG

The deployment of significant additional RES capacities increases RES system costs in Bulgaria in the 55 % scenarios. Higher wholesale prices imply higher market revenues of RES generation and thus decrease support needs. The additional required RES support (compared to the 40 % PM scenario) decreases in the mid-20s before increasing slightly after 2029.

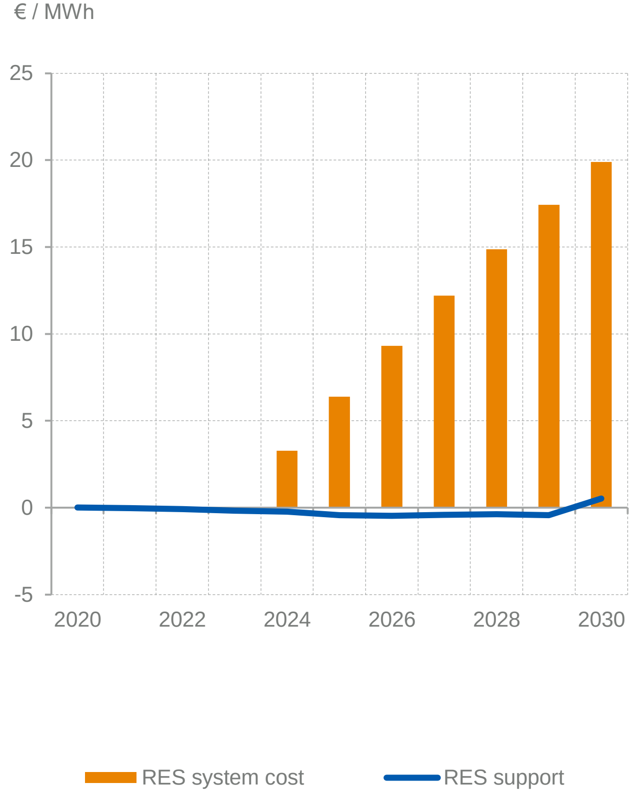
55 % PM



55 % MCE



55 % MCTC

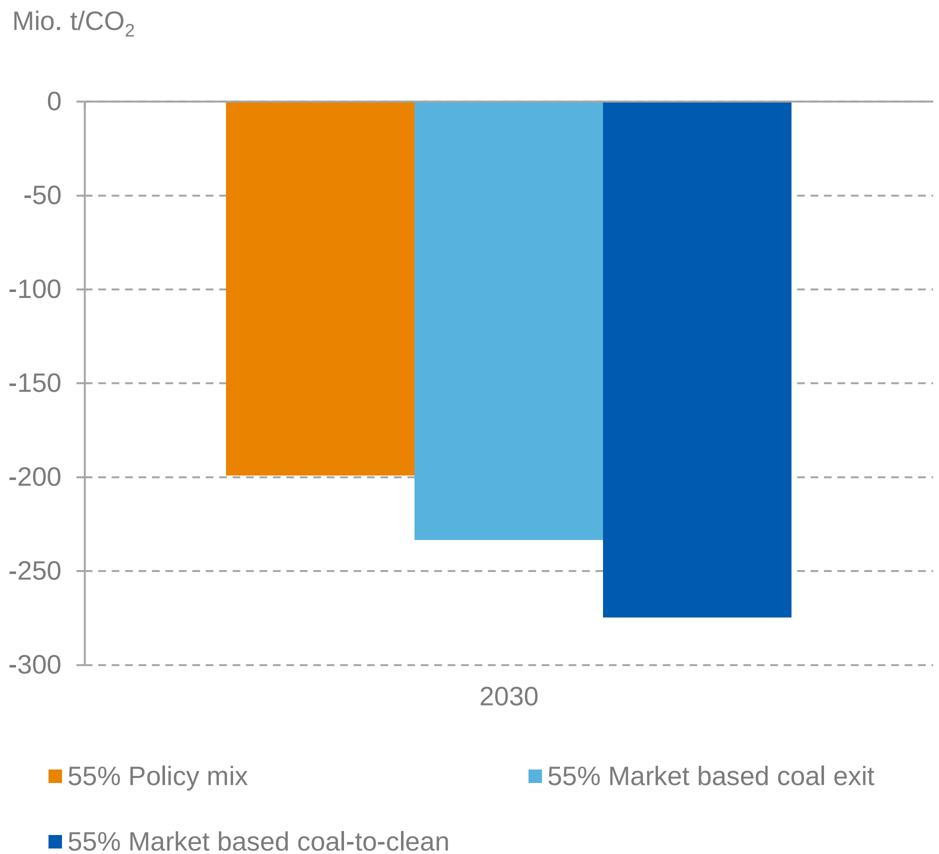


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

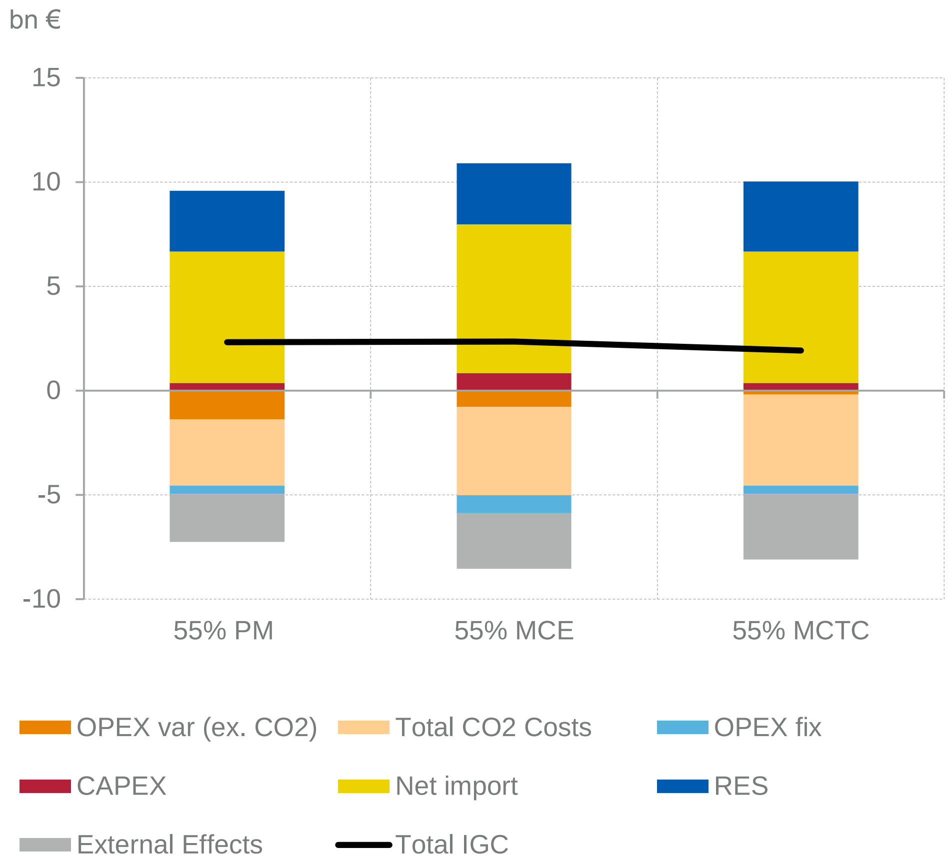
cz

Total emissions & system costs – CZ

Total CO_2 emissions (2020-2030)
Deltas minus 40 % PM



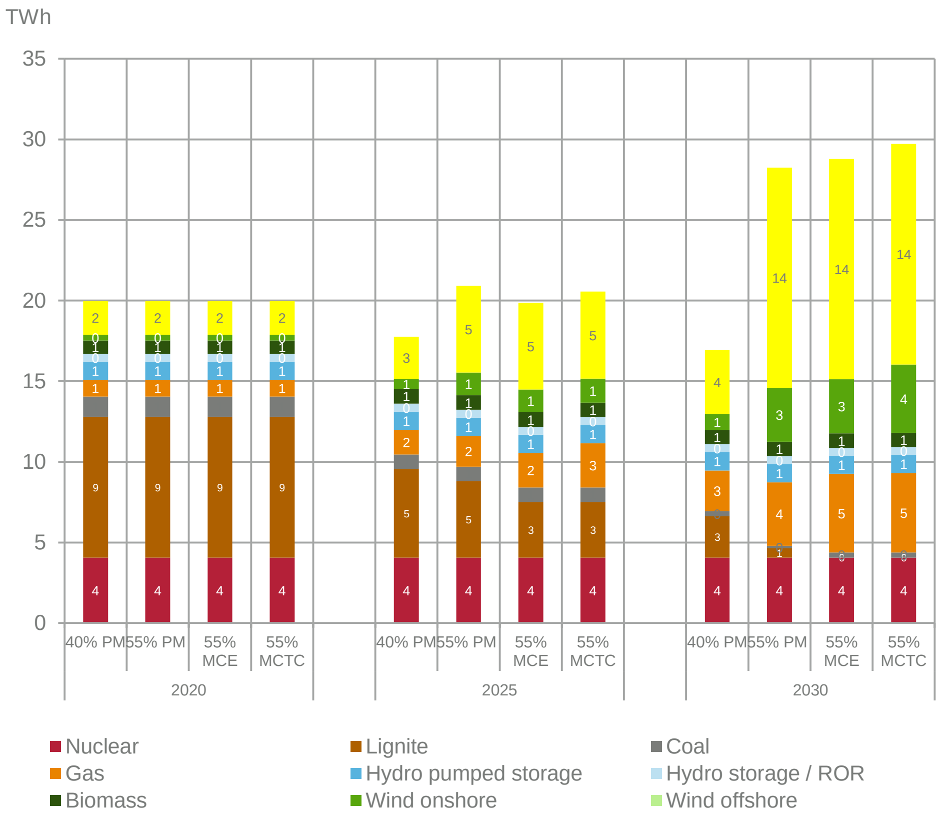
Total IGC (2020-2030)
Deltas minus 40 % PM



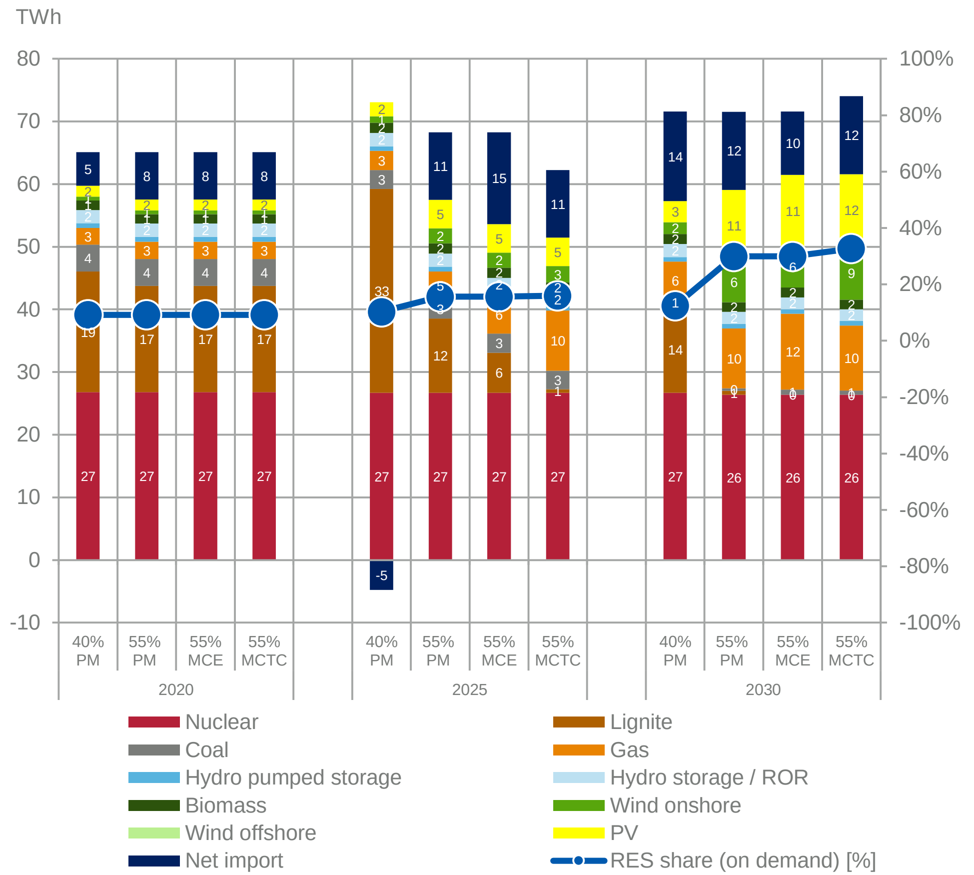
Capacity & generation – CZ

Compared to the 40 % PM, the 55 % scenarios lead to an earlier decommissioning & accelerated reduction of remaining coal capacities in the Czech Republic, which are substituted over time with a mix of wind onshore, PV & gas units (flexibility demand). The generation mix becomes less carbon-intensive and RES shares (on demand) increase by 20 percentage points by 2030 (55 % scenarios).

Capacities



Generation



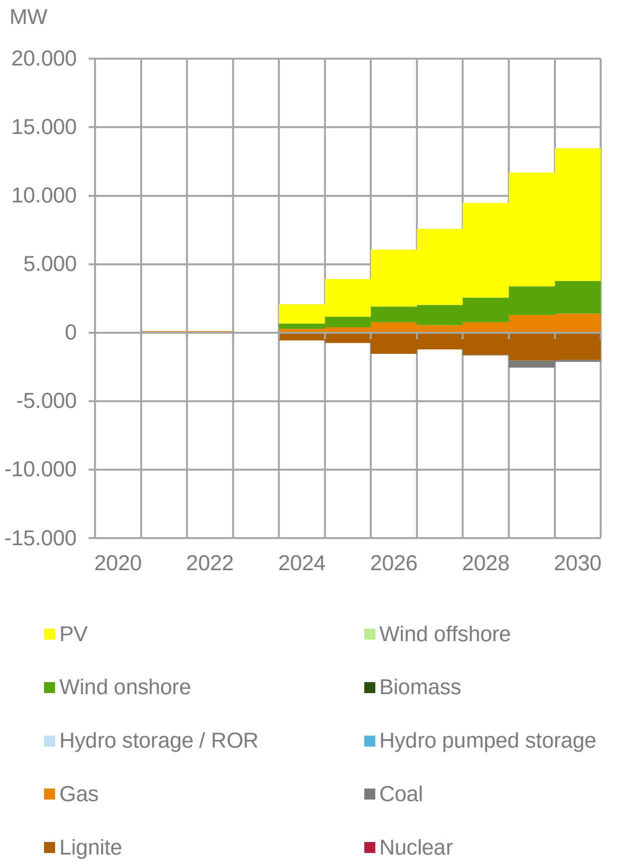
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM).

PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

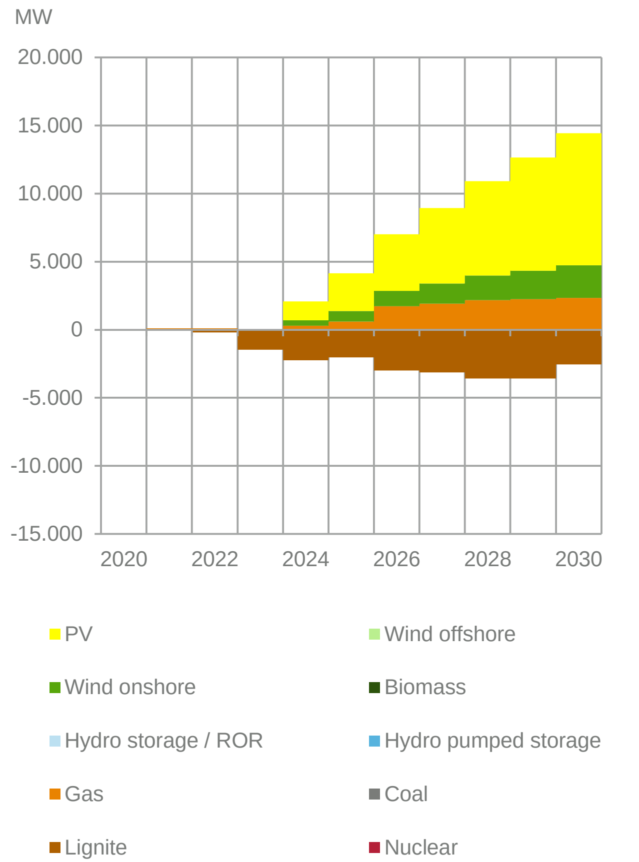
Scenario differences: Installed capacities in CZ

In all 55 % scenarios, the remaining coal capacities are substituted with a mix of wind onshore, PV and gas. Compared to the 55 % PM, the 55 % Market based scenarios see an earlier and steeper capacity reduction of coal units driven by higher CO_2-price trajectories. The higher CO_2-prices also trigger additional market based RES expansion, especially in the 55 % Market based coal-to-clean scenario.

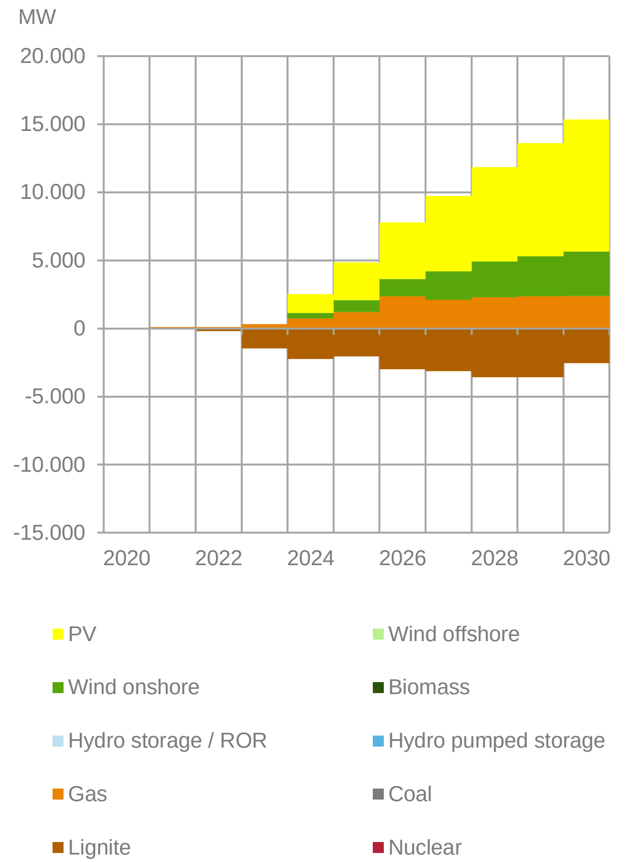
55 % PM



55 % MCE



55 % MCTC

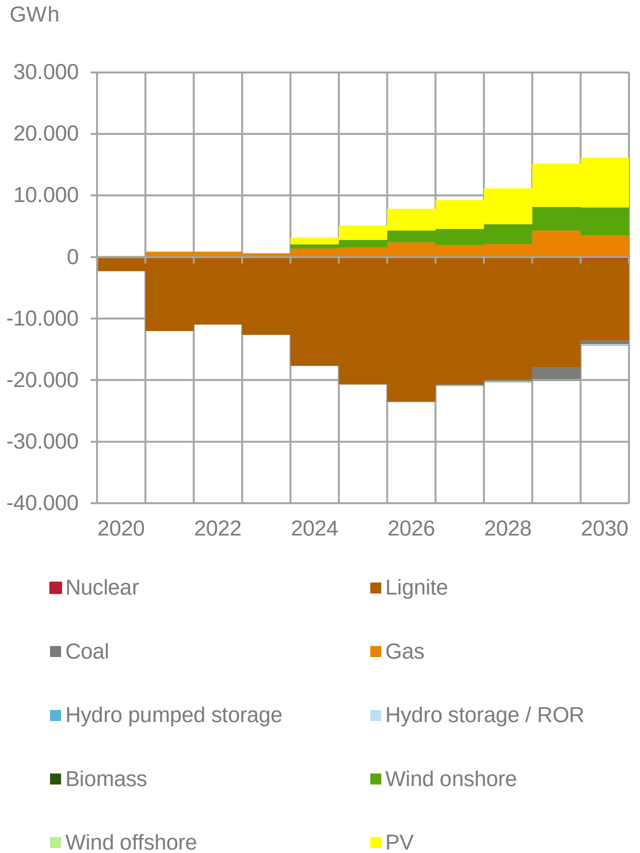


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

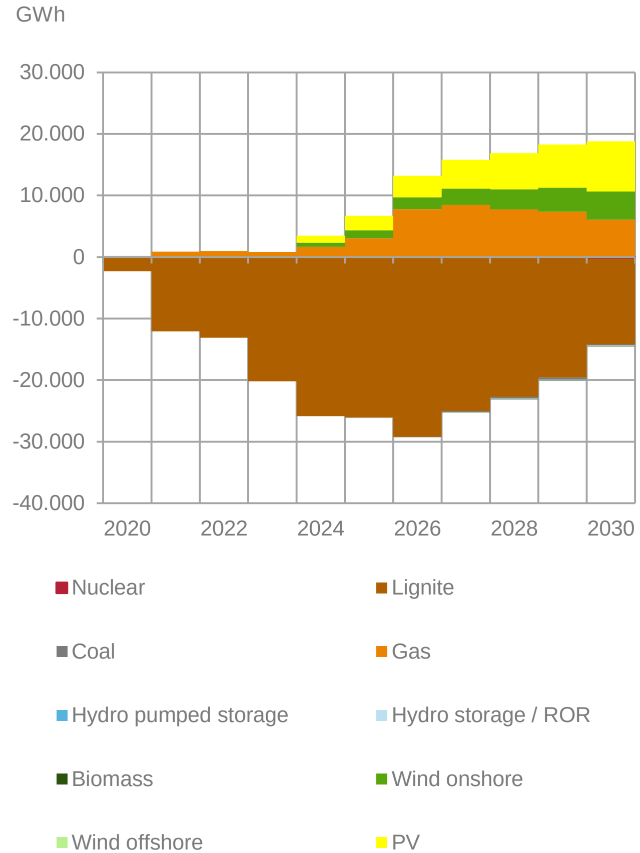
Scenario differences: Power generation in CZ

Earlier decommissioning and lower utilization of the remaining coal-fired units in the Czech Republic trigger temporary increased gas-based generation (mid-term), especially in both 55 % Market based scenarios. In the long run, coal-based generation is compensated by wind onshore, PV and gas-based generation.

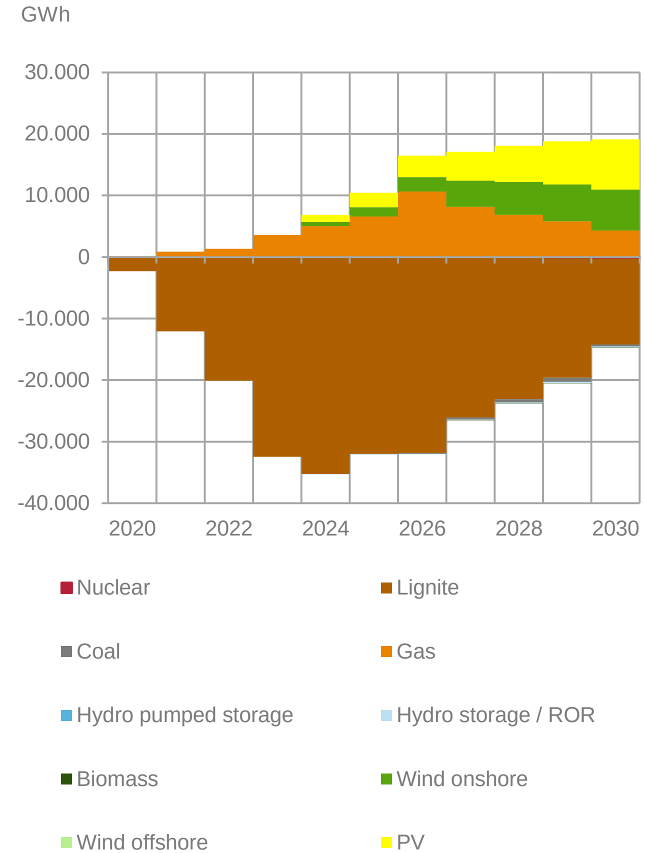
55 % PM



55 % MCE



55 % MCTC

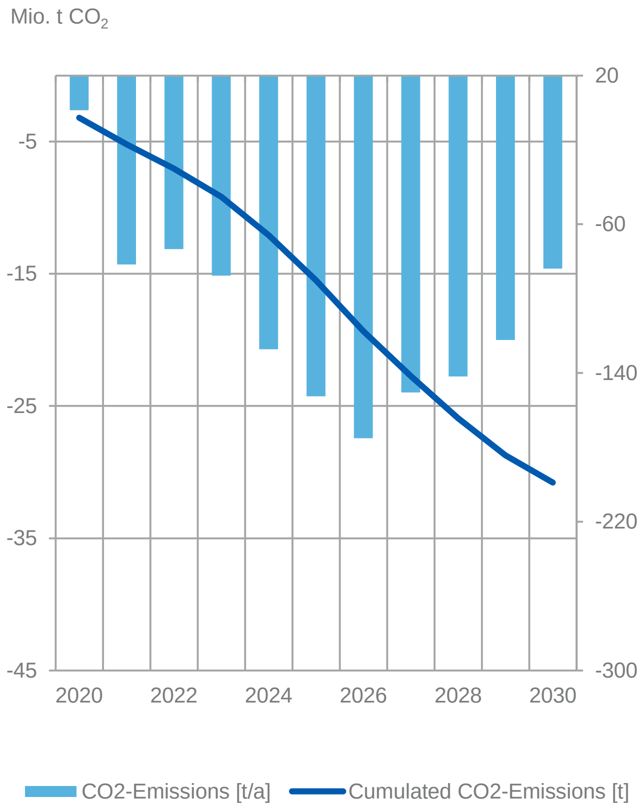


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

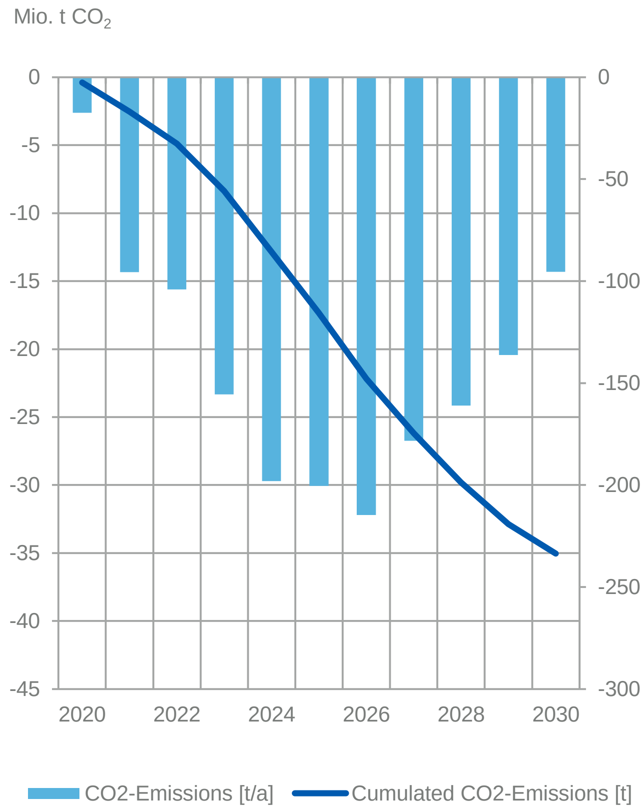
Scenario differences: CO_2 emissions in CZ

All 55 % scenarios lead to significant CO_2 savings in the Czech Republic compared to the 40 % PM scenario. Until 2024, the additional reduction is driven only by the CO_2 price. In total, the 55 % PM scenario results in a cumulative reduction of 200 Mio.t. of CO_2 (market based coal exit: 234 Mio.t.; market-based coal-to-clean: 275 Mio.t.) until 2030 compared to the 40 % PM scenario.

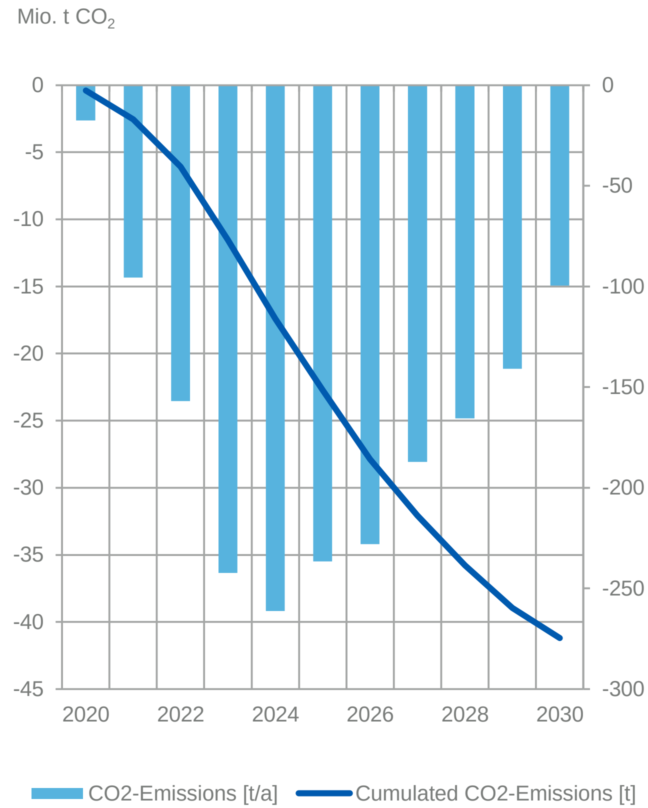
55 % PM



55 % MCE



55 % MCTC

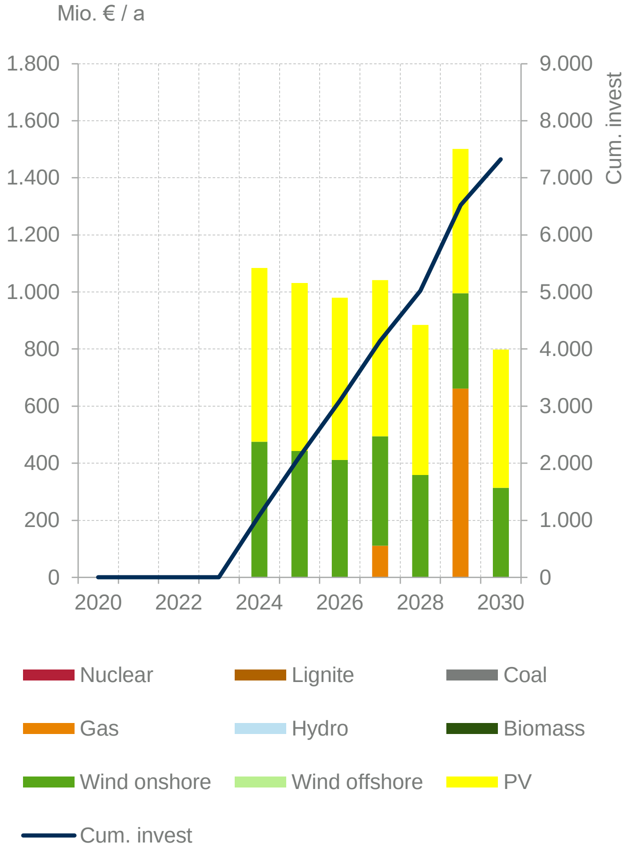


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

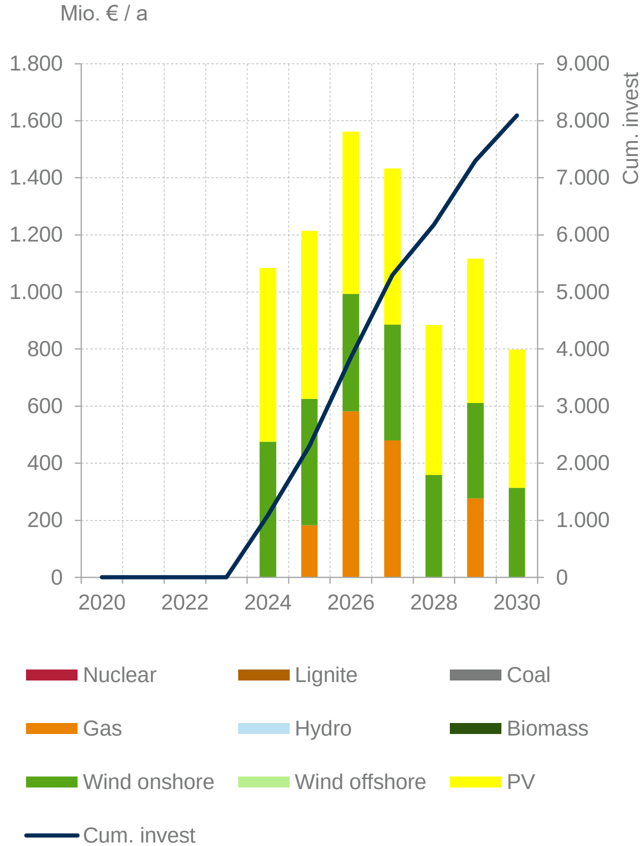
Scenario differences: Investment volumes in CZ

Required additional investments into the Czech Republic's power-generating infrastructure accumulate to 7.3 bn € (55 % PM), 8.1 bn € (55 % Market based coal exit) and 8.3 bn € (55 % Market based coal-to-clean) until 2030. Additional investments are mainly channelled towards onshore wind and PV assets and, to a lesser extent, into gas-based capacities.

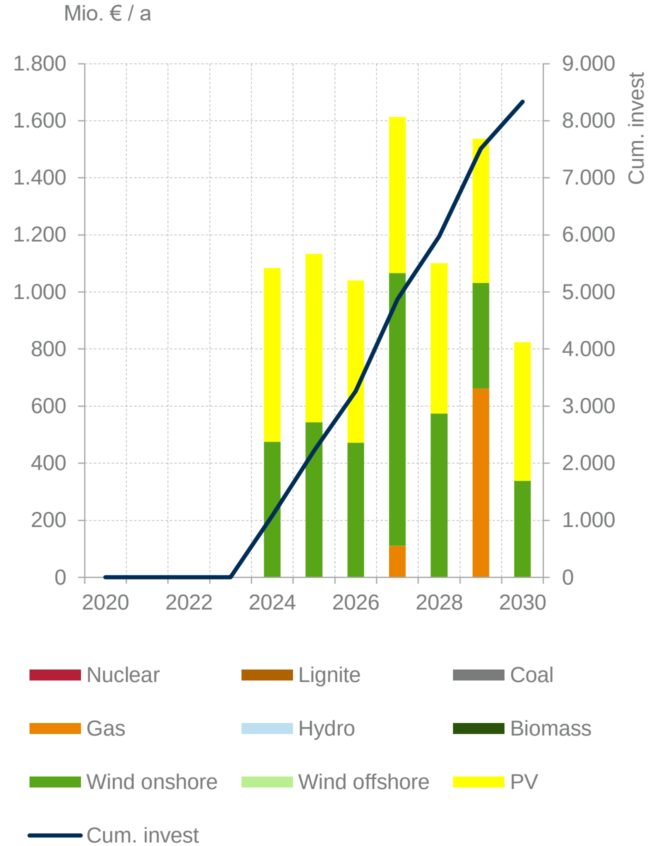
55 % PM



55 % MCE



55 % MCTC

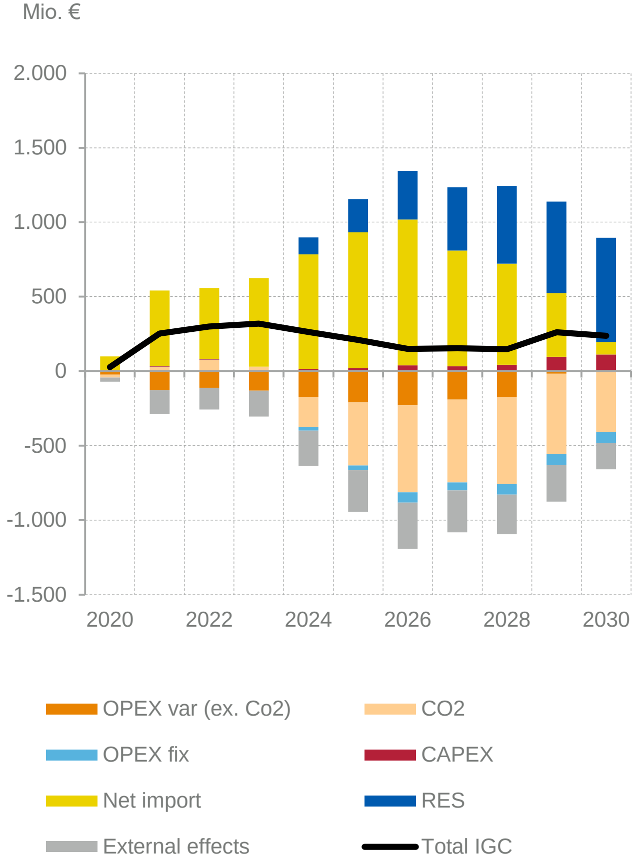


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

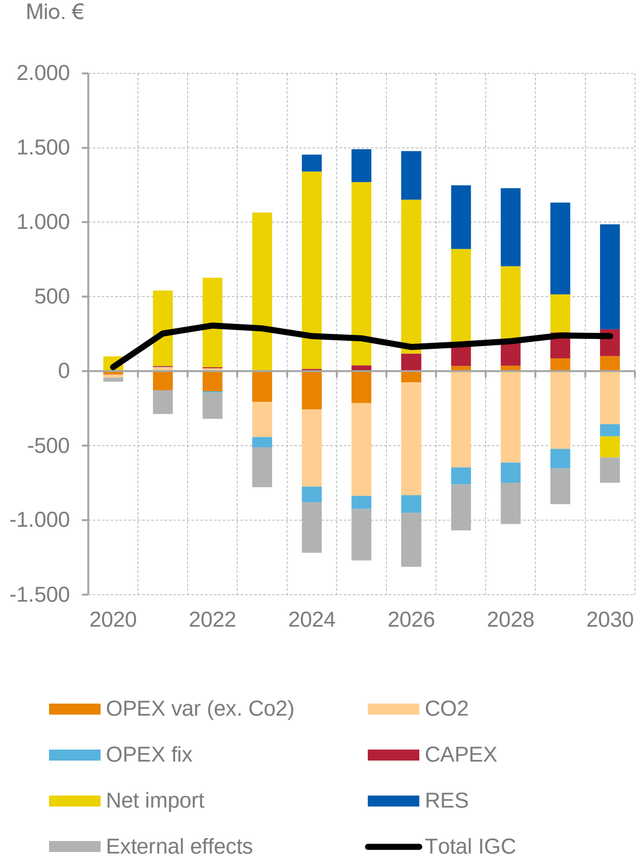
Scenario differences: Incremental generation costs in CZ

Annual incremental generation costs in the Czech Republic are higher in all 55 % scenarios. Main drivers are higher RES & significant import costs which dominate diverse savings in OPEX and external effects by the end of the decade. Note: Revenues from auctioned CO_2 certificates can also be seen as a source of income.

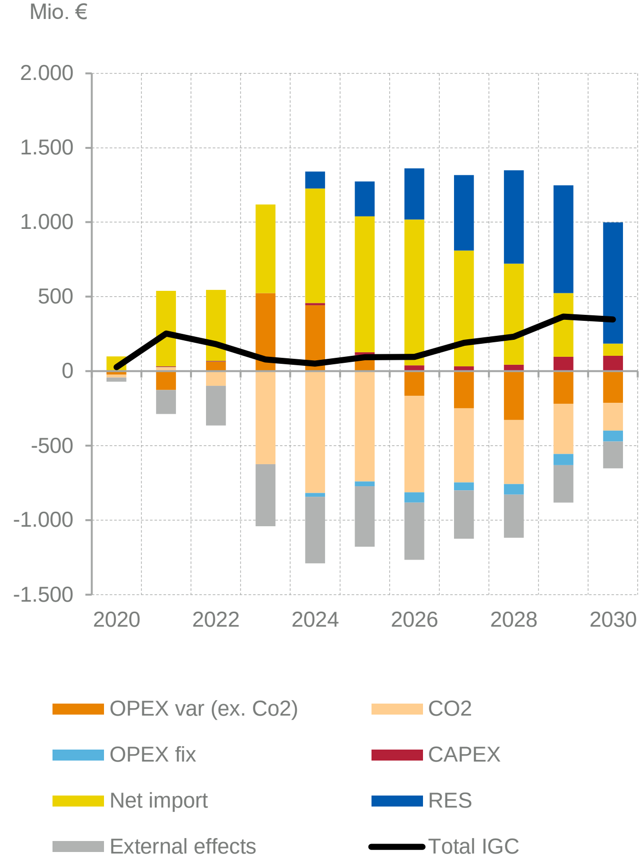
55 % PM



55 % MCE



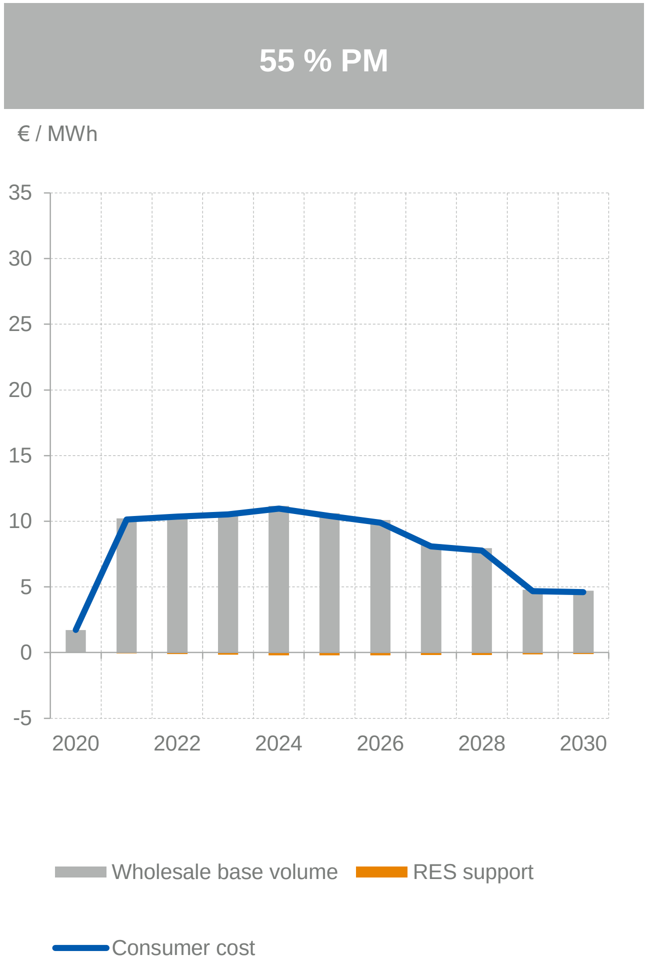
55 % MCTC

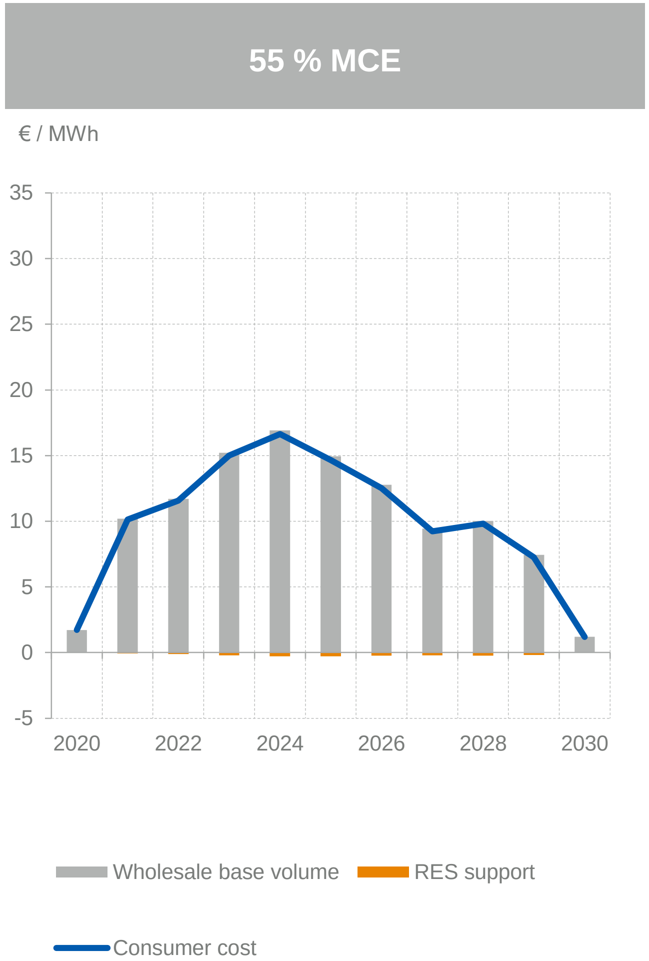


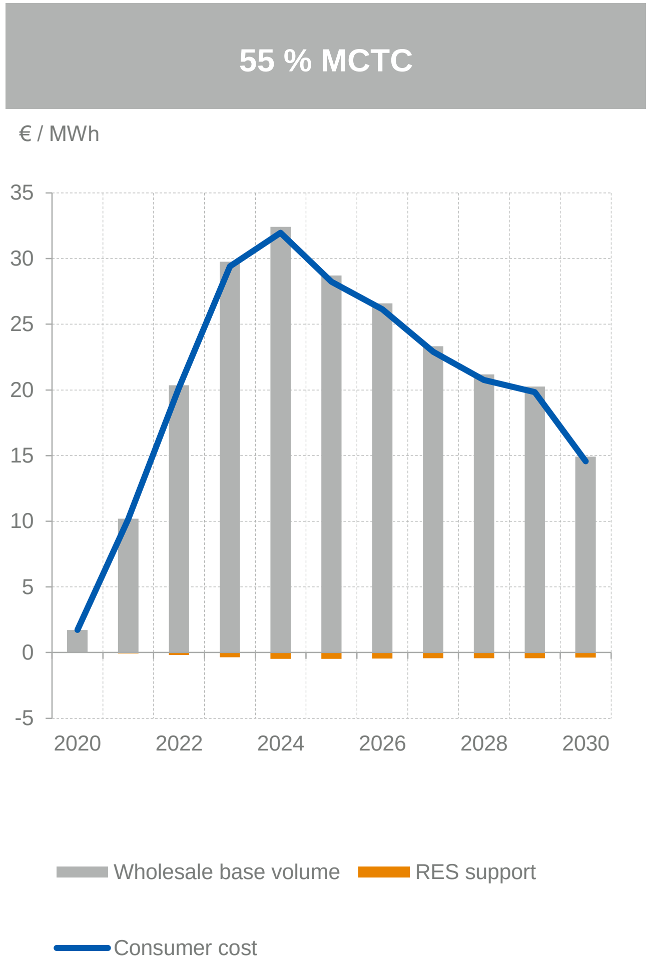
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Scenario differences: Consumer costs in CZ

Costs to consumers increase in all 55 % scenarios in the Czech Republic (in comparison with the 40 % PM scenario) due to higher wholesale price levels, partly driven by higher CO_2 prices and net-imports. The effect is mitigated with increased availability of carbon-free renewable generation towards 2030.





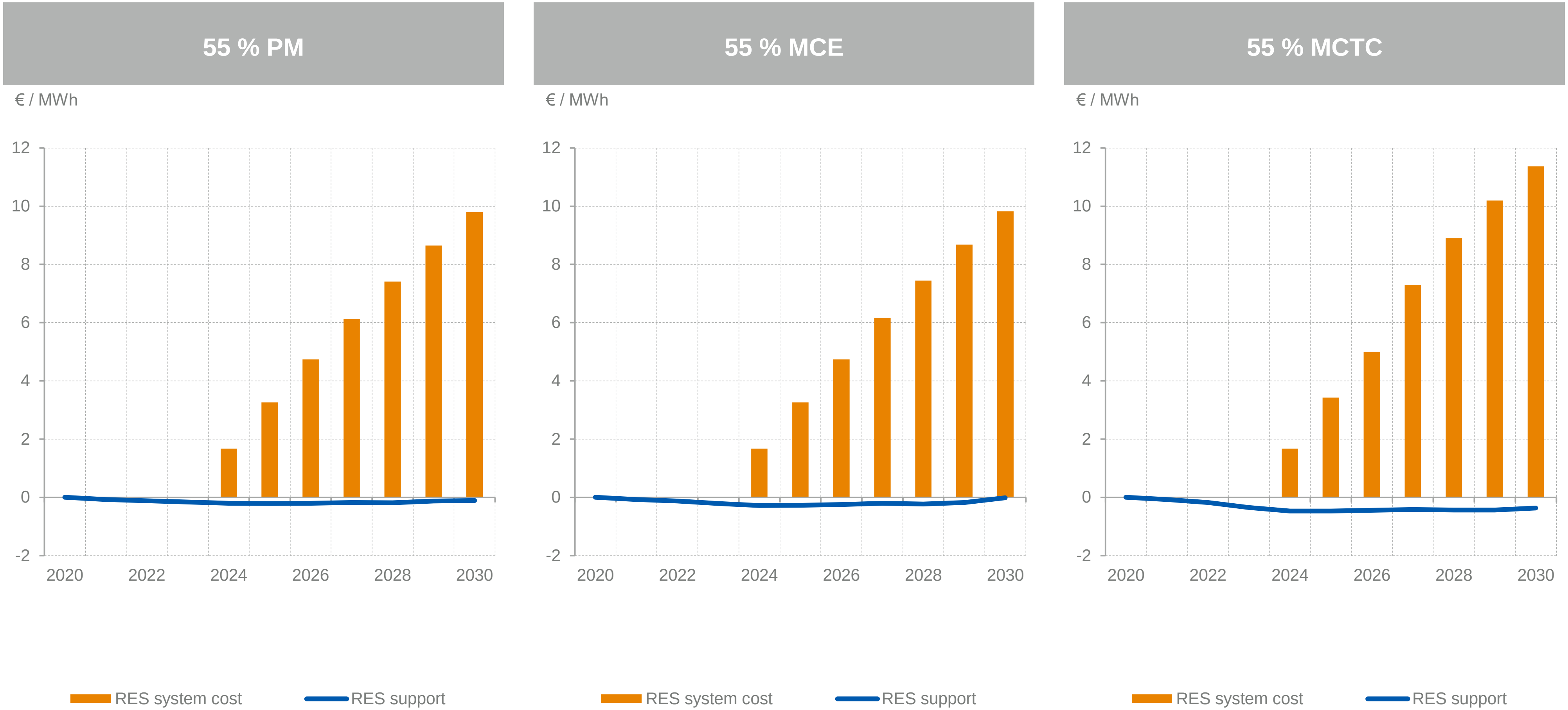


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM).

PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Scenario differences: RES re-financing in CZ

The deployment of significant additional RES capacities increases RES system costs in the Czech Republic in the 55 % scenarios. Higher wholesale prices imply higher market revenues of RES generation and thus decrease support needs. The required additional RES support decreases over time, especially in the 55 % Market based coal-to-clean scenario.

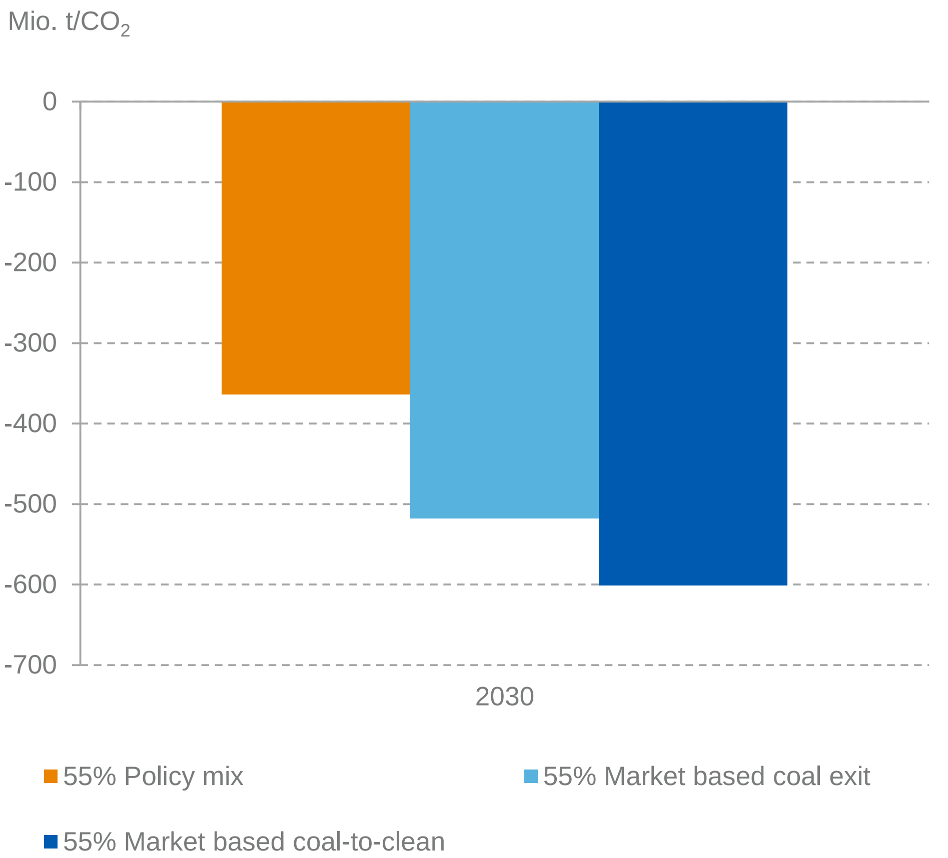


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

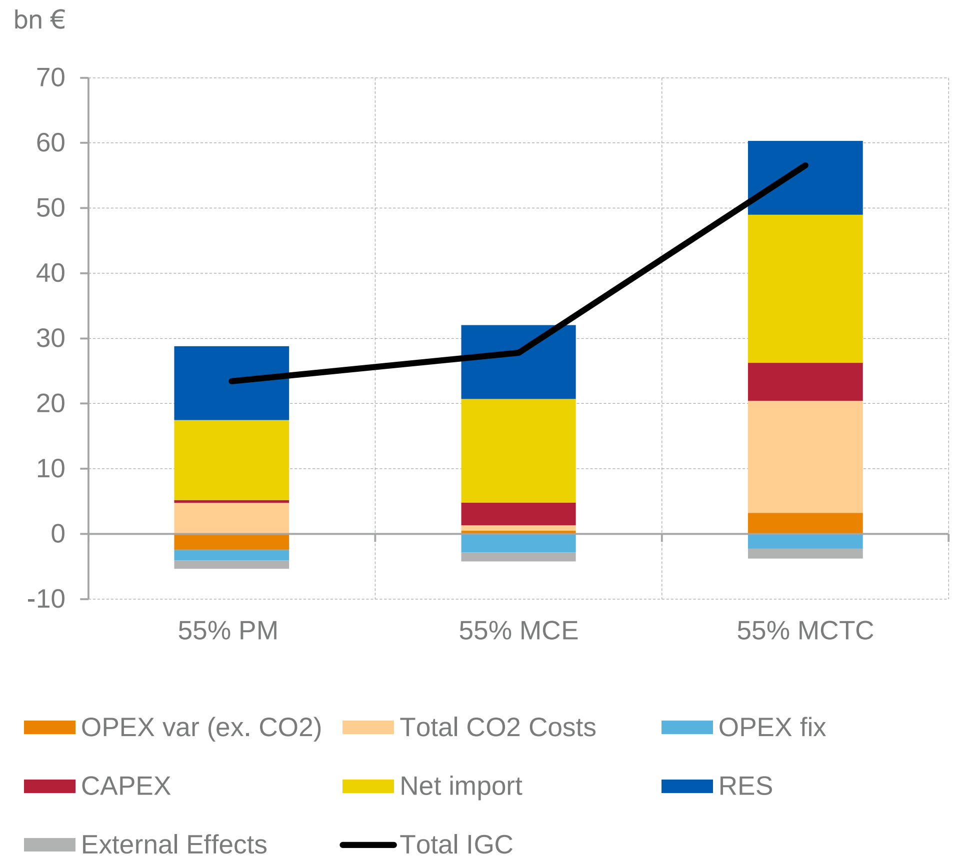
DE

Total emissions & system costs – DE

Total CO_2 emissions (2020-2030)
Deltas minus 40 % PM



Total IGC (2020-2030)
Deltas minus 40 % PM



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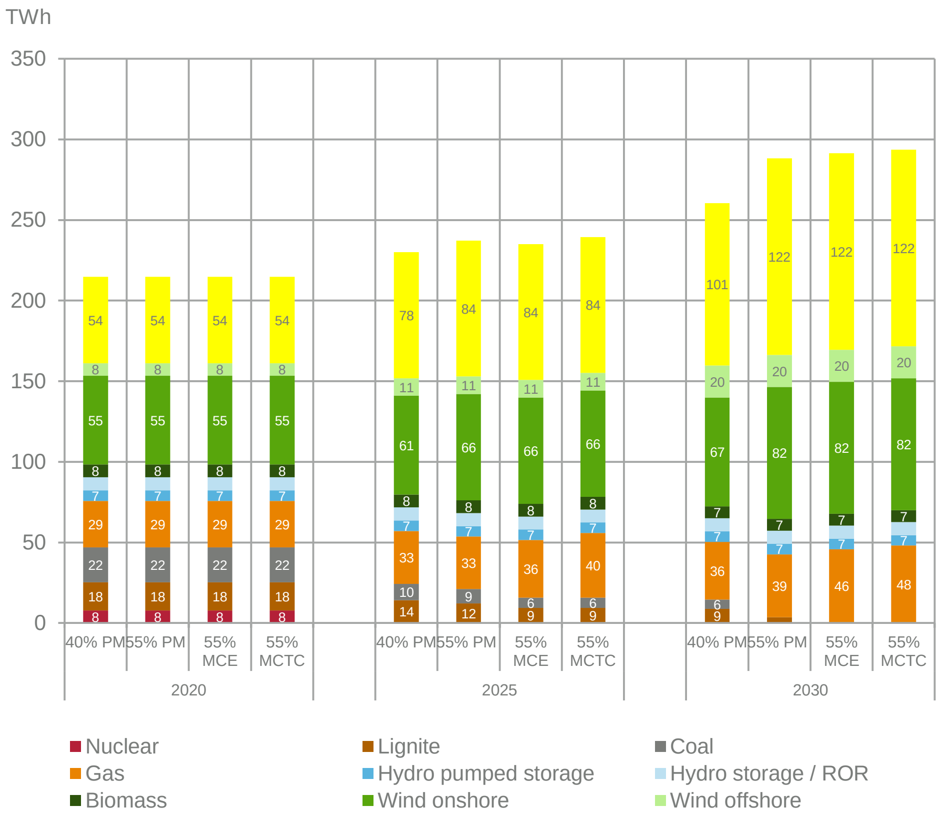
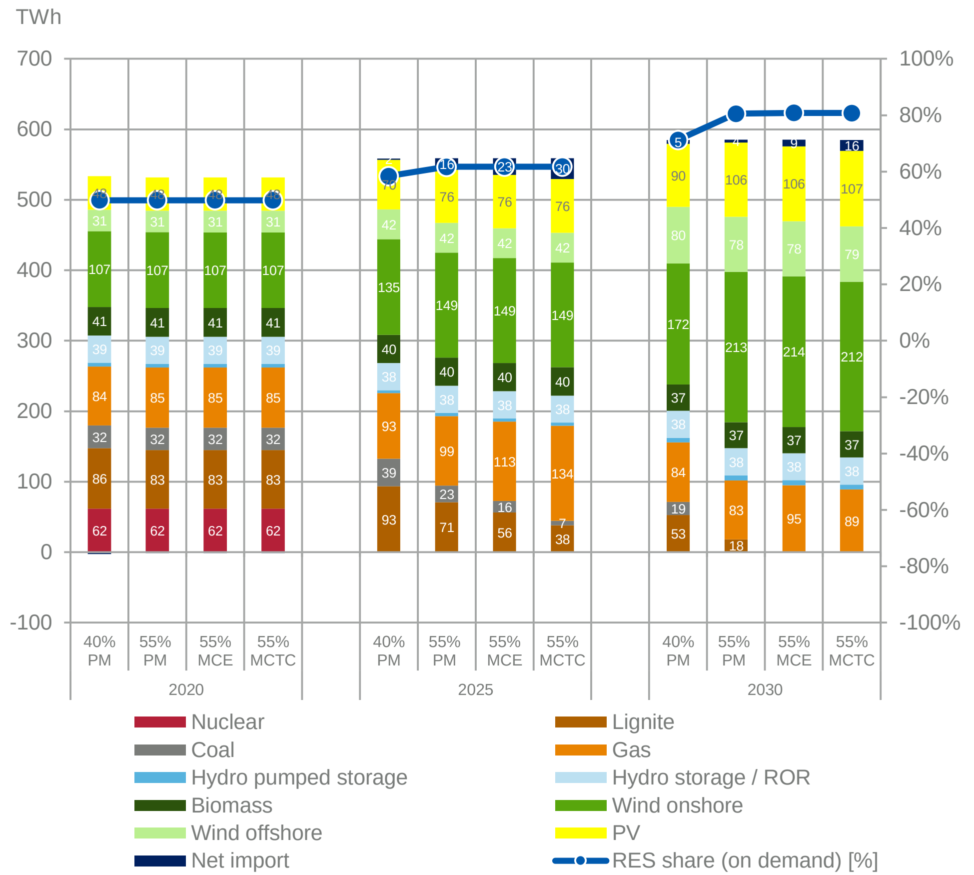
Capacity & generation – DE

Compared to the 40 % PM, the 55 % scenarios lead to an earlier decommissioning & accelerated reduction of remaining coal capacities in Germany, which are substituted over time with a mix of wind onshore, PV & gas units (flexibility demand). The generation mix becomes less carbon-intensive & RES shares (on demand) increase by over 30 percentage points by 2030 (55 % scenarios).

Capacities



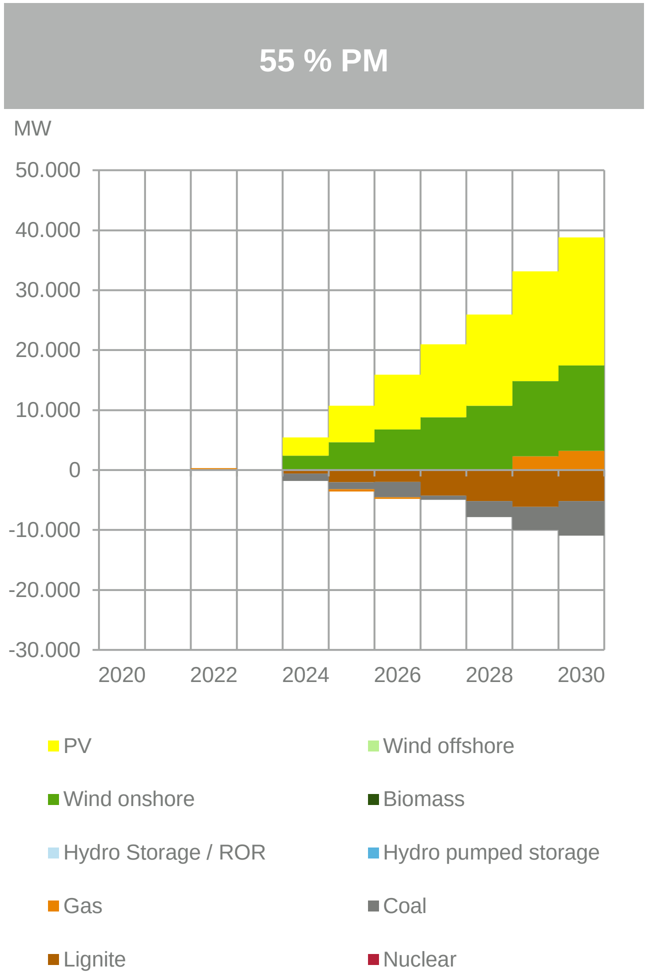
Generation

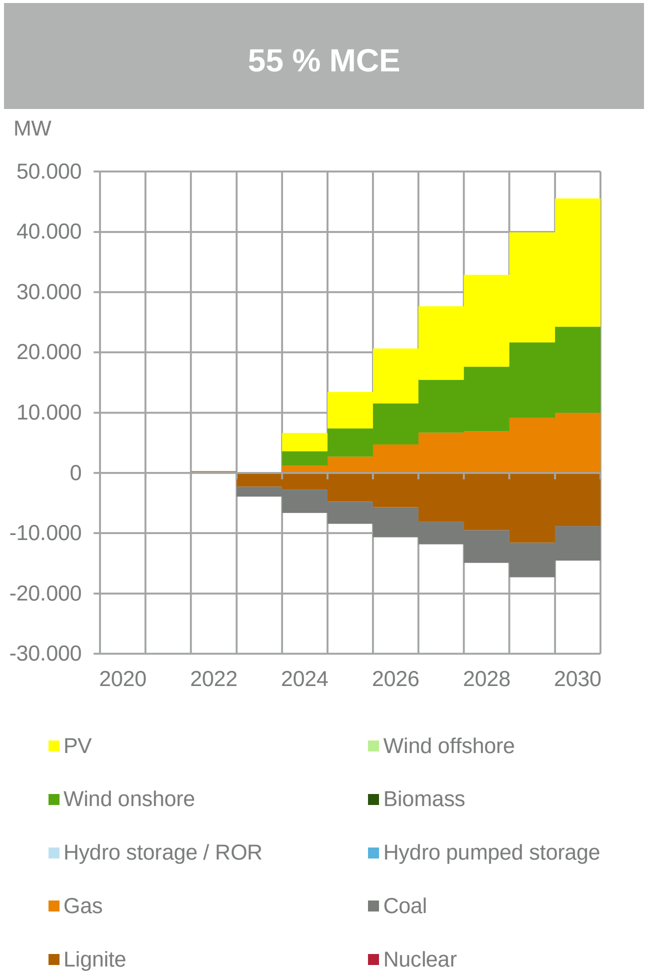


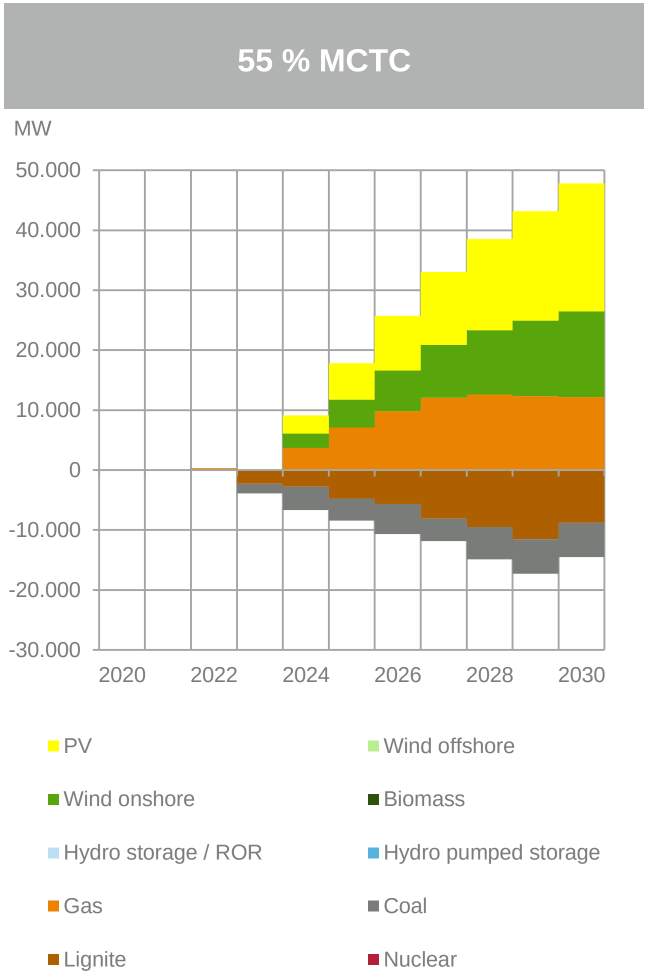
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Scenario differences: Installed capacities in DE

In all 55 % scenarios, the remaining coal capacities are substituted with a mix of wind onshore, PV and gas. Compared to the 55 % PM, the 55 % Market based scenarios see an earlier and steeper capacity reduction of coal units driven by higher CO_2-price trajectories. The higher CO_2-prices also trigger additional market based RES expansion, especially in the 55 % Market based coal-to-clean scenario.





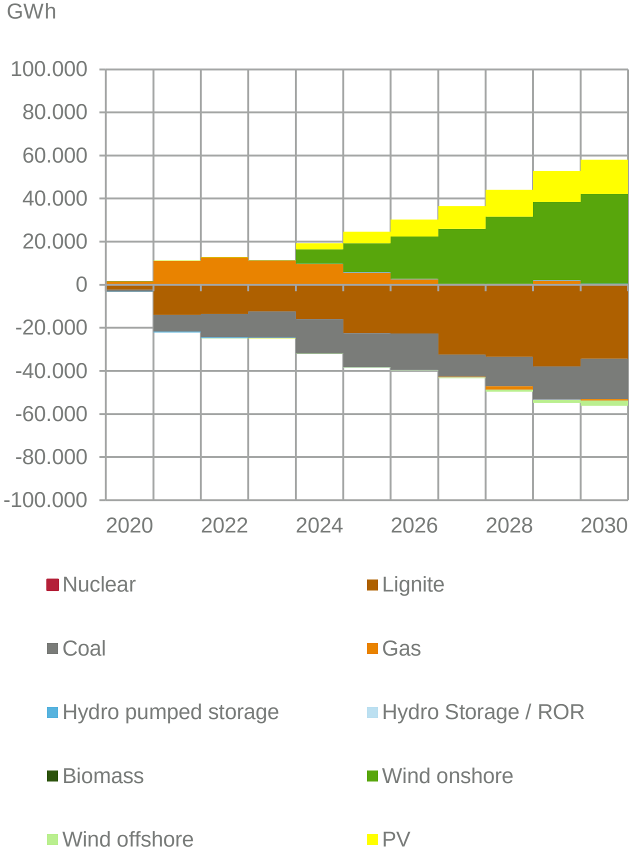


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

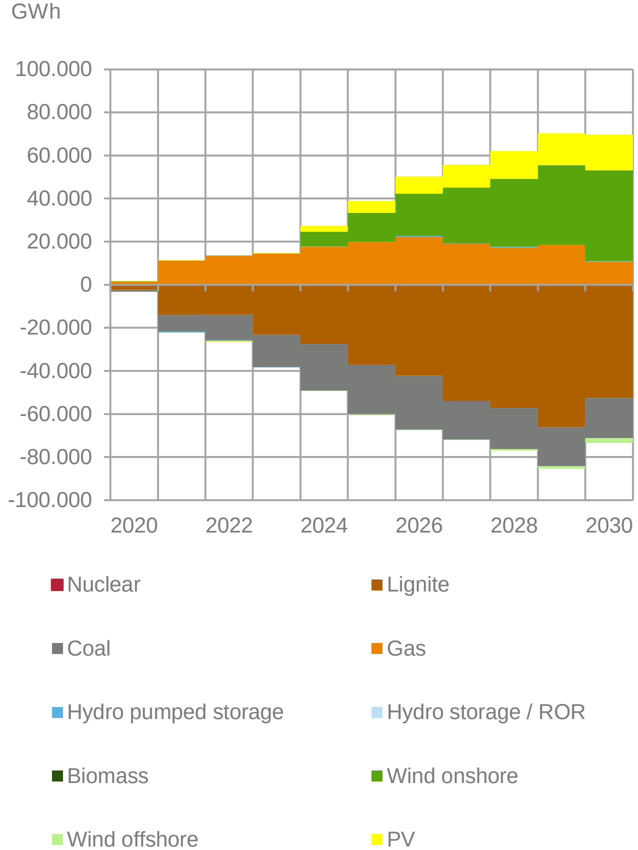
Scenario differences: Power generation in DE

Earlier decommissioning and lower utilization of the remaining coal-fired units in Germany trigger temporary increased gas-based generation (mid-term), especially in both 55 % Market based scenarios. In the long run, coal-based generation is compensated by wind onshore, PV and gas-based generation.

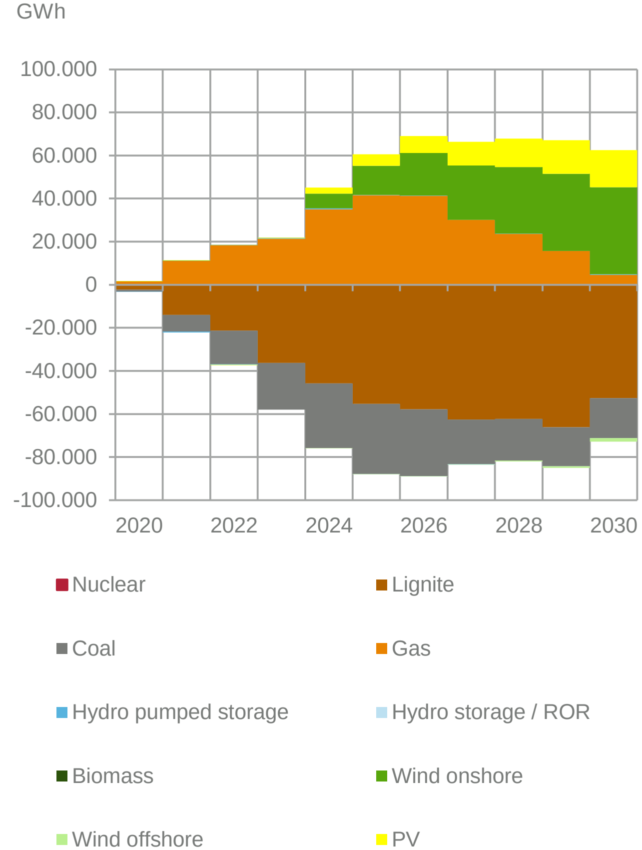
55 % PM



55 % MCE



55 % MCTC

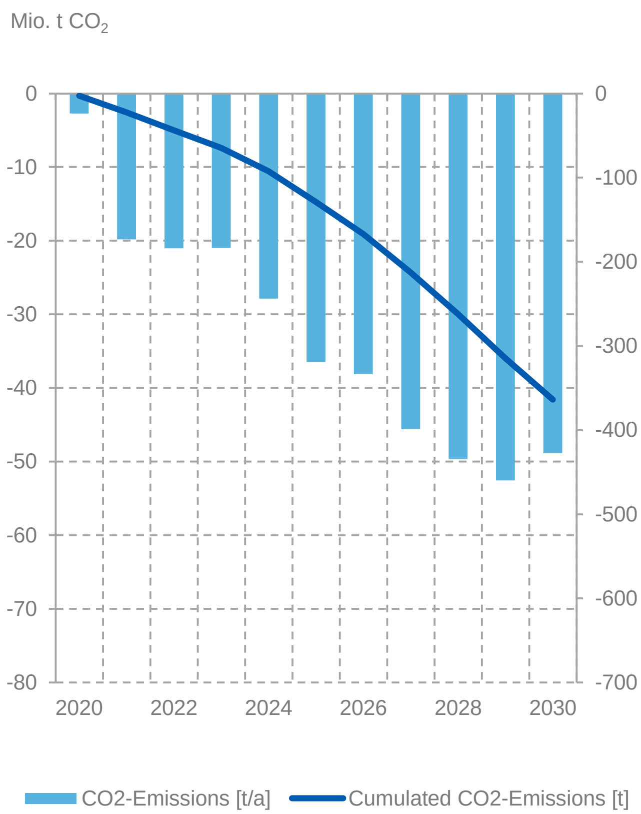


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

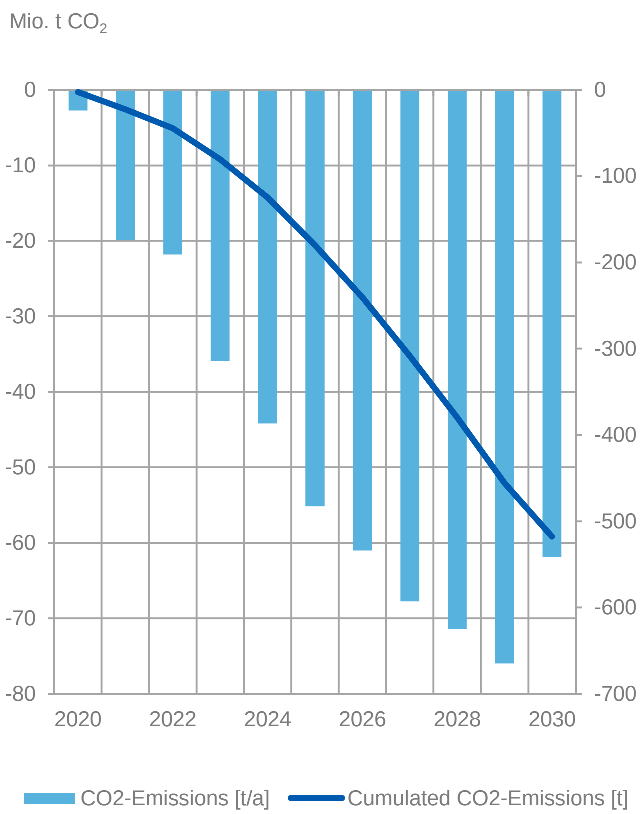
Scenario differences: CO_2 emissions in DE

All 55 % scenarios lead to significant CO_2 savings in Germany compared to the 40 % PM scenario. Until 2024, the additional reduction is driven only by the CO_2 price. In total, the 55 % PM scenario results in a cumulative reduction of 364 Mio. t of CO_2 (market based coal exit: 518 Mio.t.; market-based coal-to-clean: 601 Mio.t.) until 2030 compared to the 40 % PM scenario.

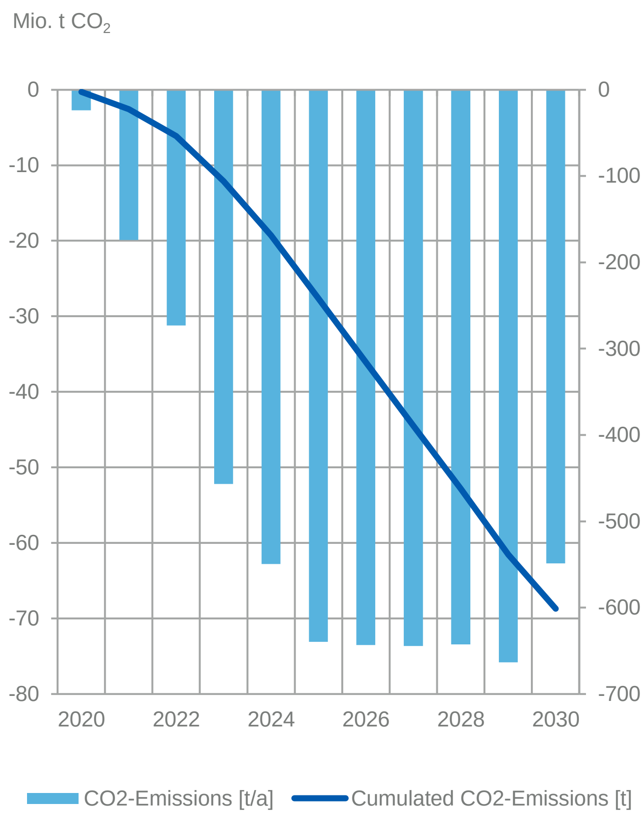
55 % PM



55 % MCE



55 % MCTC

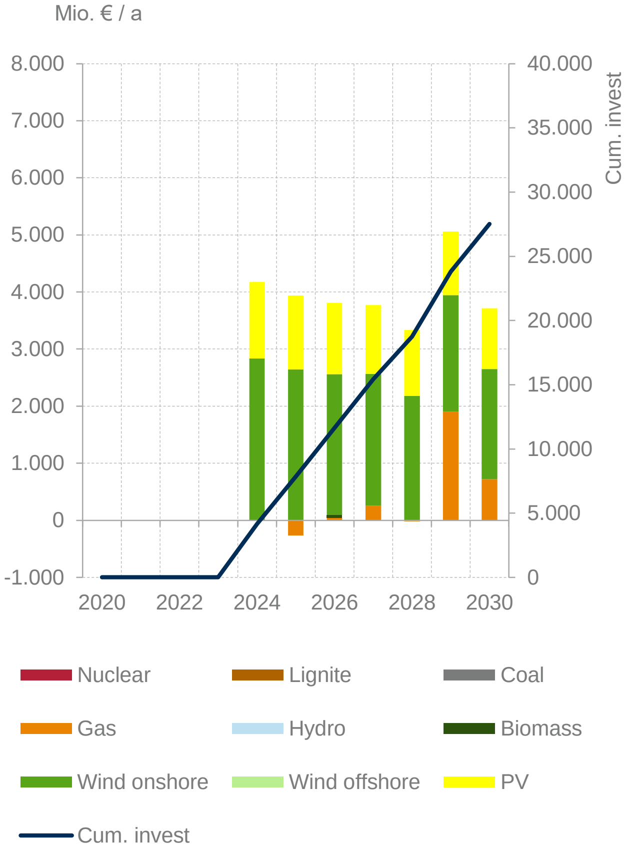


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM).   PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

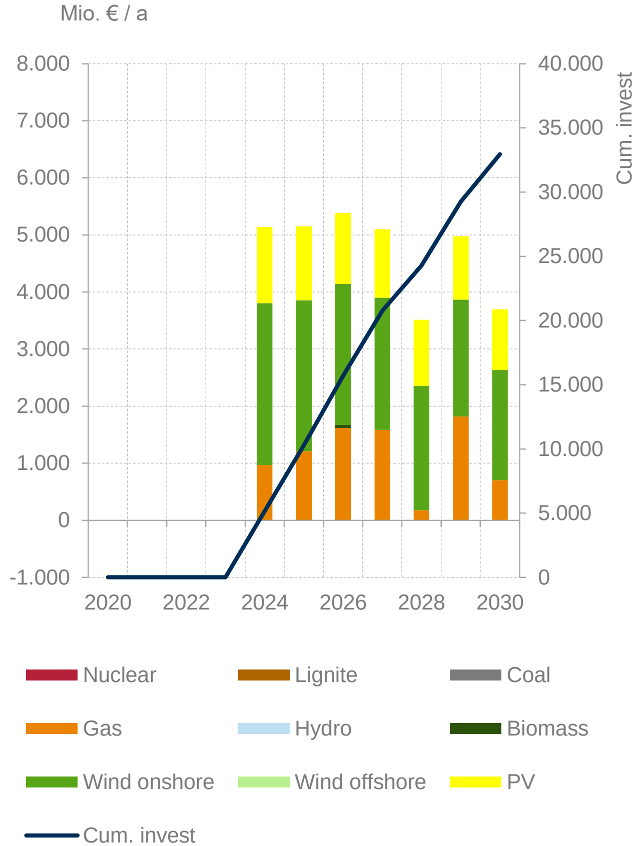
Scenario differences: Investment volumes in DE

Required additional investments into Germany's power-generating infrastructure accumulate to 28 bn € (55 % PM), 33 bn € (55 % Market based coal exit) and 35 bn € (55 % Market based coal-to-clean) until 2030. Additional investments are mainly channelled towards onshore wind and PV assets and, especially in the 55 % Market based scenarios, to some extent into gas-based capacities.

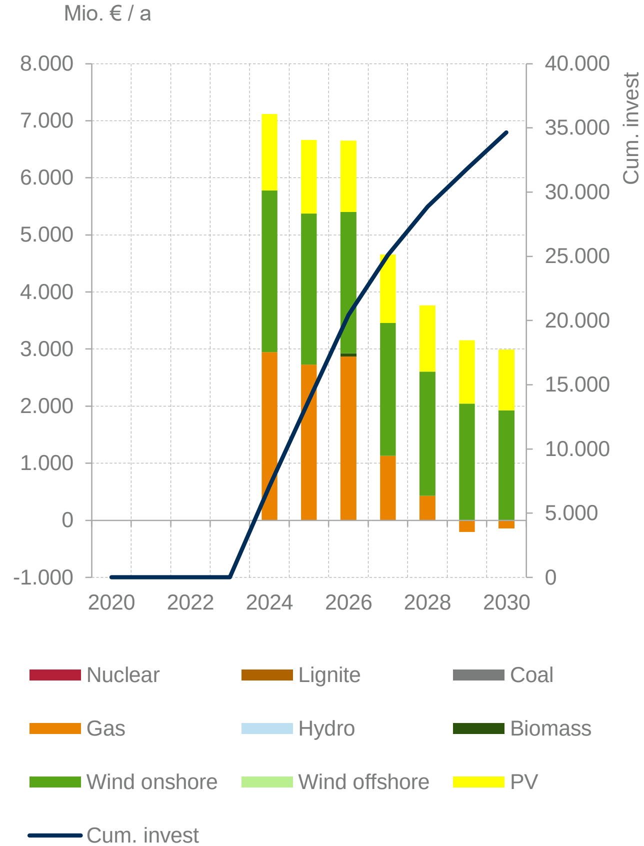
55 % PM



55 % MCE



55 % MCTC

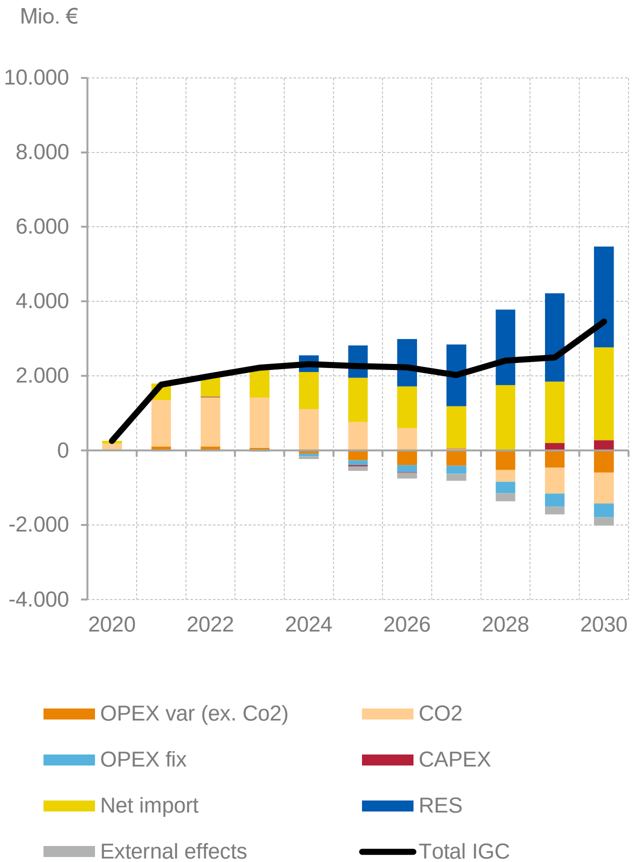


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

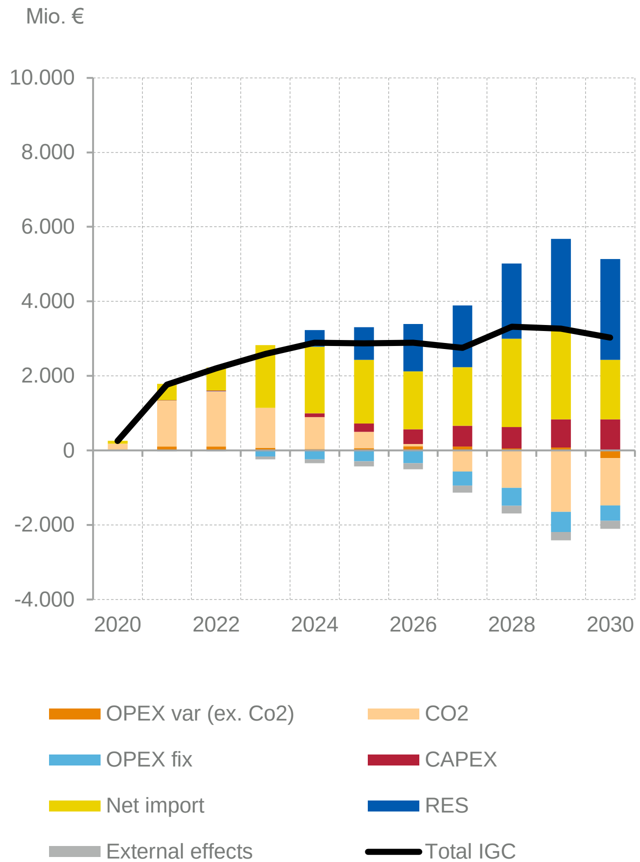
Scenario differences: Incremental generation costs in DE

Annual incremental generation costs in Germany are higher in all 55 % scenarios. Main drivers are higher CO_2 costs (mid-term), and (long-term) RES & import costs which dominate diverse savings in OPEX and external effects by the end of the decade. Note: Revenues from auctioned CO_2 certificates can also be seen as a source of income.

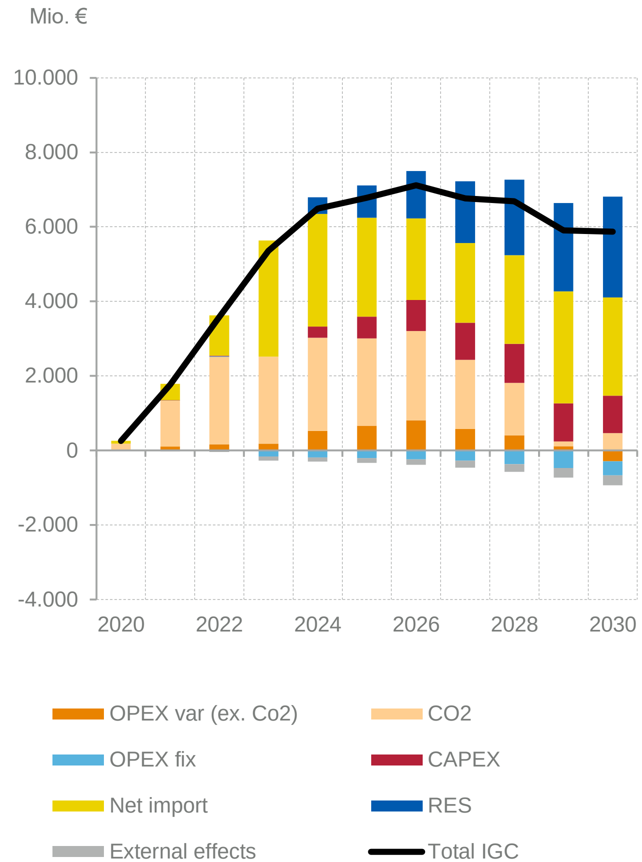
55 % PM



55 % MCE



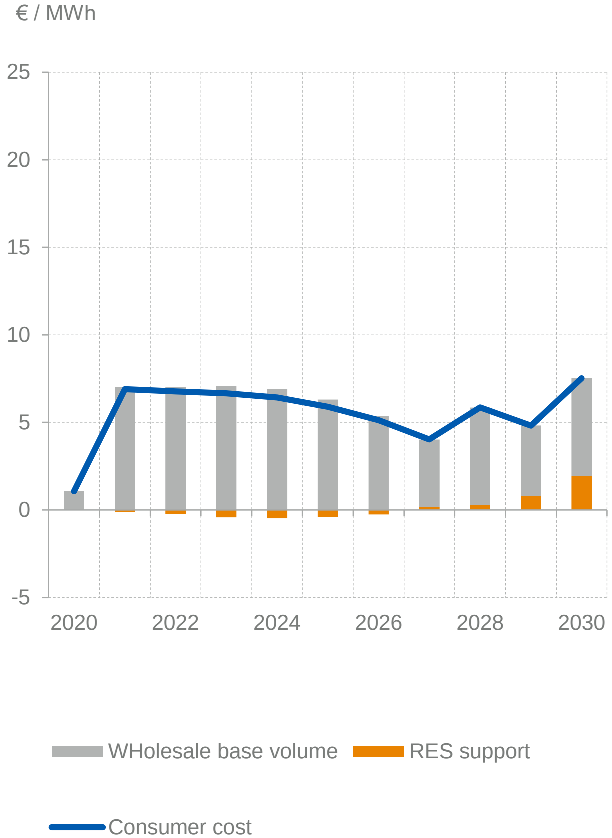
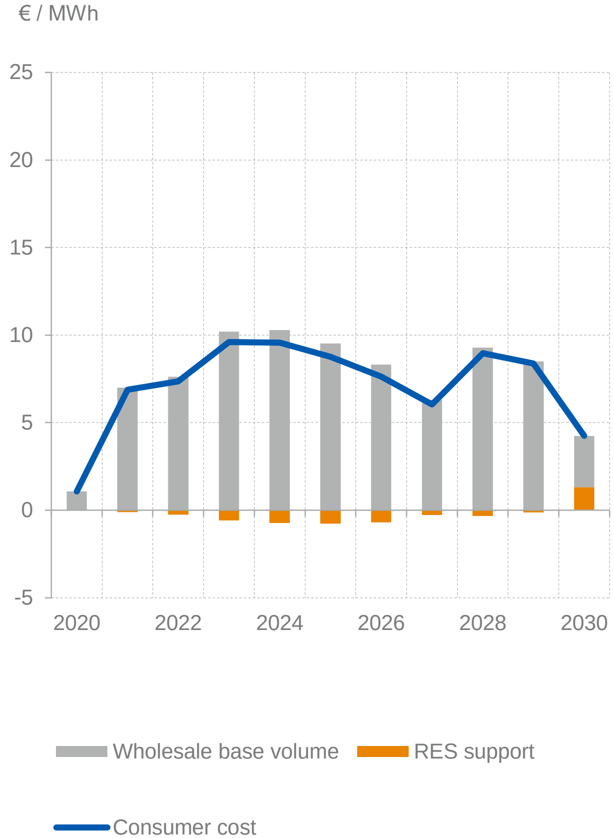
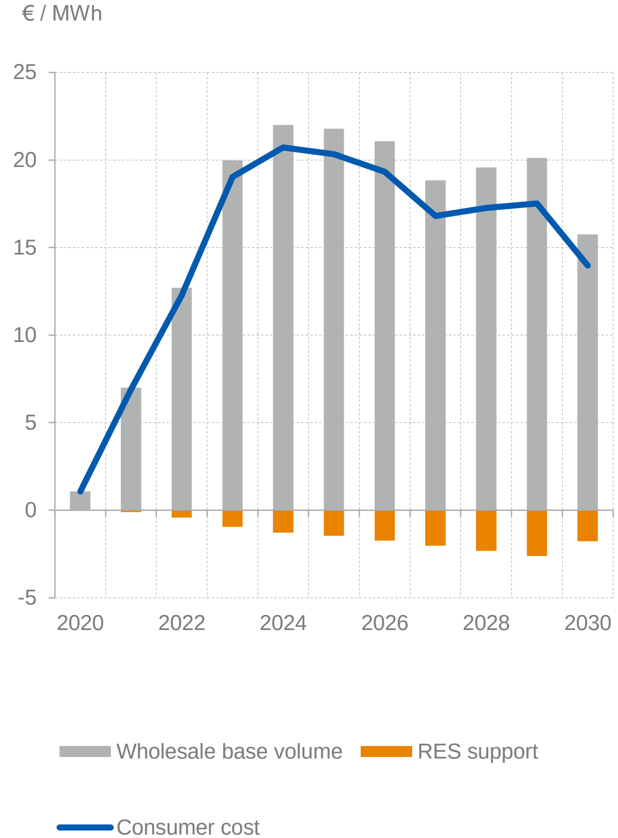
55 % MCTC



Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Scenario differences: Consumer costs in DE

Costs to consumers increase in all 55 % scenarios in Germany (in comparison with the 40 % PM scenario) due to higher wholesale price levels, partly driven by higher CO_2 prices and net-imports. The effect is mitigated with increased availability of carbon-free renewable generation towards 2030.

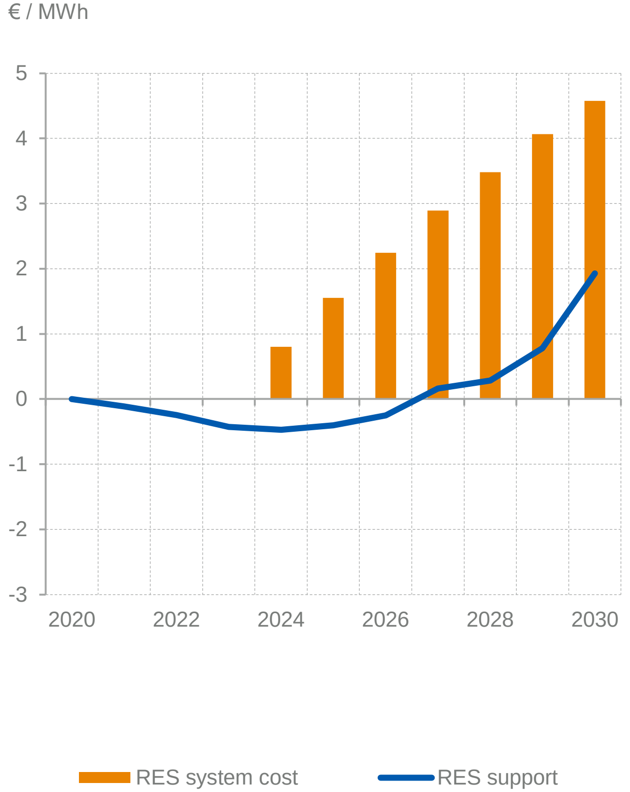
55 % PM	55 % MCE	55 % MCTC
		

Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

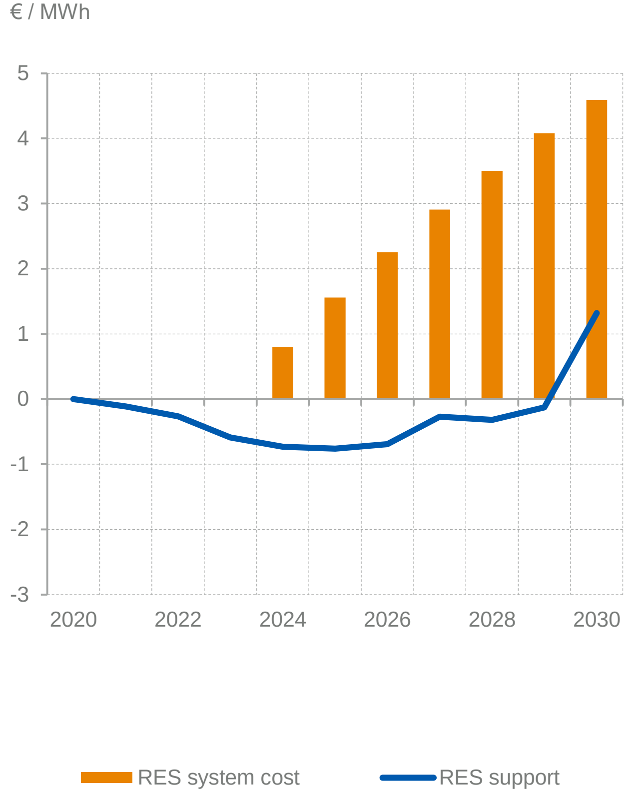
Scenario differences: RES re-financing in DE

The deployment of significant additional RES capacities increases RES system costs in Germany in the 55 % scenarios. Higher wholesale prices imply higher market revenues of RES generation and thus decrease support needs. In the 55 % Market based coal-to-clean scenario, no additional RES support is required in comparison with the 40 % PM scenario.

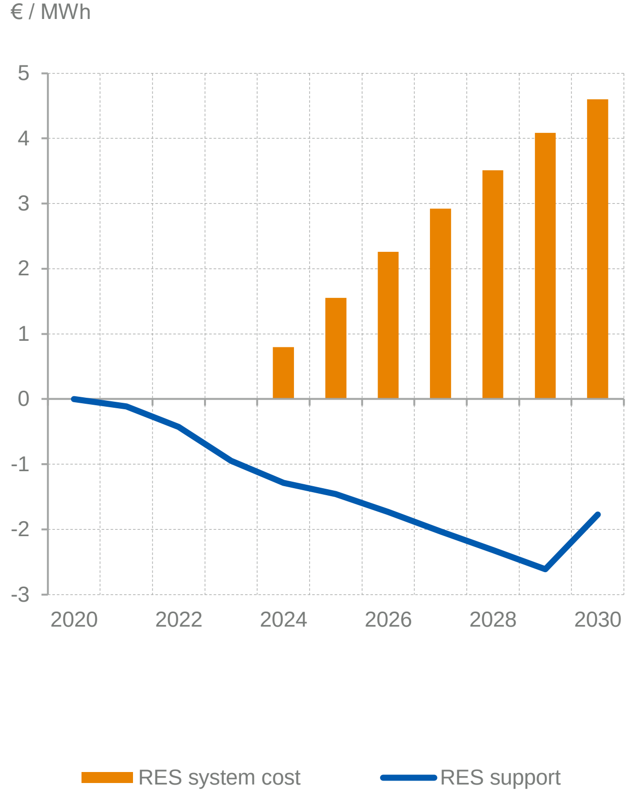
55 % PM



55 % MCE



55 % MCTC

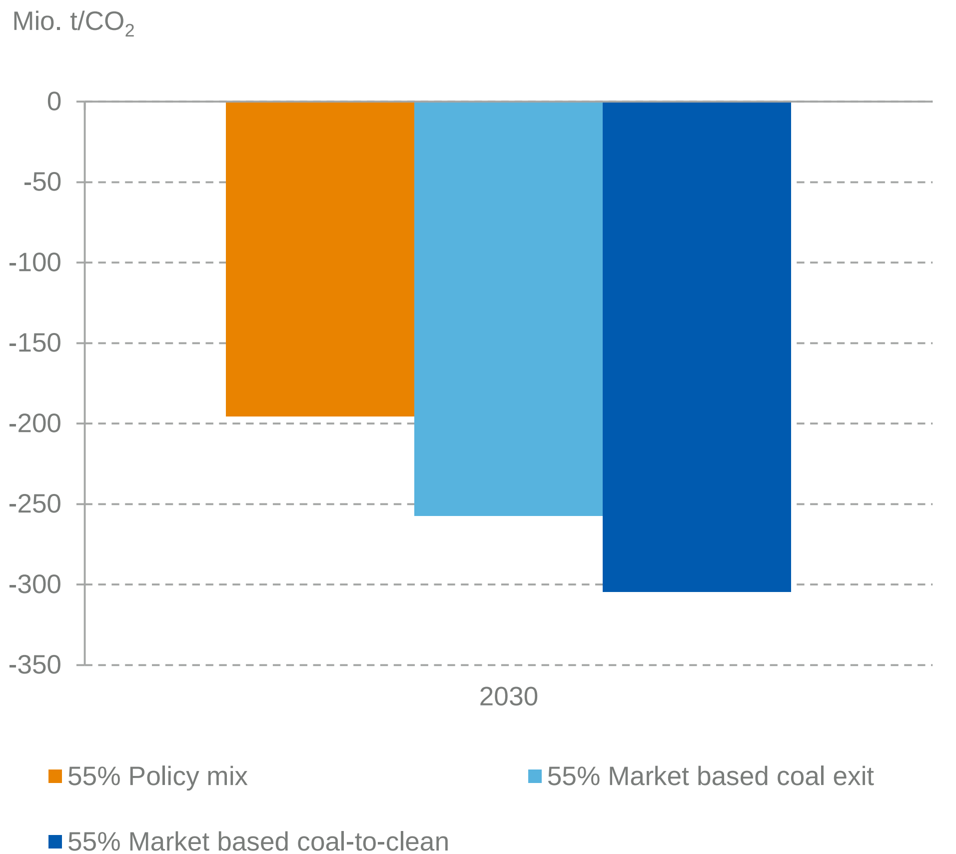


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

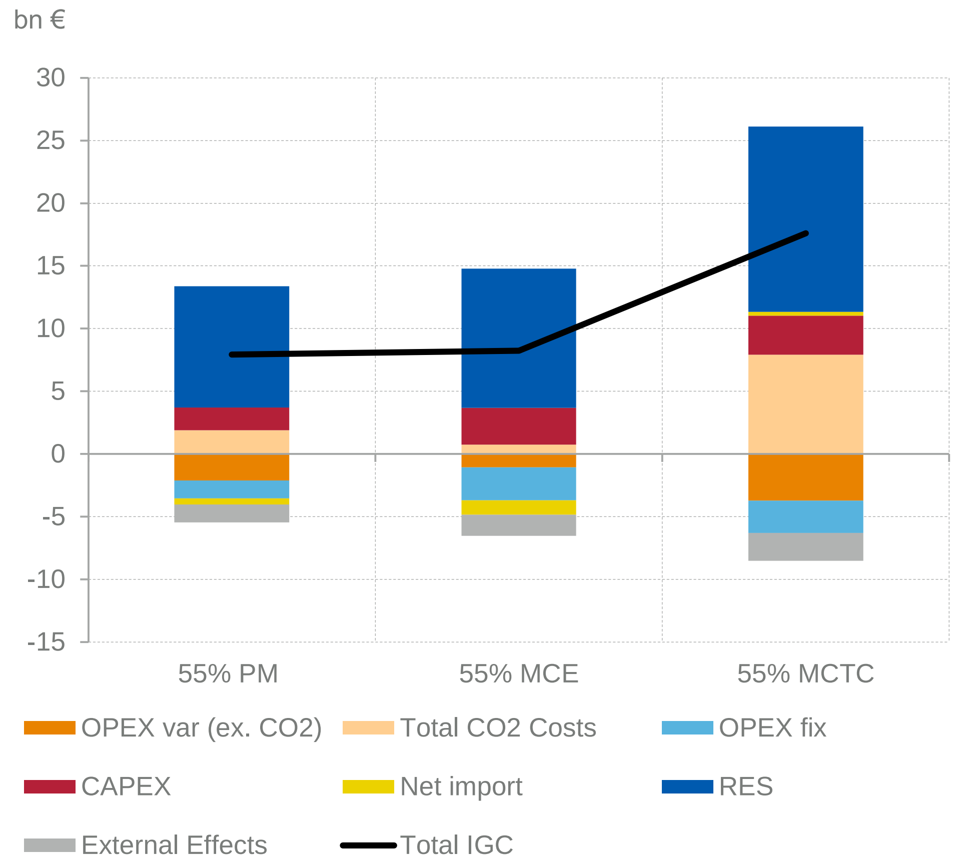
PL

Total emissions & system costs – PL

Total CO_2 emissions (2020-2030)
Deltas minus 40 % PM



Total IGC (2020-2030)
Deltas minus 40 % PM

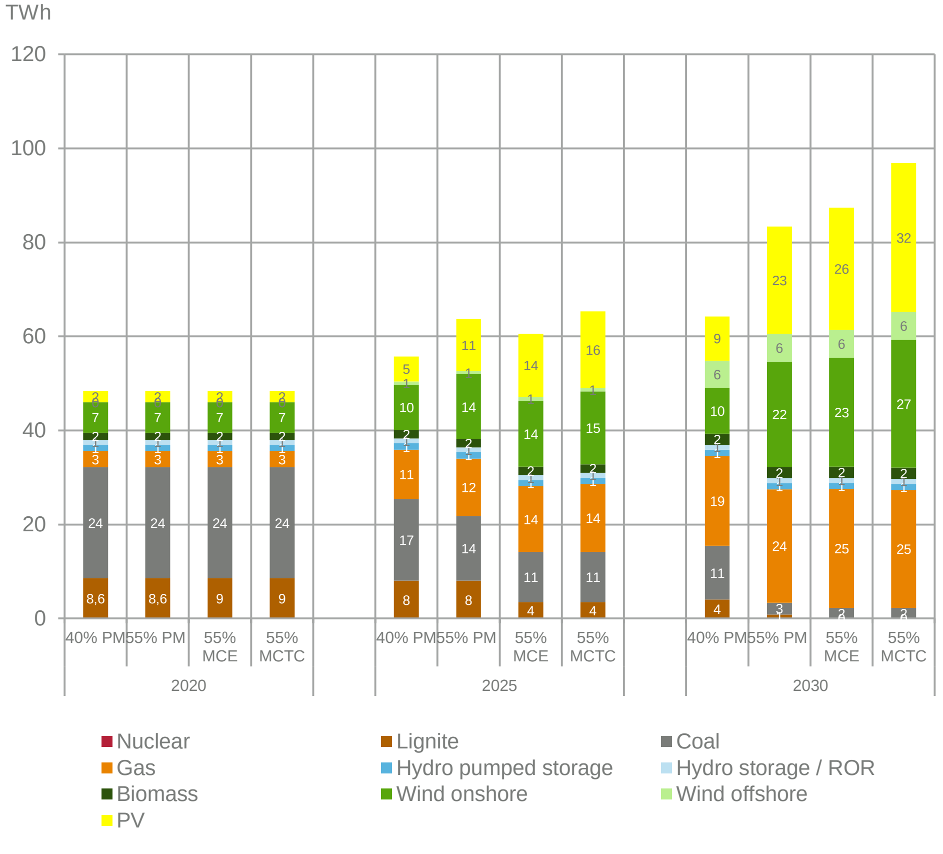


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

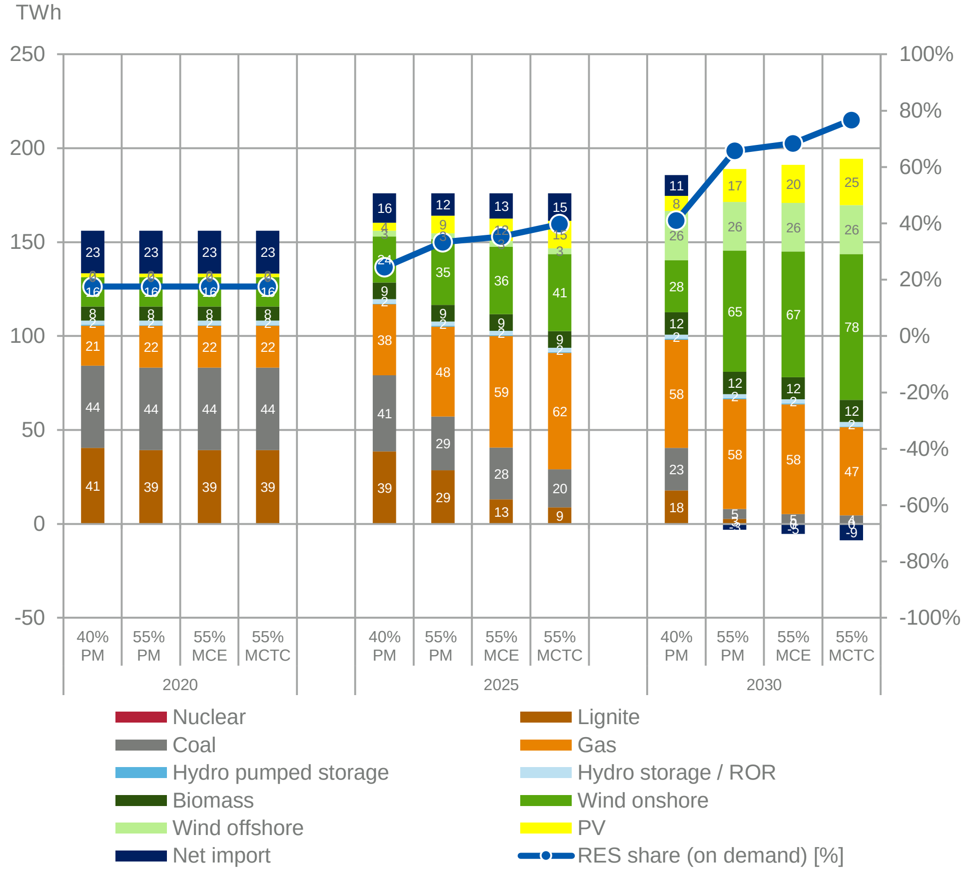
Capacity & generation – PL

Compared to the 40 % PM scenario, the 55 % scenarios lead to an earlier decommissioning & accelerated reduction of remaining coal capacities in Poland, which are substituted over time with a mix of wind onshore, PV & gas units (flexibility demand). The generation mix becomes less carbon-intensive & RES shares (on demand) increase by over 45 percentage points by 2030 (55 % scenarios).

Capacities



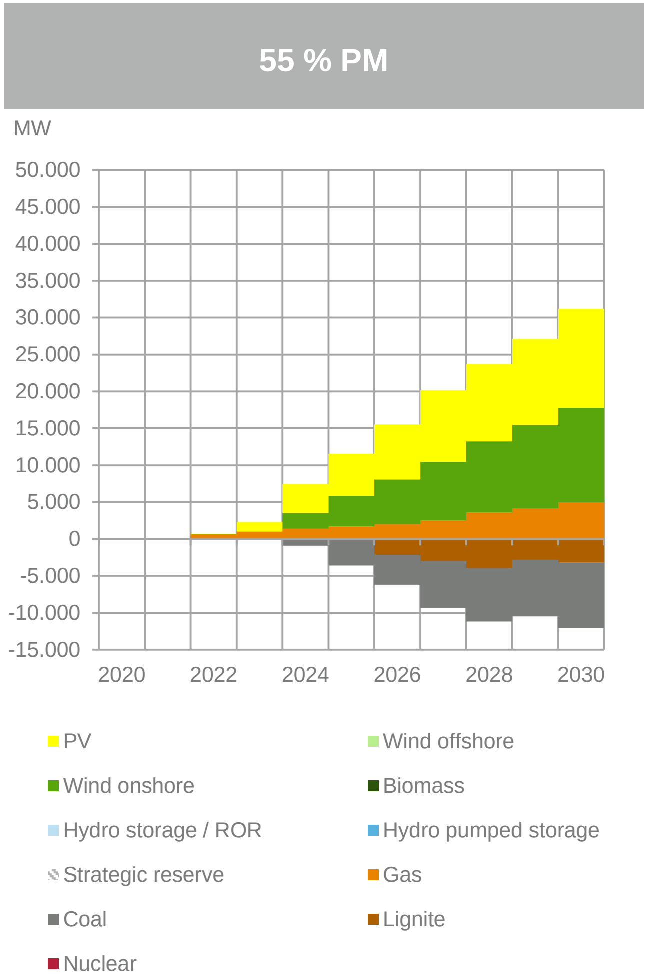
Generation

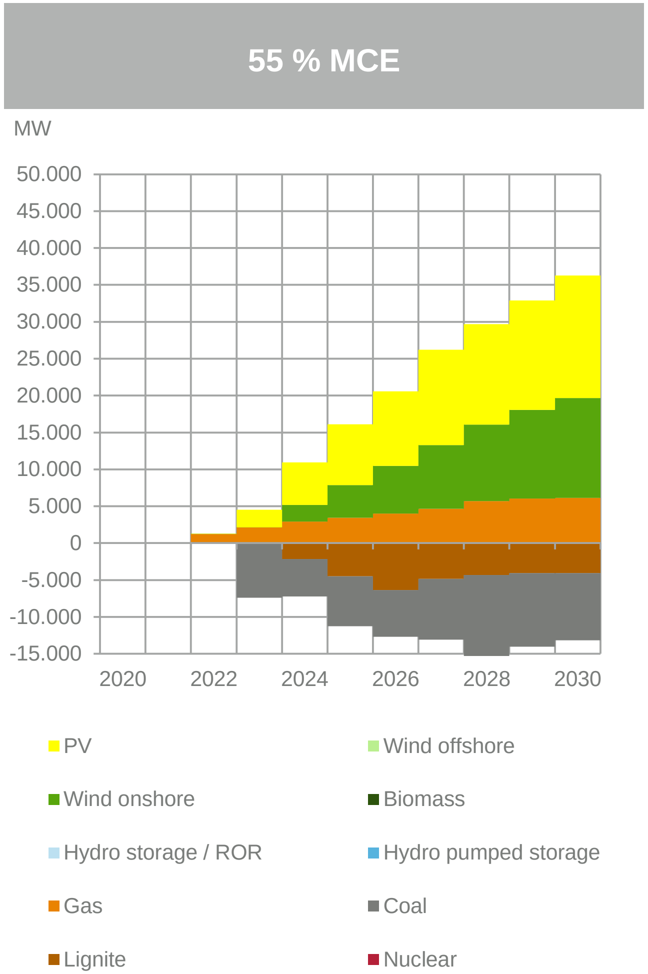


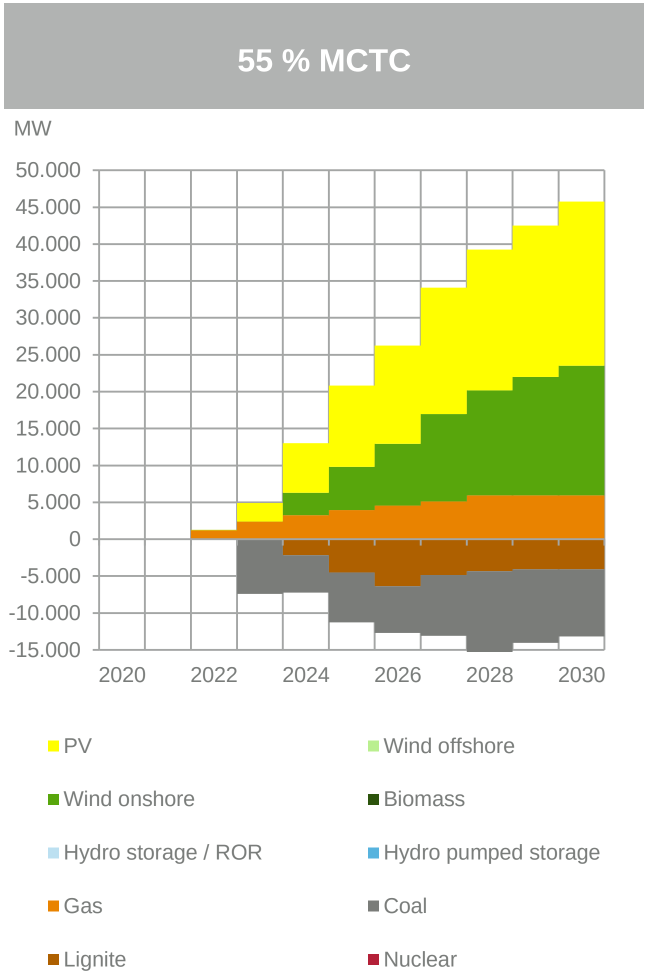
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Scenario differences: Installed capacities in PL

In all 55 % scenarios, the remaining coal capacities are substituted with a mix of wind onshore, PV and gas. Compared to the 55 % PM, the 55 % Market based scenarios see an earlier and steeper capacity reduction of coal units driven by higher CO_2-price trajectories. The higher CO_2-prices also trigger additional market based RES expansion, especially in the 55 % Market based coal-to-clean scenario.





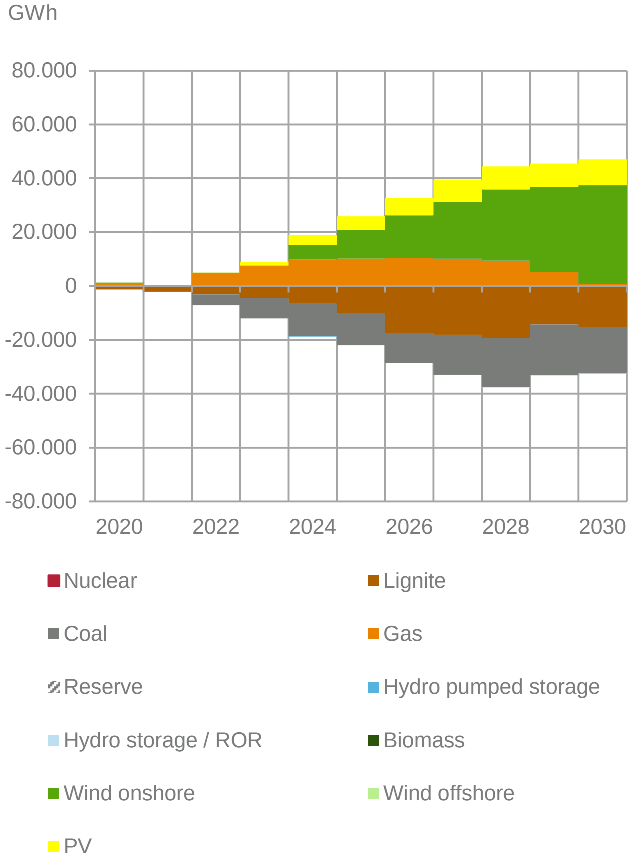


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

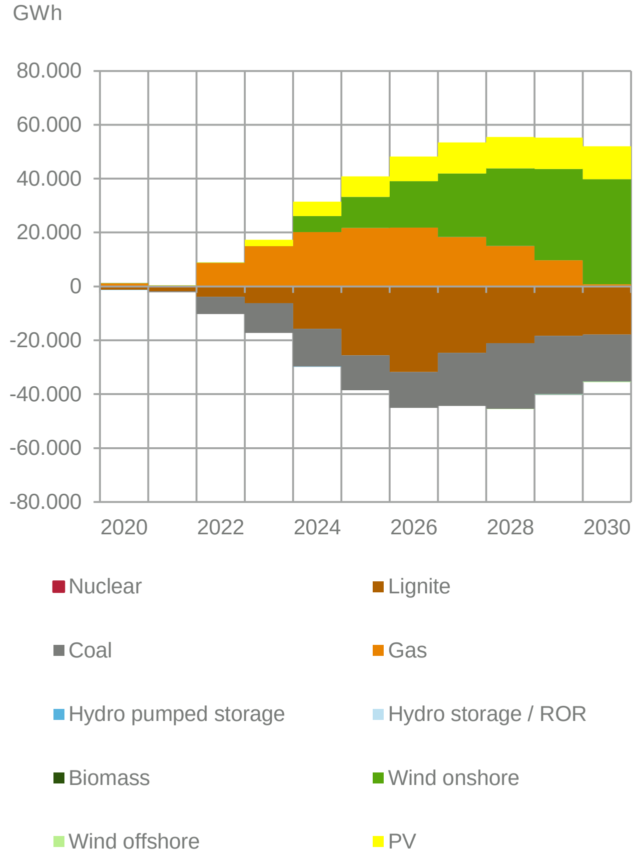
Scenario differences: Power generation in PL

Earlier decommissioning and lower utilization of the remaining coal-fired units in Poland trigger temporary increased gas-based generation (mid-term), especially in both 55 % Market based scenarios. In the long run, coal-based generation in Poland is entirely compensated by wind onshore and PV generation.

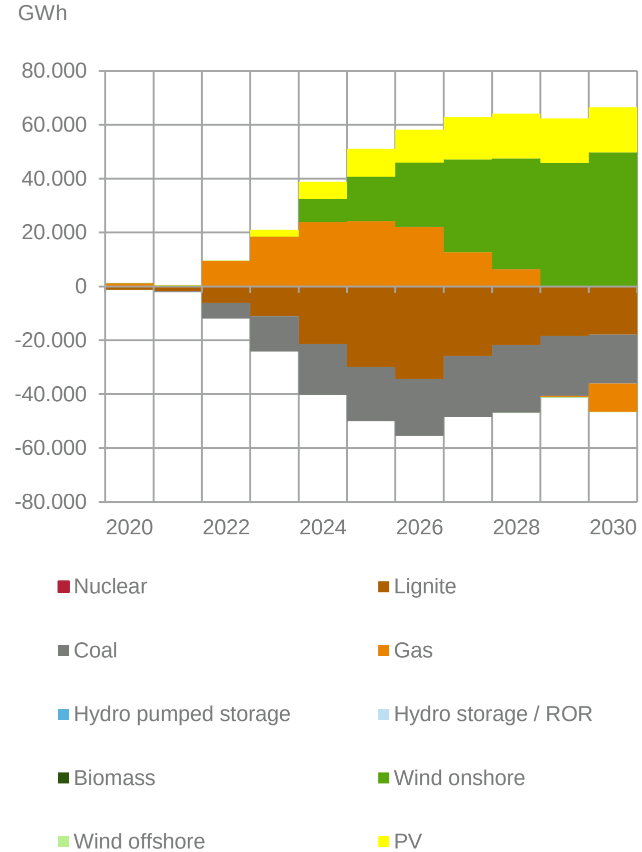
55 % PM



55 % MCE



55 % MCTC

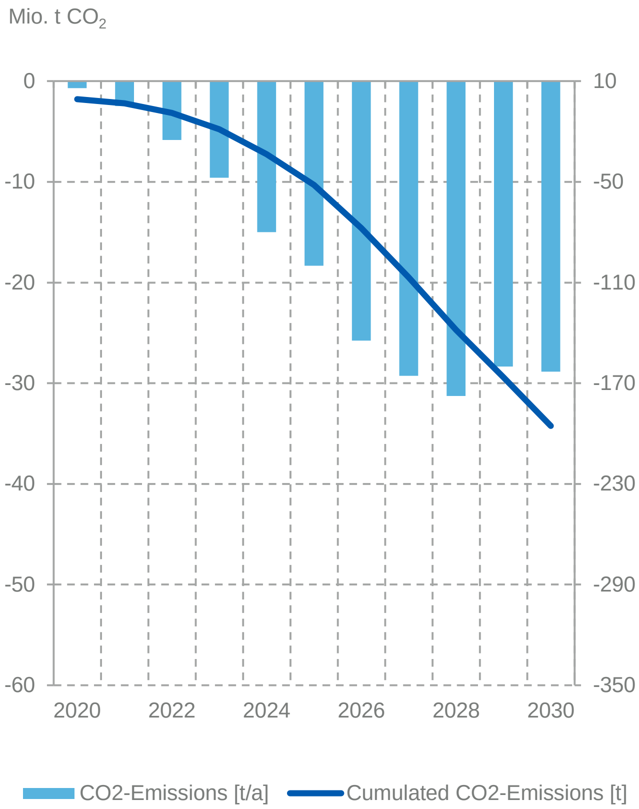


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

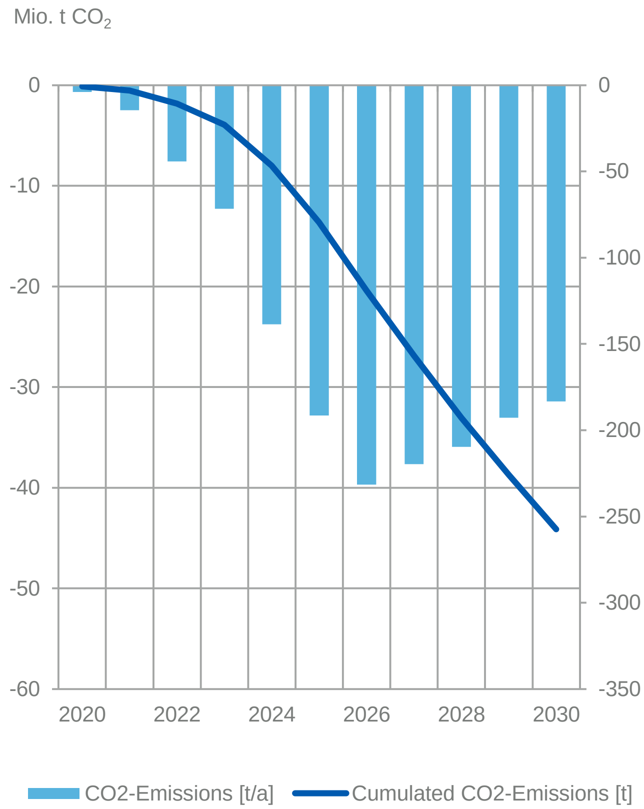
Scenario differences: CO_2 emissions in PL

All 55 % scenarios lead to significant CO_2 savings in Poland compared to the 40 % PM scenario. Until 2024, the additional reduction is driven only by the CO_2 price. In total, the 55 % PM scenario results in a cumulative reduction of 195 Mio.t. of CO_2 (market based coal exit: 257 Mio.t.; market-based coal-to-clean: 304 Mio.t.) until 2030 compared to the 40 % PM scenario.

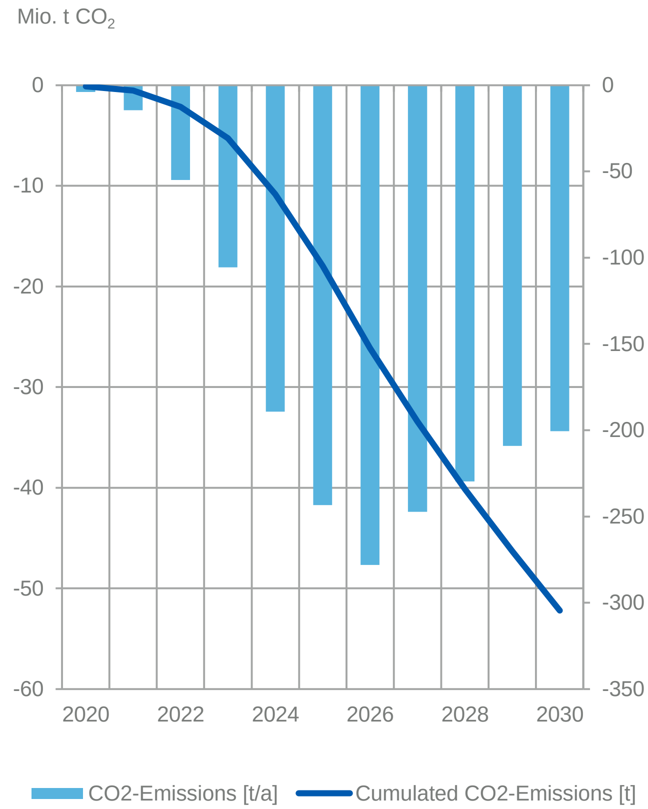
55 % PM



55 % MCE



55 % MCTC

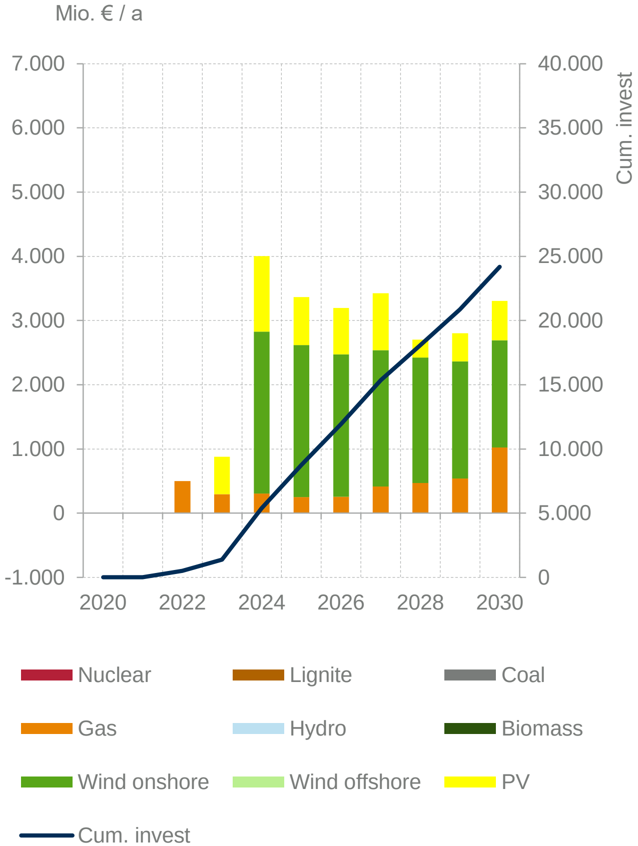


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

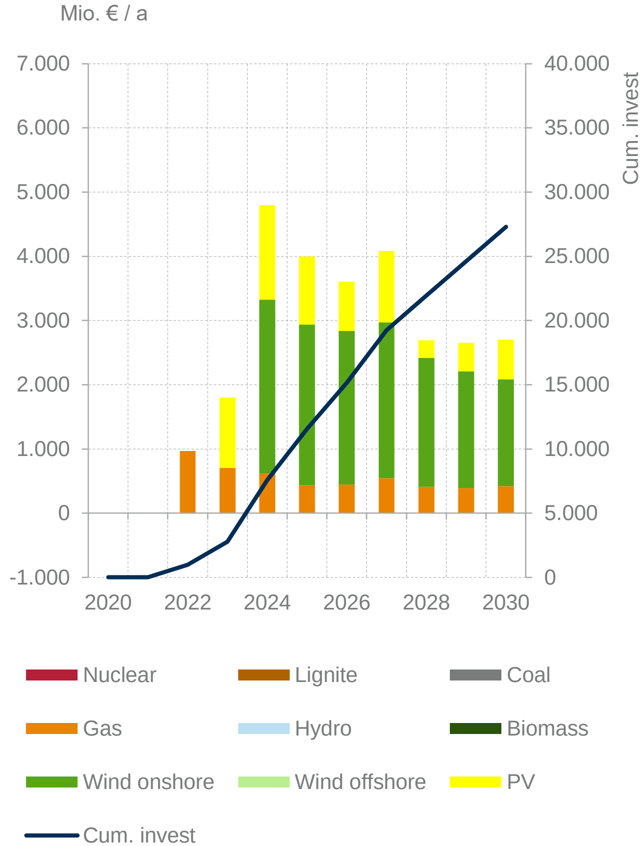
Scenario differences: Investment volumes in PL

Required additional investments into Poland's power-generating infrastructure accumulate to 24 bn € (55 % PM), 27 bn € (55 % Market based coal exit) and 34 bn € (55 % Market based coal-to-clean) until 2030. Investments are mainly channelled towards onshore wind and PV assets, to a lesser extent into gas-firing units.

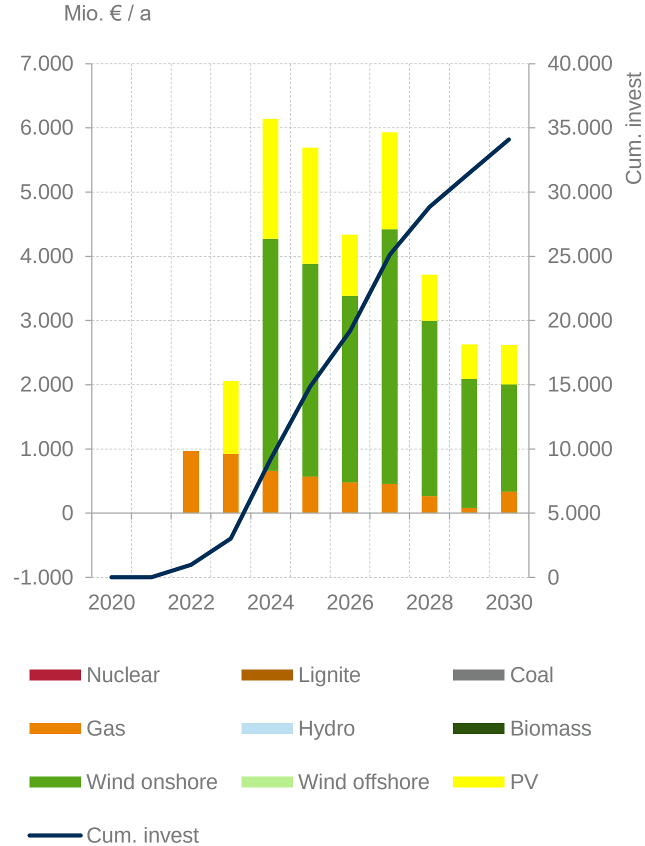
55 % PM



55 % MCE



55 % MCTC



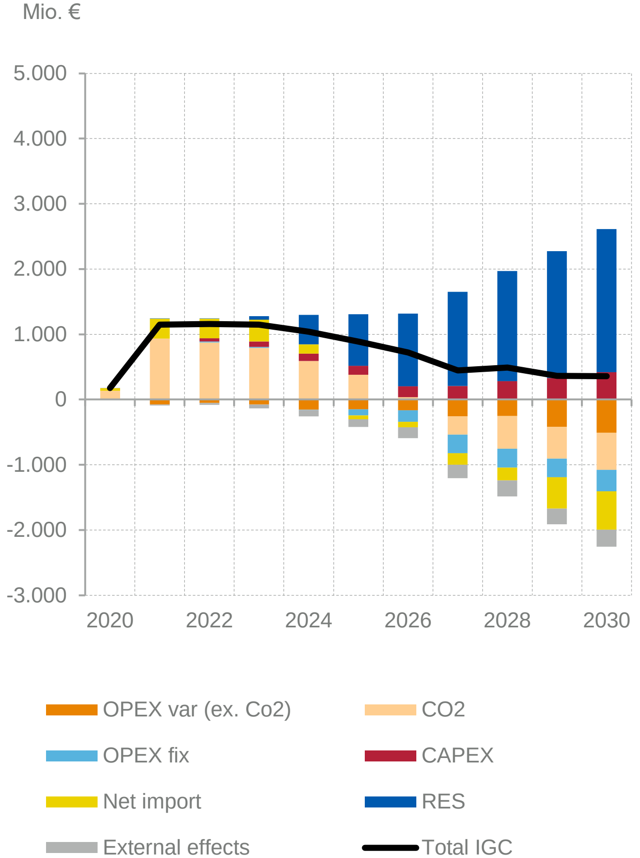
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM).

PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

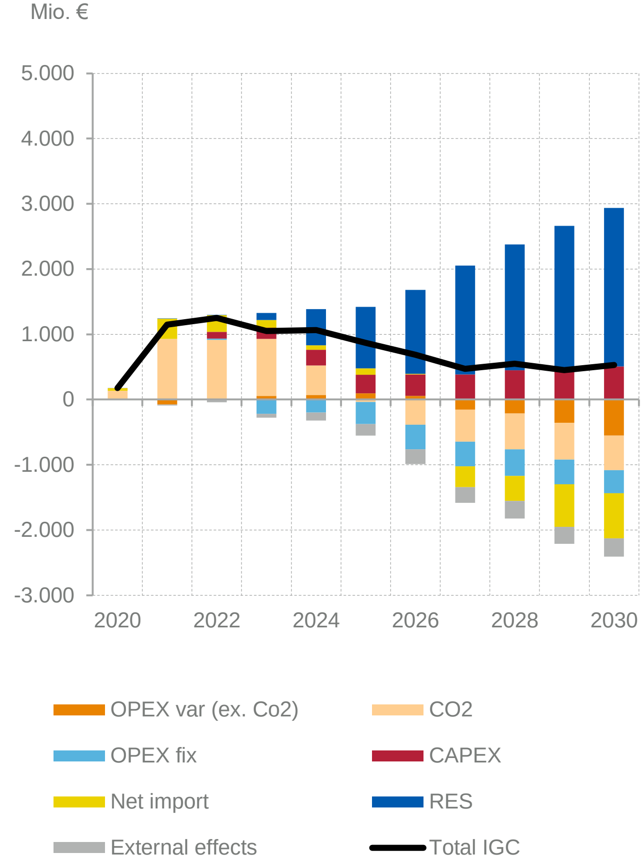
Scenario differences: Incremental generation costs in PL

Annual incremental generation costs in Poland are higher in all 55 % scenarios. Main drivers are higher CO_2 costs (mid-term), and RES costs (long-term) which dominate diverse savings in OPEX, external effects by the end of the decade. Note: Revenues from auctioned CO_2 certificates can also be seen as a source of income.

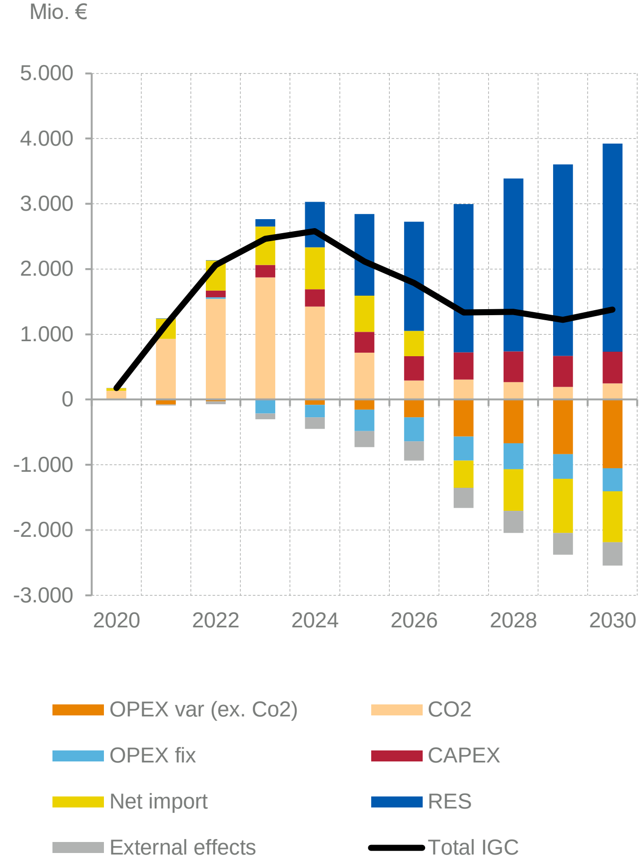
55 % PM



55 % MCE



55 % MCTC

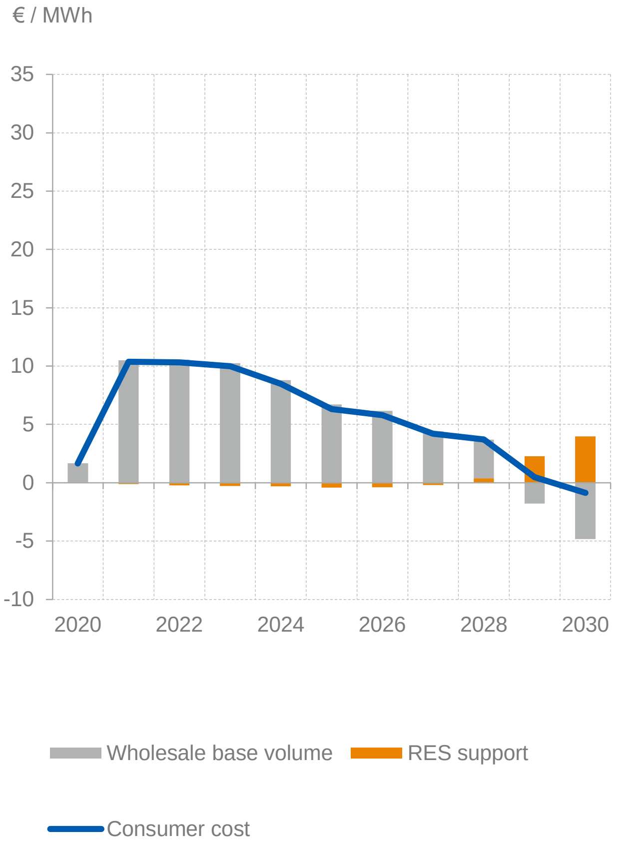


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

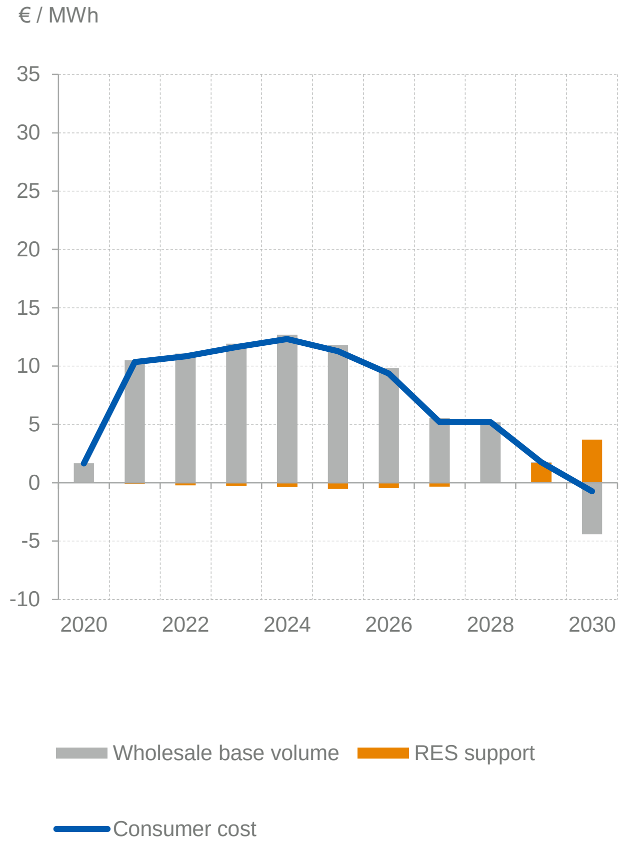
Scenario differences: Consumer costs in PL

Costs to consumers increase in all 55 % scenarios in Poland (in comparison with the 40 % PM scenario) due to higher wholesale price levels, partly driven by higher CO_2 prices and net-imports. The effect is mitigated with increased availability of carbon-free renewable generation towards 2030. Revenues from auctioned CO_2 certificates at the same time imply a source of income.

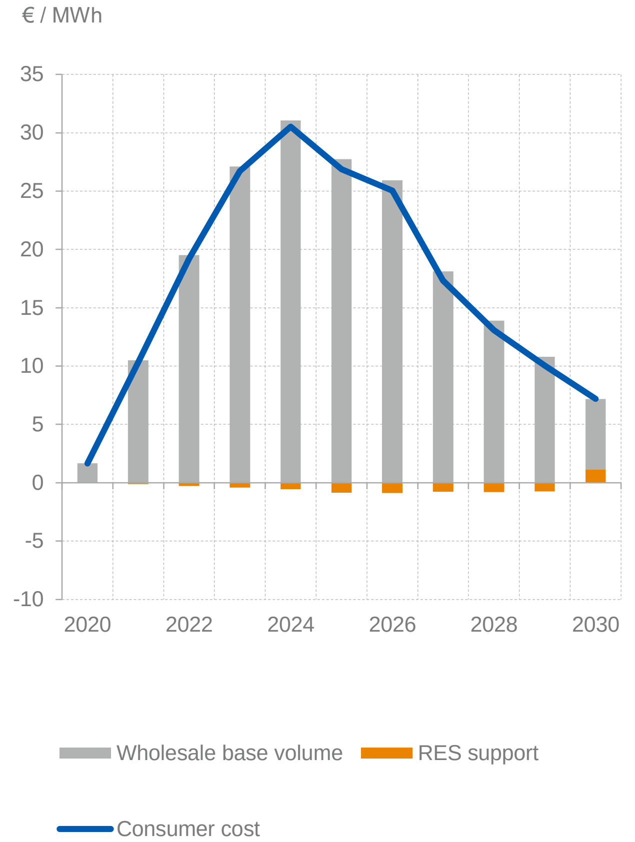
55 % PM



55 % MCE



55 % MCTC

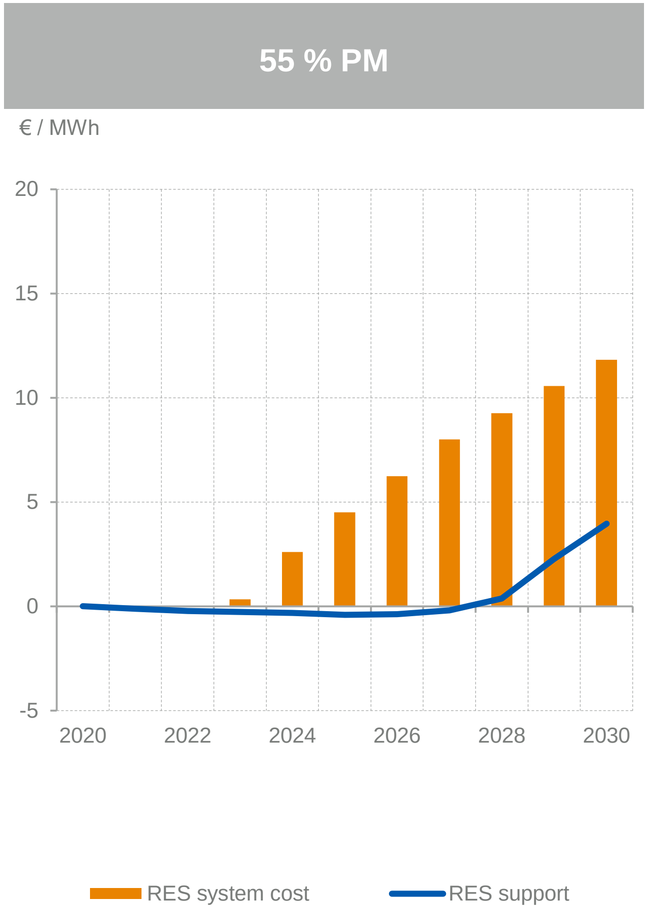


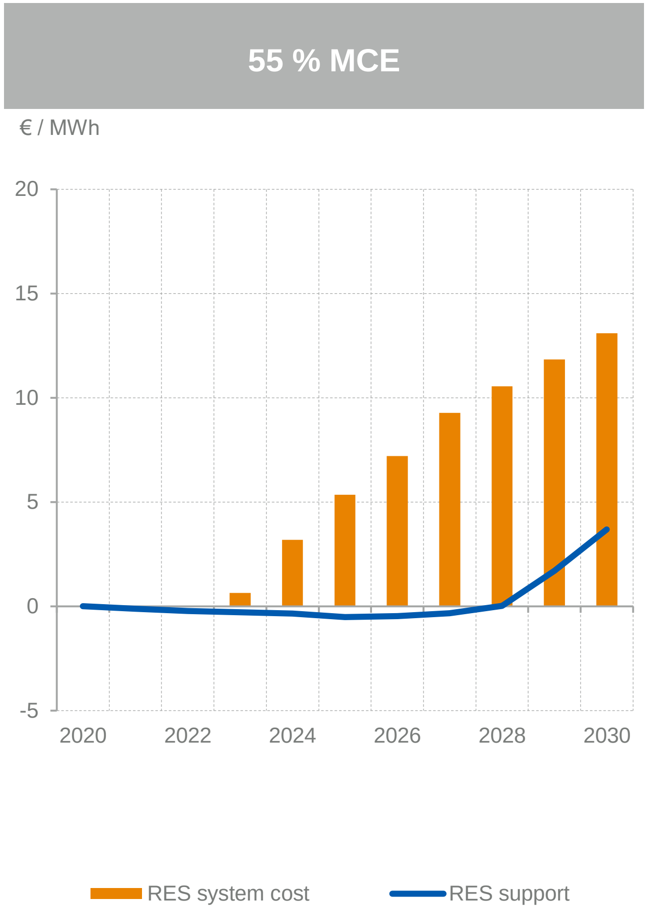
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM).

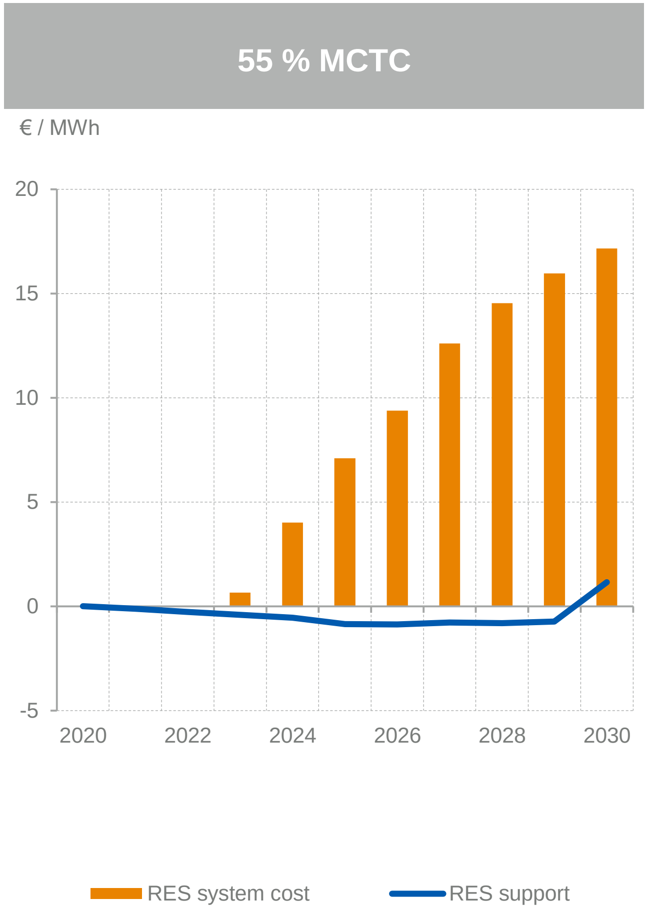
PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Scenario differences: RES re-financing in PL

The deployment of significant additional RES capacities increases RES system costs in Poland in the 55 % scenarios. Higher wholesale prices imply higher market revenues of RES generation and thus mitigate support needs. The additional required RES support (compared to the 40 % PM scenario) decreases in the mid-20s before increasing slightly after 2028.





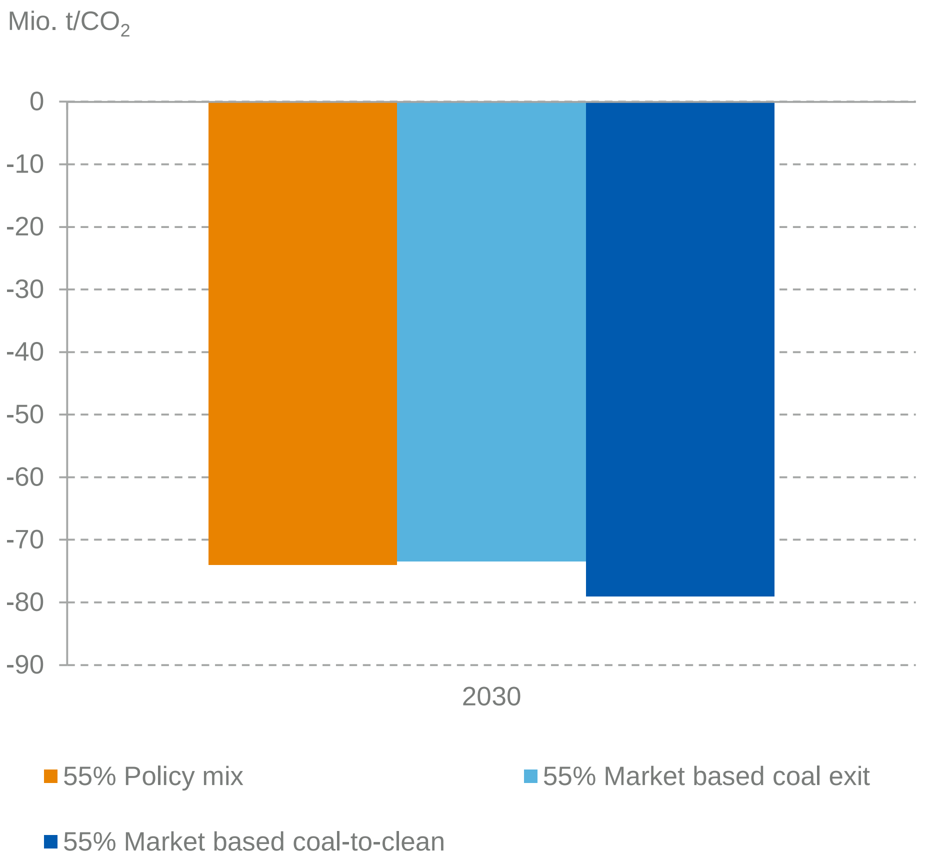


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

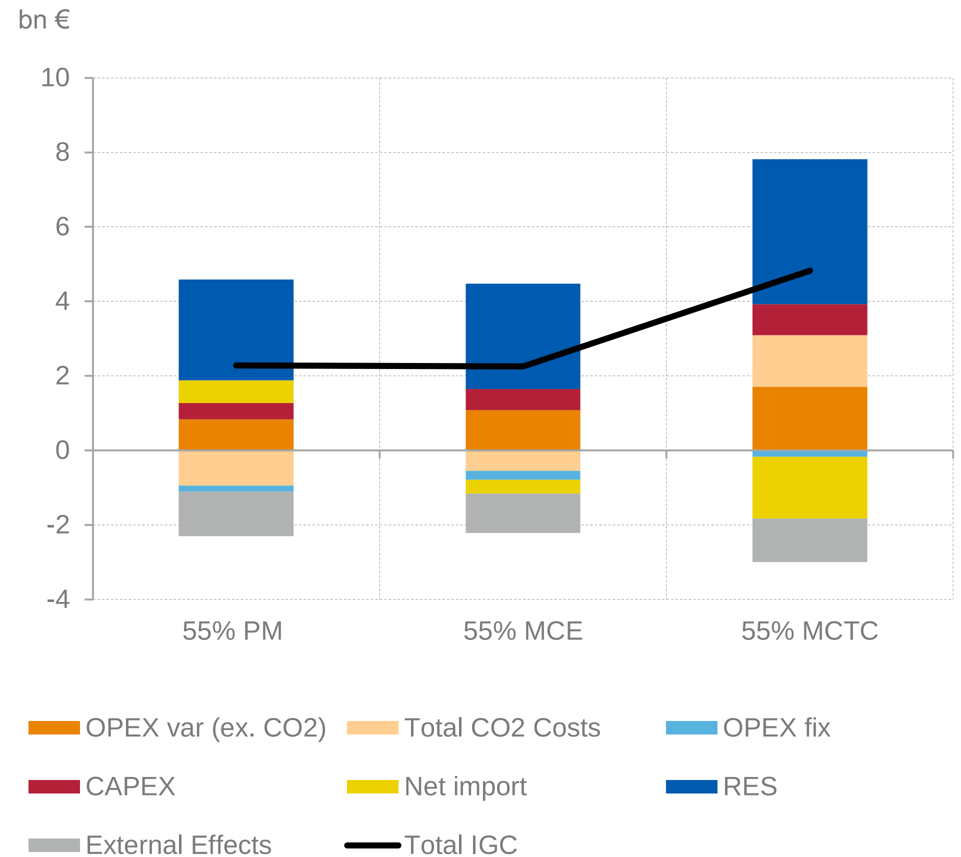
RO

Total emissions & system costs – RO

Total CO_2 emissions (2020-2030)
Deltas minus 40 % PM



Total IGC (2020-2030)
Deltas minus 40 % PM

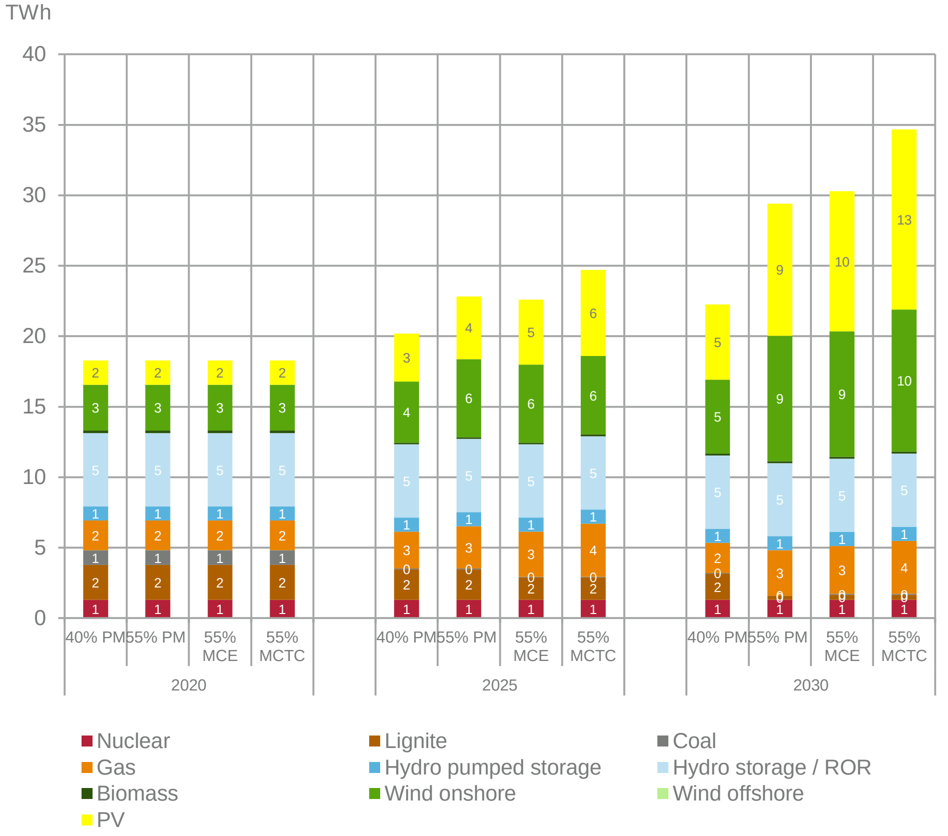


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

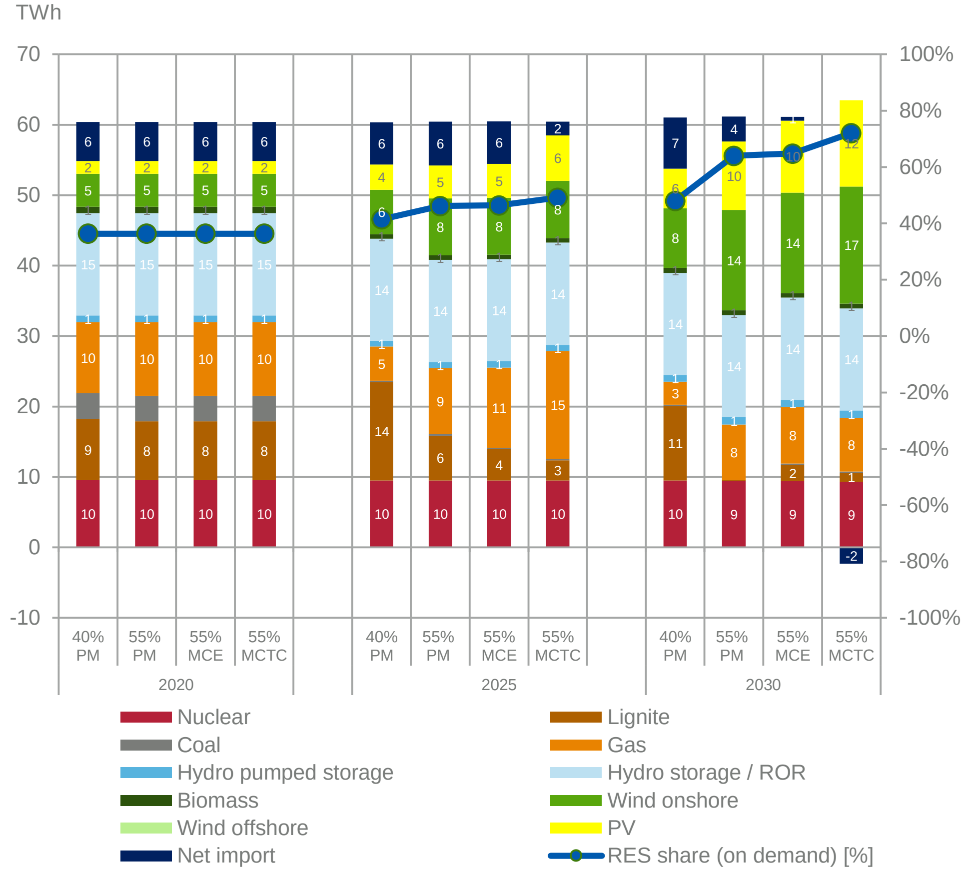
Capacity & generation – RO

Compared to the 40 % PM scenario, the 55 % scenarios lead to an earlier decommissioning & accelerated reduction of remaining coal capacities in Romania, which are substituted over time with a mix of wind onshore, PV & gas units (flexibility demand). The generation mix becomes less carbon-intensive & RES shares (on demand) increase by over 25 percentage points by 2030 (55 % scenarios).

Capacities



Generation

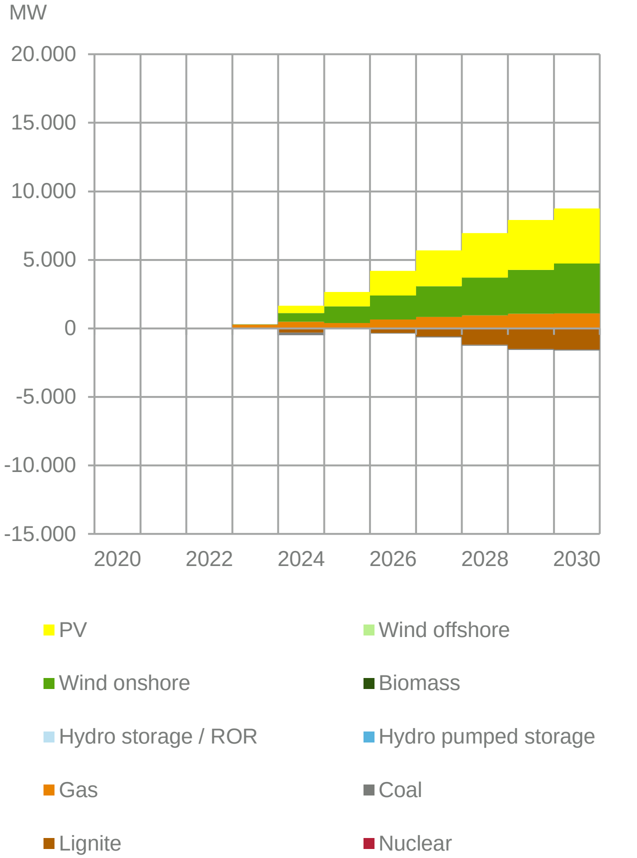


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

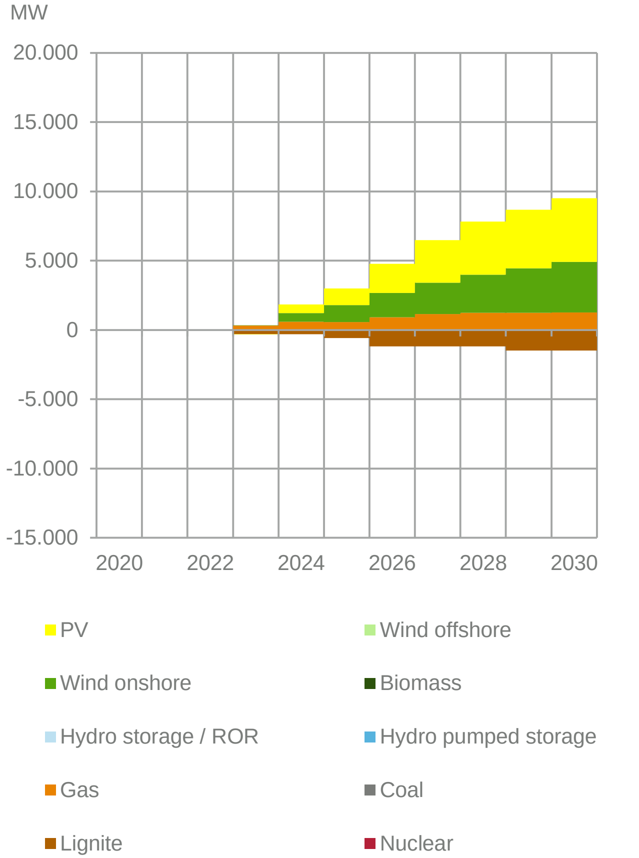
Scenario differences: Installed capacities in RO

In all 55 % scenarios, the remaining coal capacities are substituted with a mix of wind onshore, PV and gas. Compared to the 55 % PM, the 55 % Market based scenarios see an earlier reduction of coal capacity, which is also driven by higher CO_2-price trajectories. The higher CO_2-prices also trigger additional market based RES expansion, especially in the 55 % Market based coal-to-clean scenario.

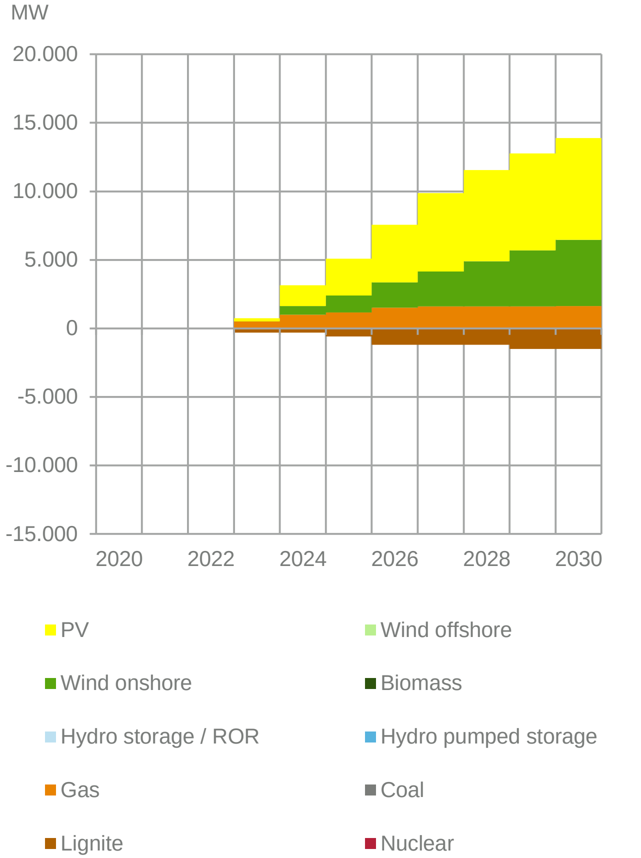
55 % PM



55 % MCE



55 % MCTC

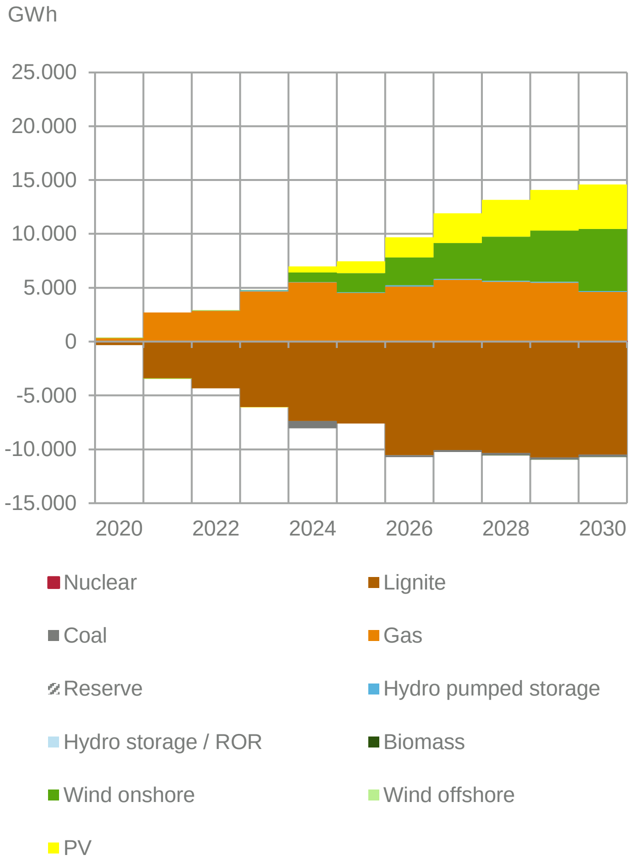


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

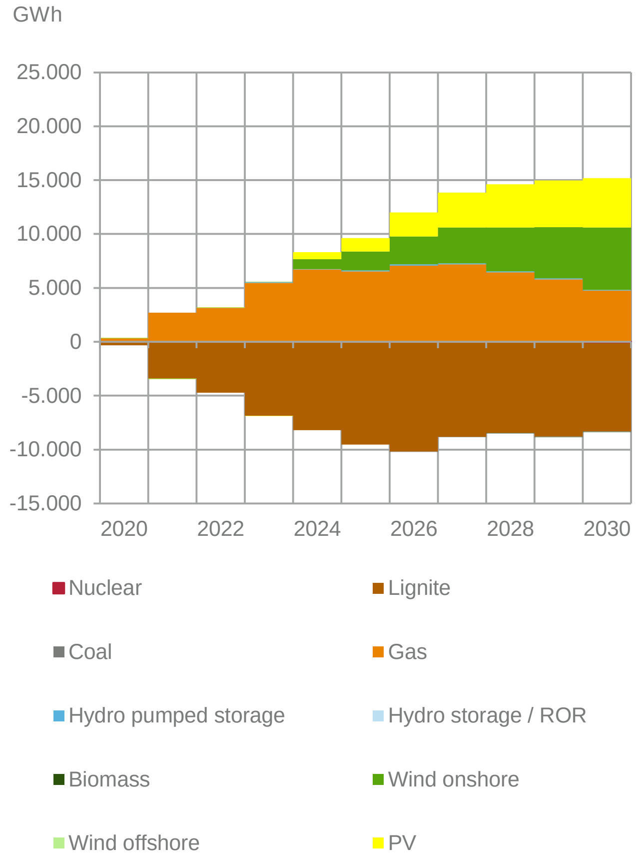
Scenario differences: Power generation in RO

Earlier decommissioning and lower utilization of the remaining coal-fired units in Romania trigger temporary increased gas-based generation (mid-term) in both 55 % Market based scenarios. In the long run, coal-based generation is compensated by wind onshore, PV and gas-based generation by 2030.

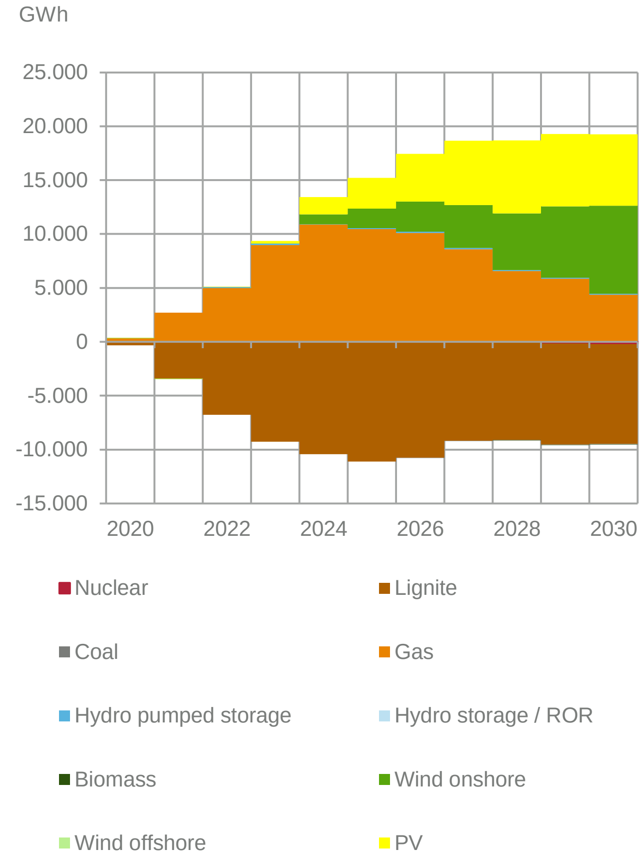
55 % PM



55 % MCE



55 % MCTC

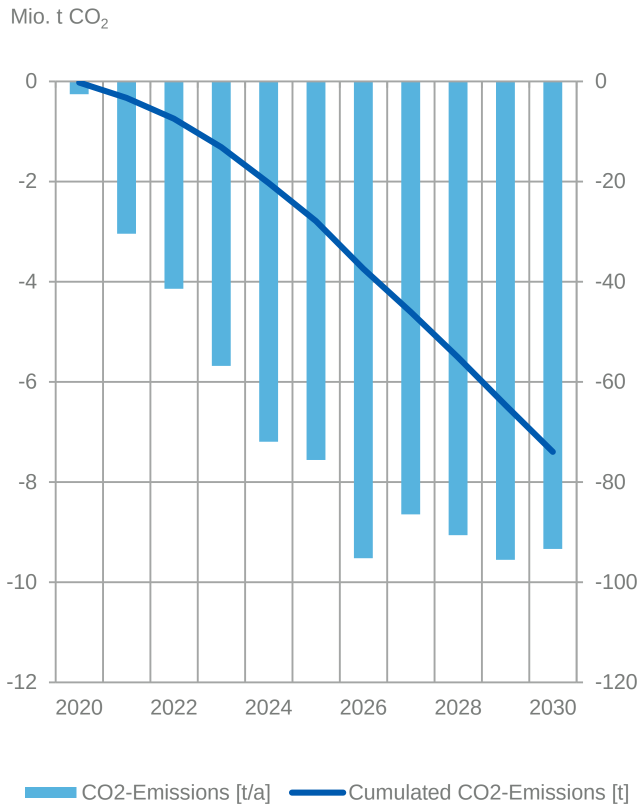


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

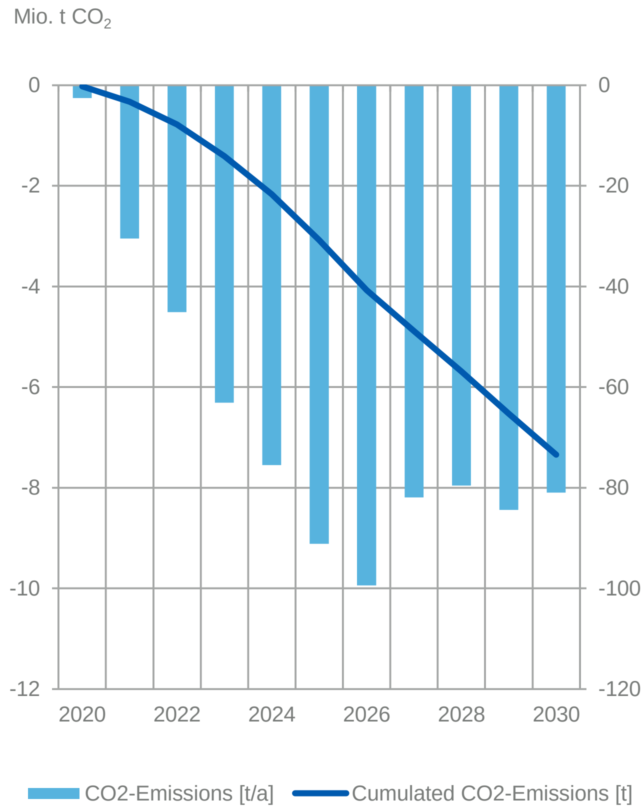
Scenario differences: CO_2 emissions in RO

All 55 % scenarios lead to significant CO_2 savings in Romania compared to the 40 % PM scenario. Until 2024, the additional reduction is driven only by the CO_2 price. In total, the 55 % PM scenario results in a cumulative reduction of 74 Mio.t. of CO_2 (market based coal exit: 73 Mio.t.; market-based coal-to-clean: 79 Mio.t.) until 2030 compared to the 40 % PM scenario.

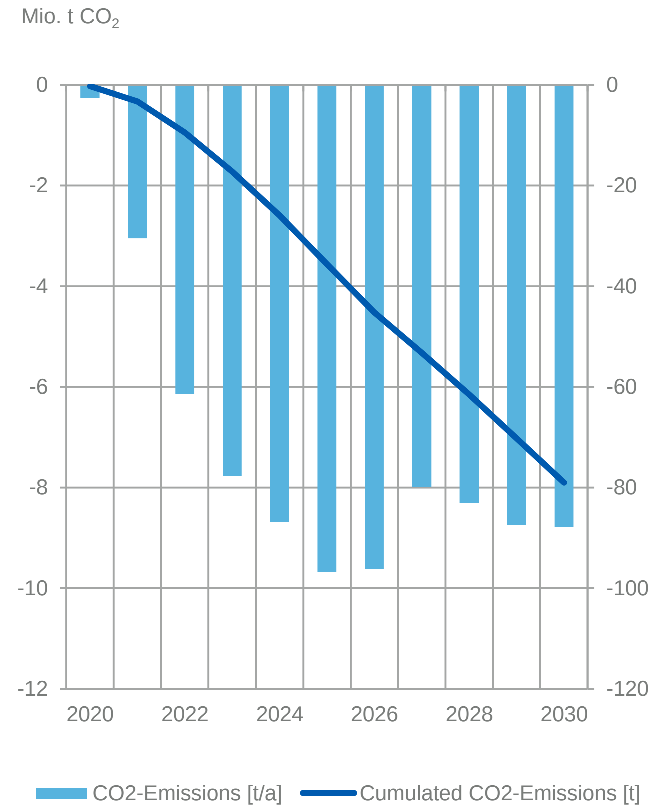
55 % PM



55 % MCE



55 % MCTC

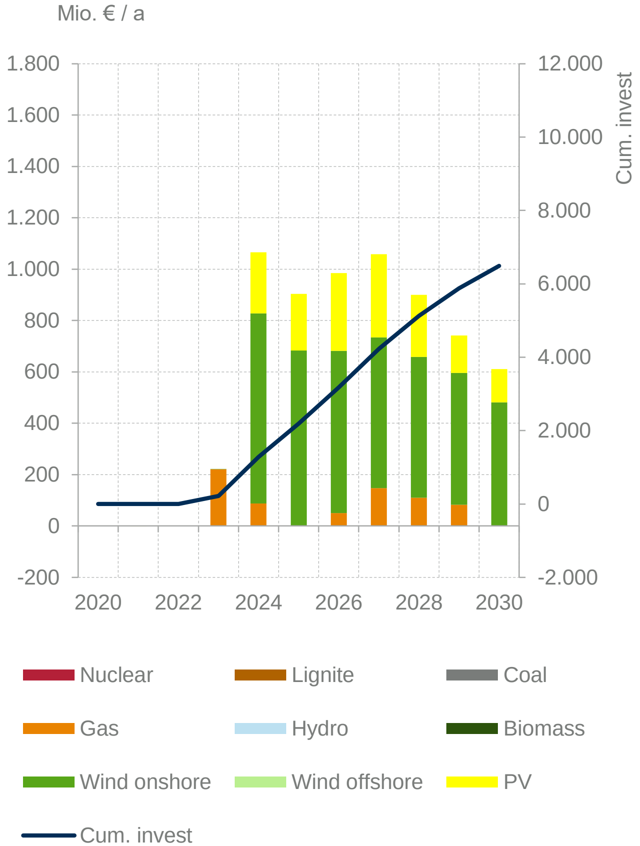


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

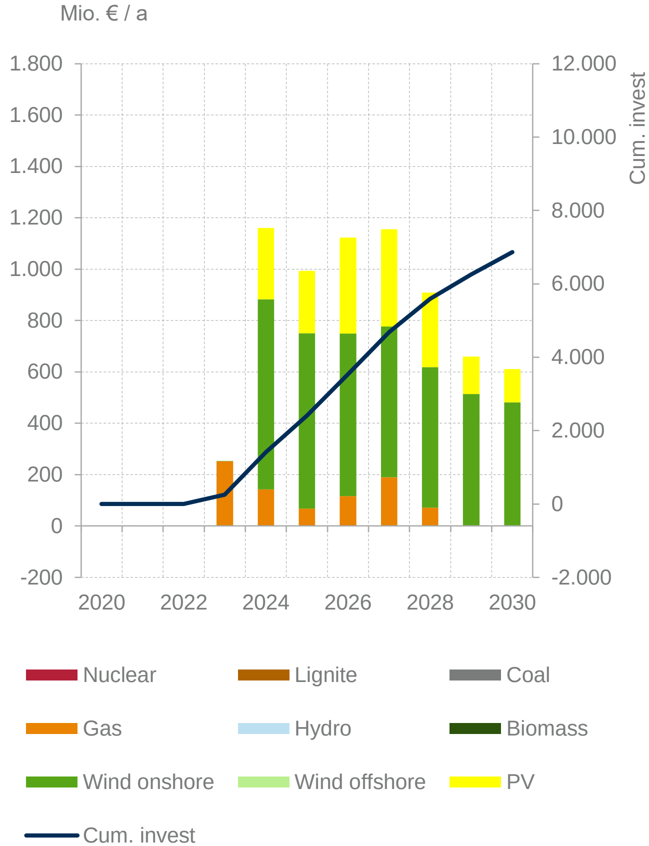
Scenario differences: Investment volumes in RO

Required additional investments into Romania's power-generating infrastructure accumulate to 6.5 bn € (55 % PM), 6.9 bn € (55 % Market based coal exit) and 9.7 bn € (55 % Market based coal-to-clean) until 2030. Investments are mainly channelled towards onshore wind and PV assets and, to a lesser extent, into gas-based capacities.

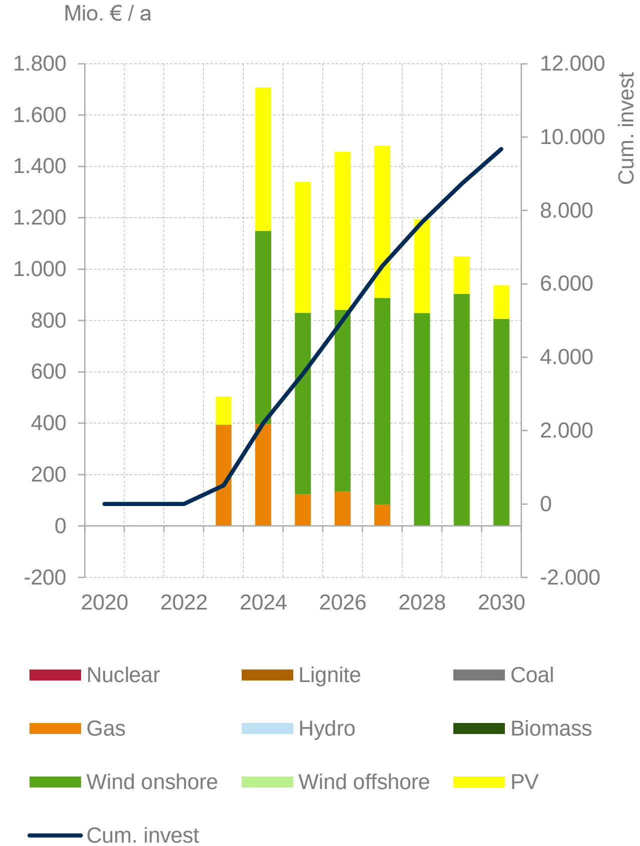
55 % PM



55 % MCE



55 % MCTC

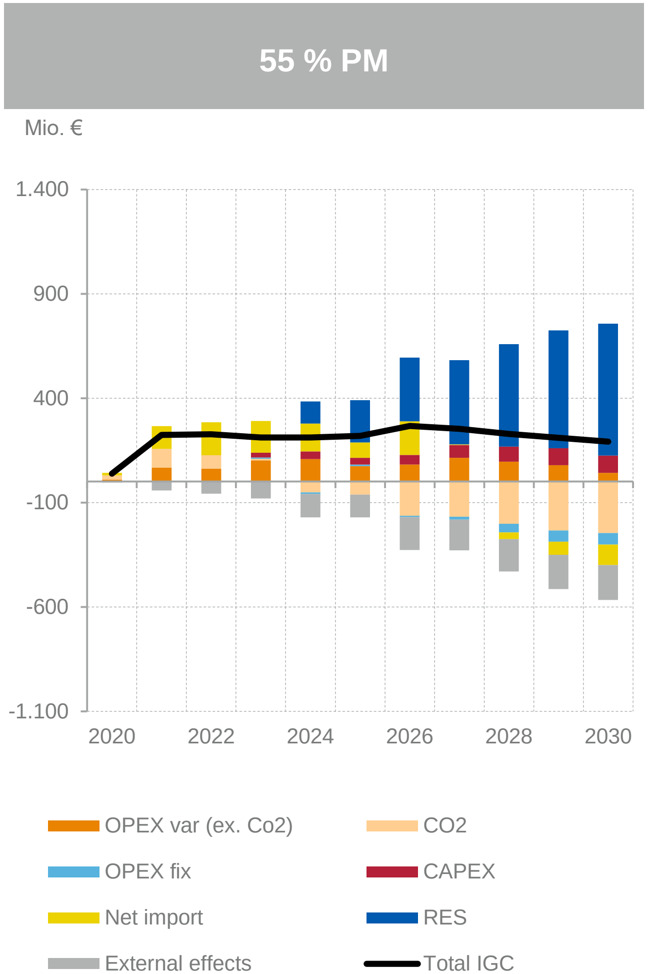


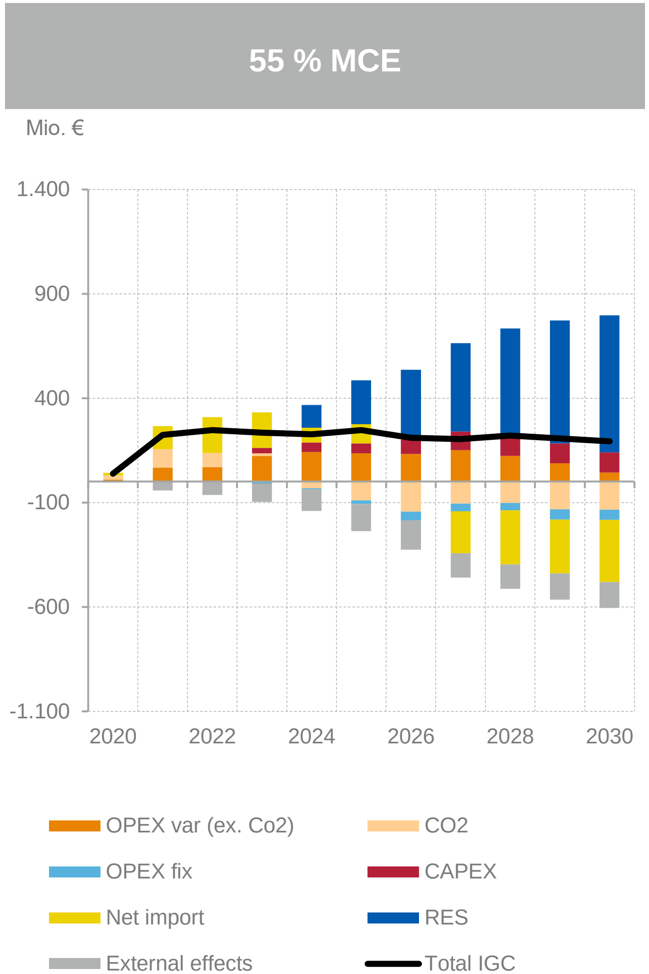
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM).

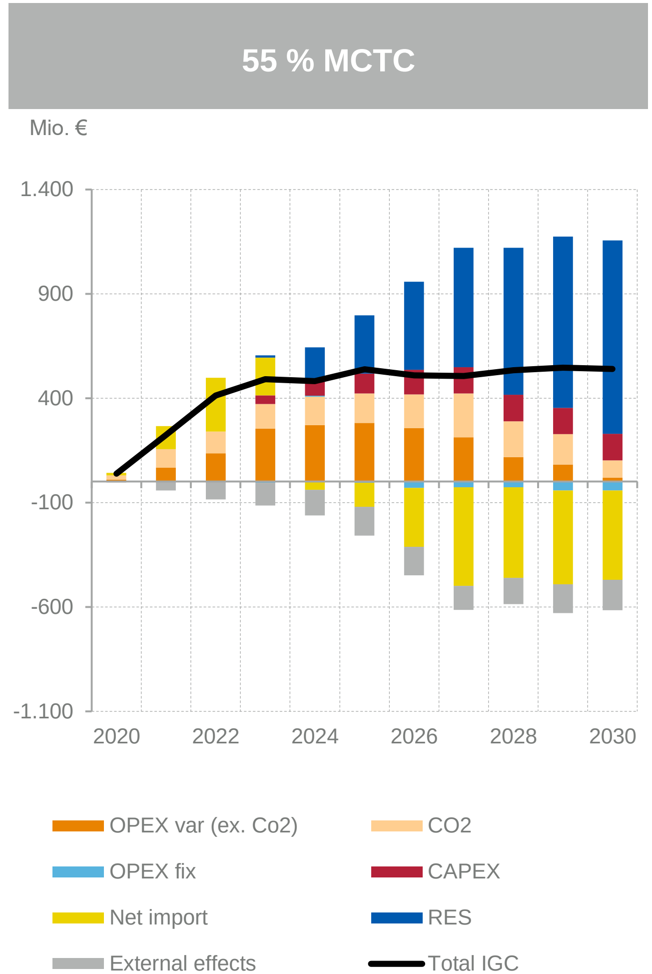
PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Scenario differences: Incremental generation costs in RO

Annual incremental generation costs in Romania are higher in all 55 % scenarios. Main drivers are higher CO_2 costs (mid-) and RES costs (long-term). Import costs remain higher in the 55 % Market based coal-to-clean scenario but tend to be lower after 2023 in both, the 55 % PM & 55 % Market based coal exit scenario. Note: Revenues from auctioned CO_2 certificates can also be seen as source of income.





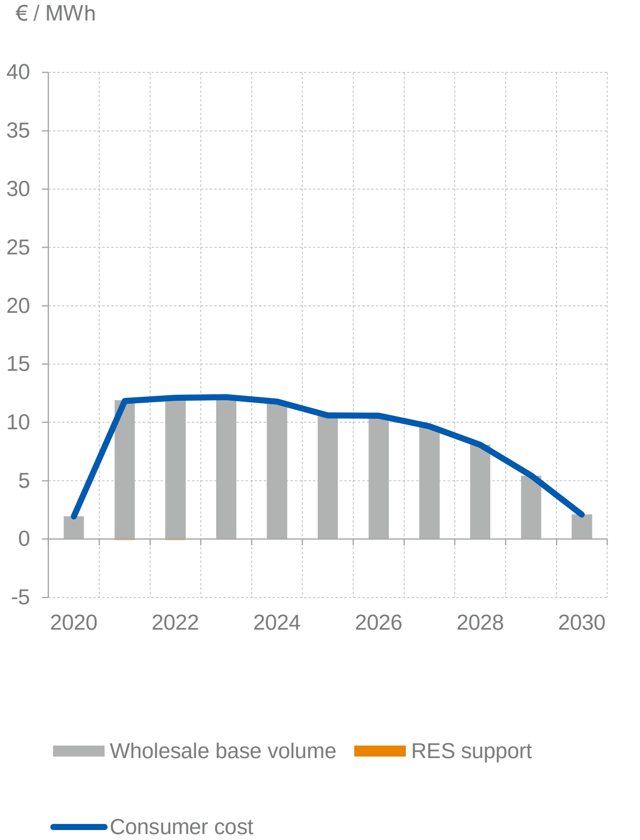


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

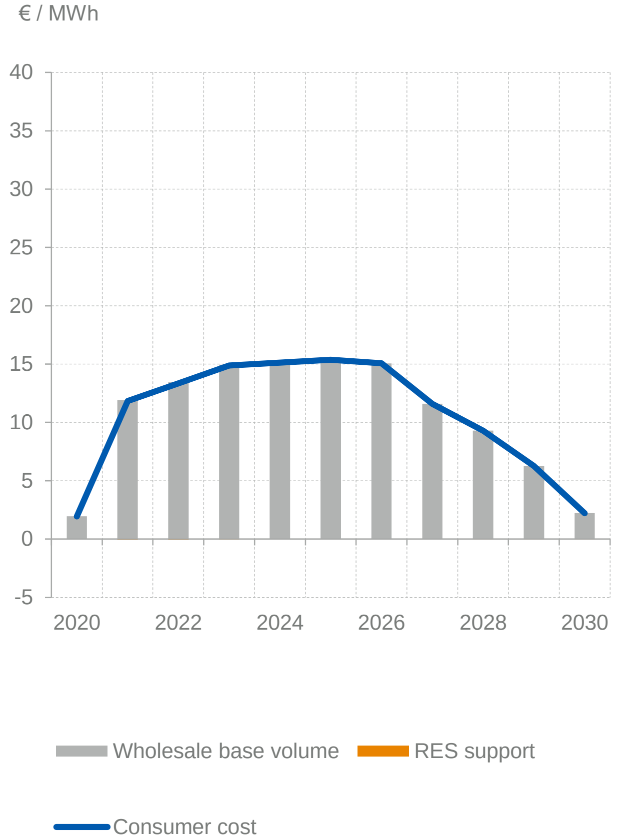
Scenario differences: Consumer costs in RO

Costs to consumers increase in all 55 % scenarios in Romania (in comparison with the 40 % PM scenario) due to higher wholesale price levels, partly driven by higher CO_2 prices and net-imports. The effect is mitigated with increased availability of carbon-free renewable generation towards 2030.

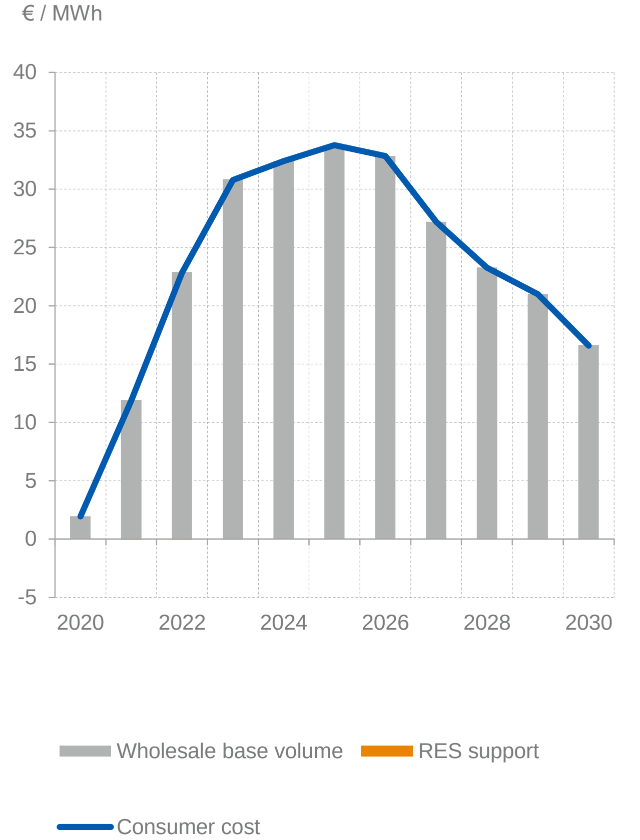
55 % PM



55 % MCE



55 % MCTC

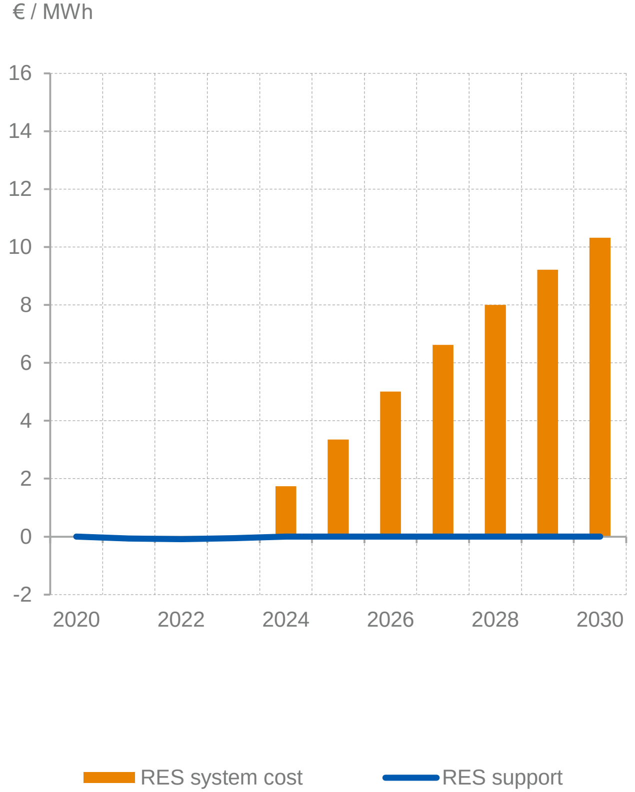


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

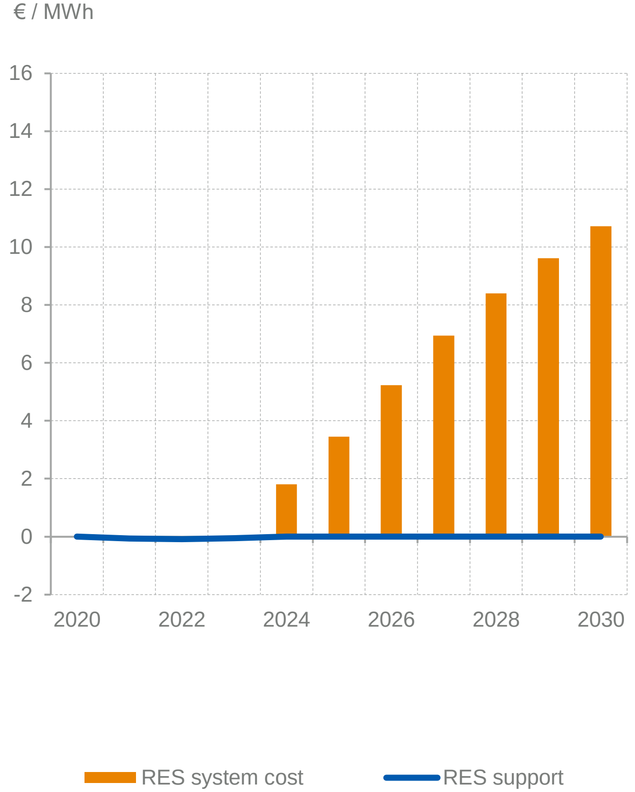
Scenario differences: RES re-financing in RO

The deployment of significant additional RES capacities increases RES system costs in Romania in the 55 % scenarios. Higher wholesale prices imply higher market revenues of RES generation and thus decrease support needs. In the case of Romania, no significant additional RES support is required, when comparing the 55 % scenarios with the 40 % PM scenario.

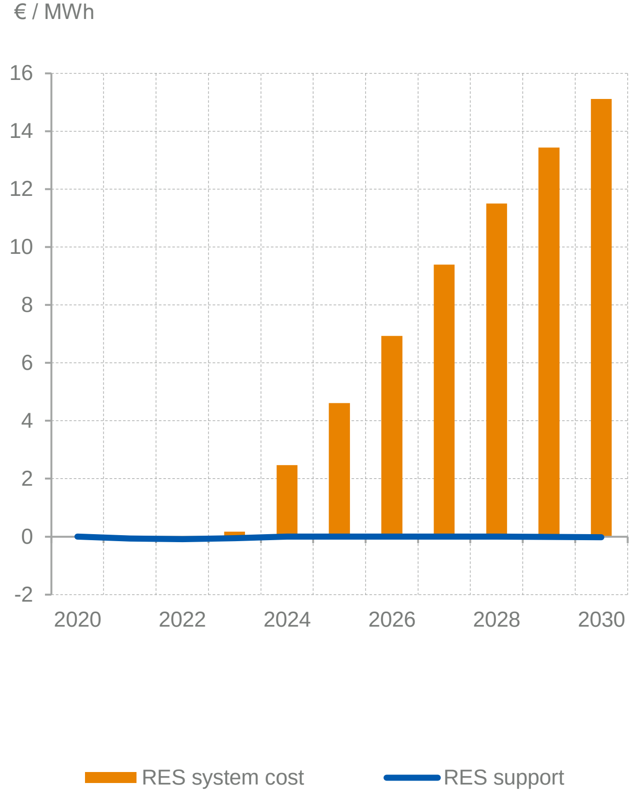
55 % PM



55 % MCE



55 % MCTC

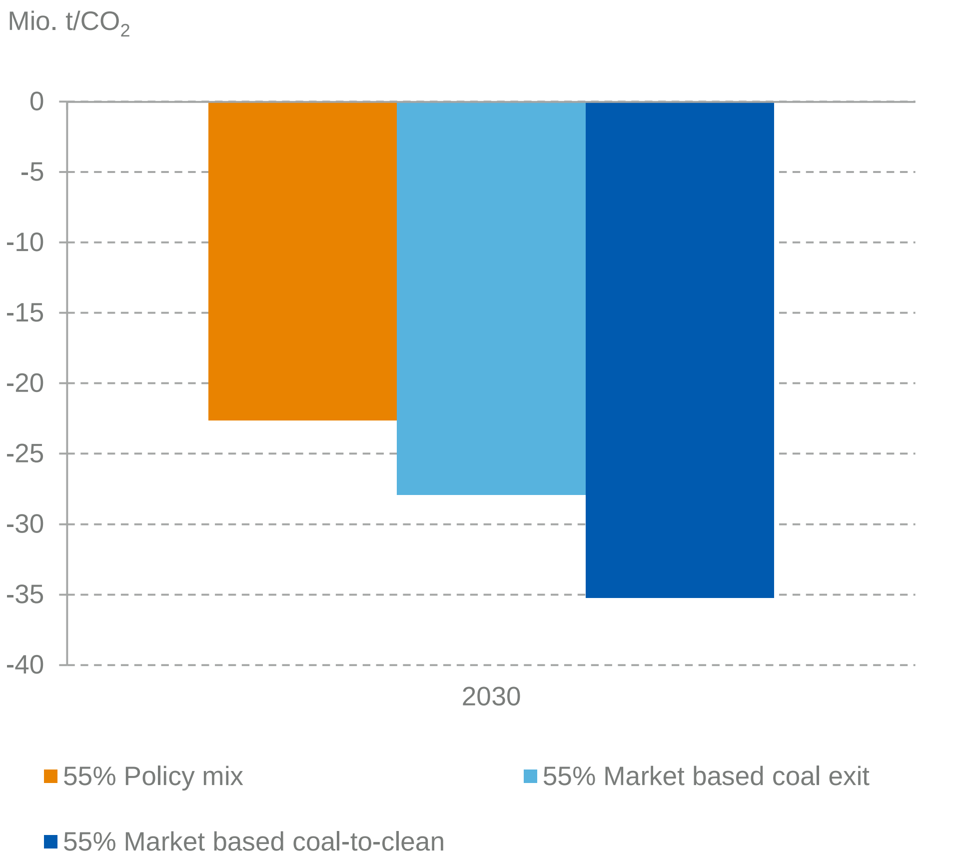


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

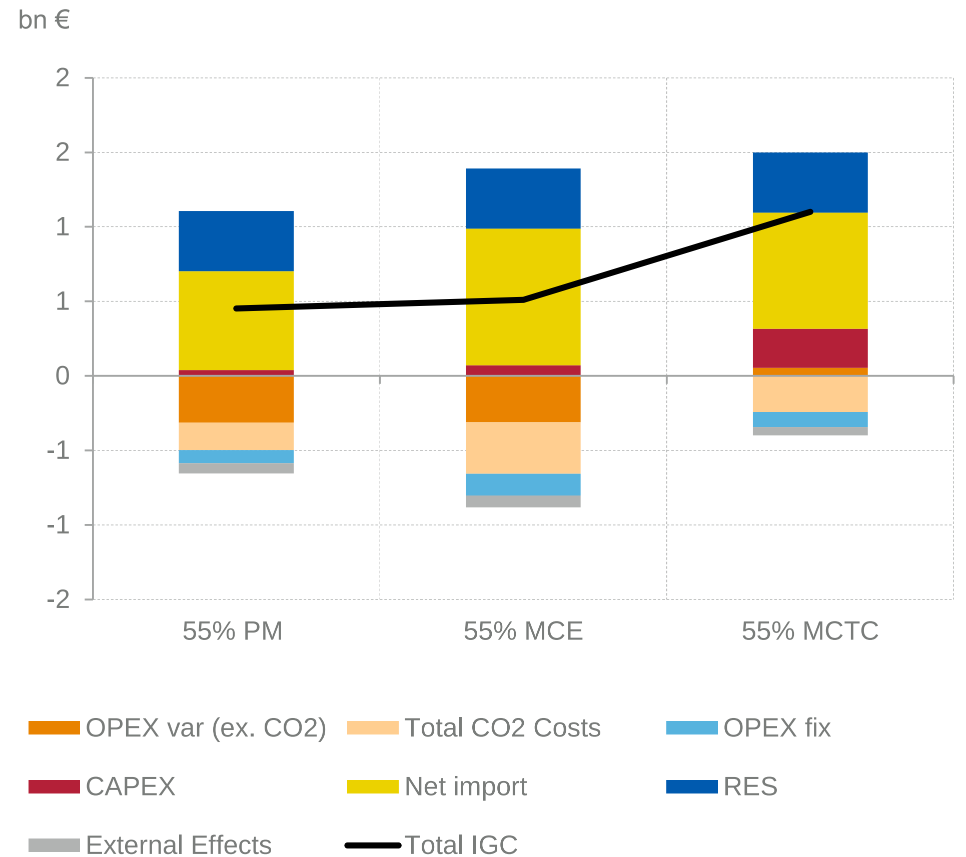
SI

Total emissions & system costs – SI

Total CO_2 emissions (2020-2030)
Deltas minus 40 % PM



Total IGC (2020-2030)
Deltas minus 40 % PM



Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

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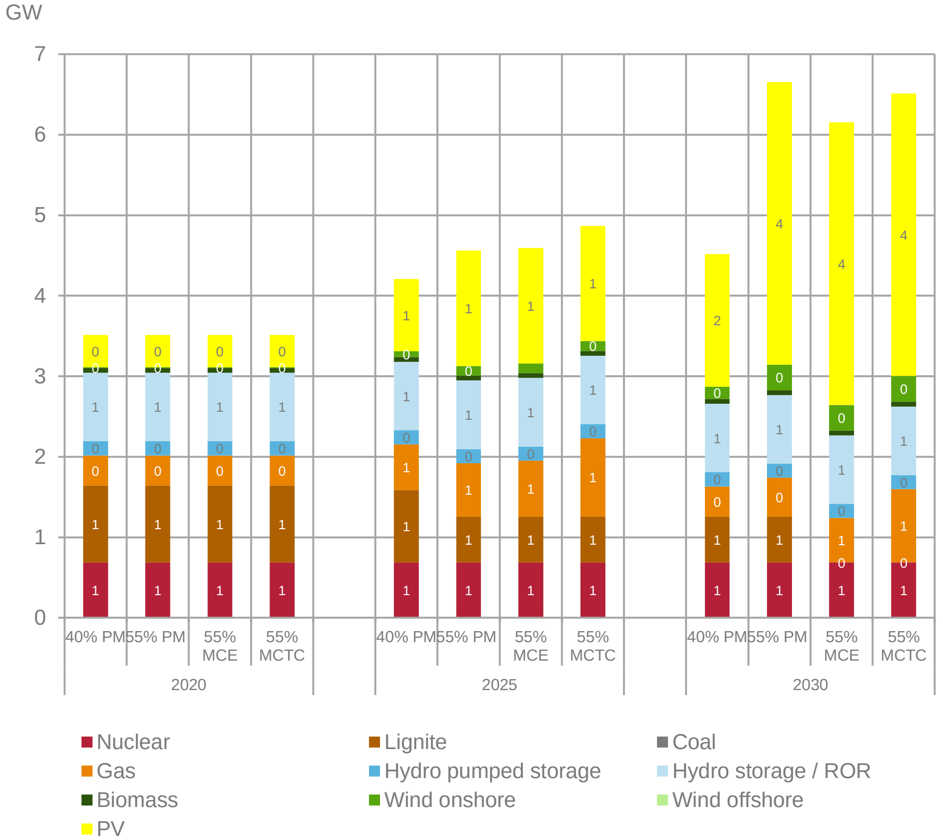
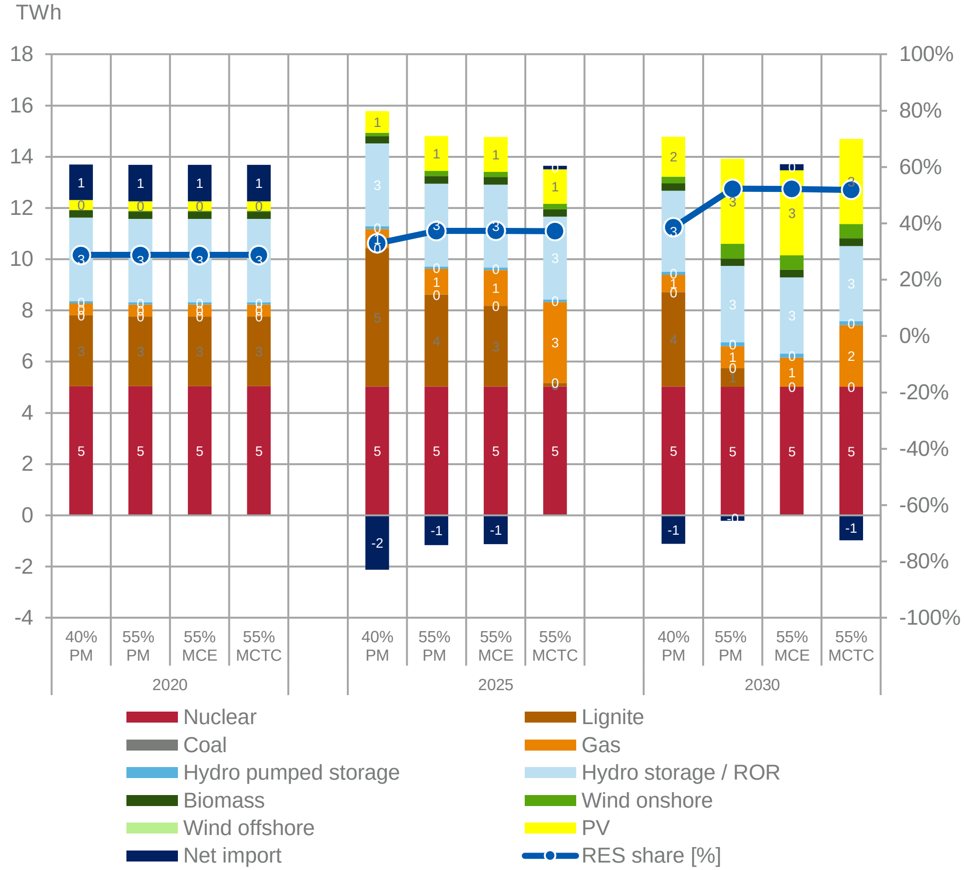
Capacity & generation – SI

Compared to the 40 % PM scenario, the 55 % scenarios lead to an earlier decommissioning & accelerated reduction of remaining coal capacities in Slovenia, which are substituted over time with a mix of wind onshore, PV & gas units (flexibility demand). The generation mix becomes less carbon-intensive & RES shares (on demand) increase by over 20 percentage points by 2030 (55 % scenarios).

Capacities



Generation

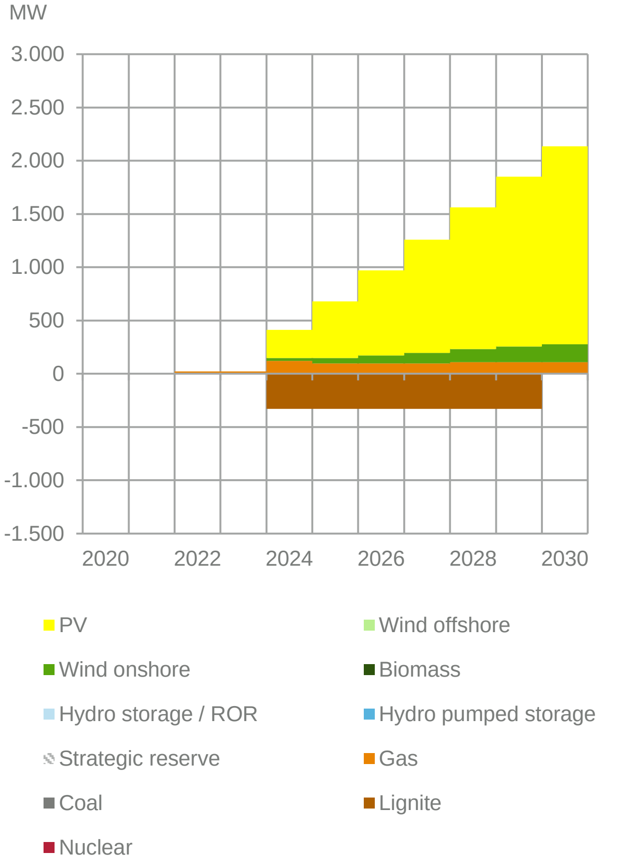


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

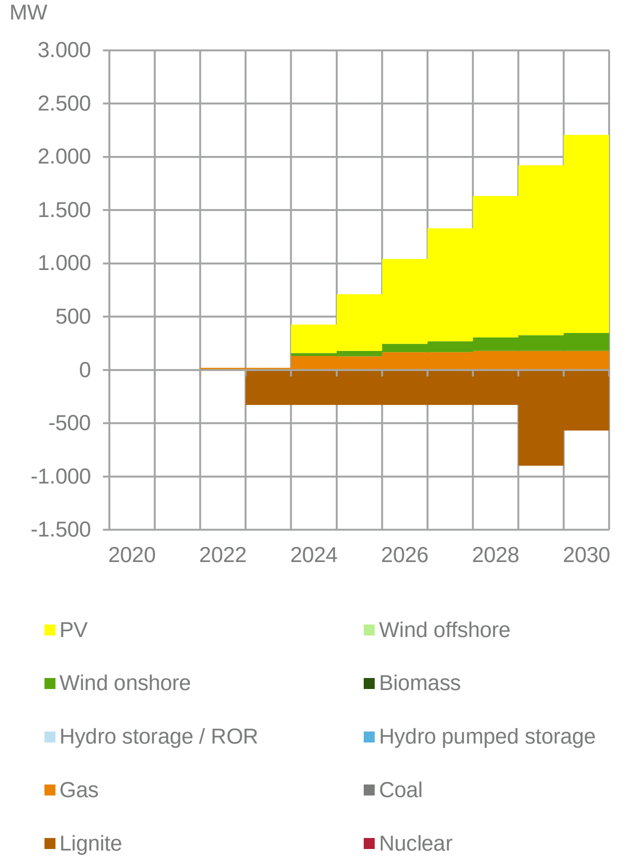
Scenario differences: Installed capacities in SI

In the 55 % scenarios, the remaining coal capacities in Slovenia are substituted with a mix of PV, wind onshore & gas. Compared to the 55 % PM, the 55 % Market based scenarios see an earlier reduction of coal capacity (2023). Higher CO_2-prices also trigger add. market based RES expansion, especially in the 55 % Market based coal-to-clean scenario, where gas units are more strongly deployed.

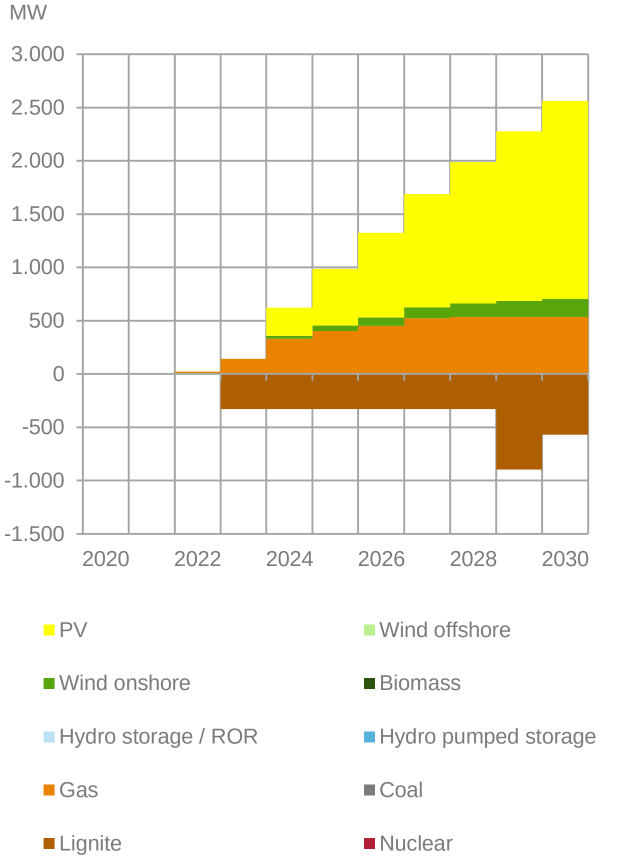
55 % PM



55 % MCE



55 % MCTC

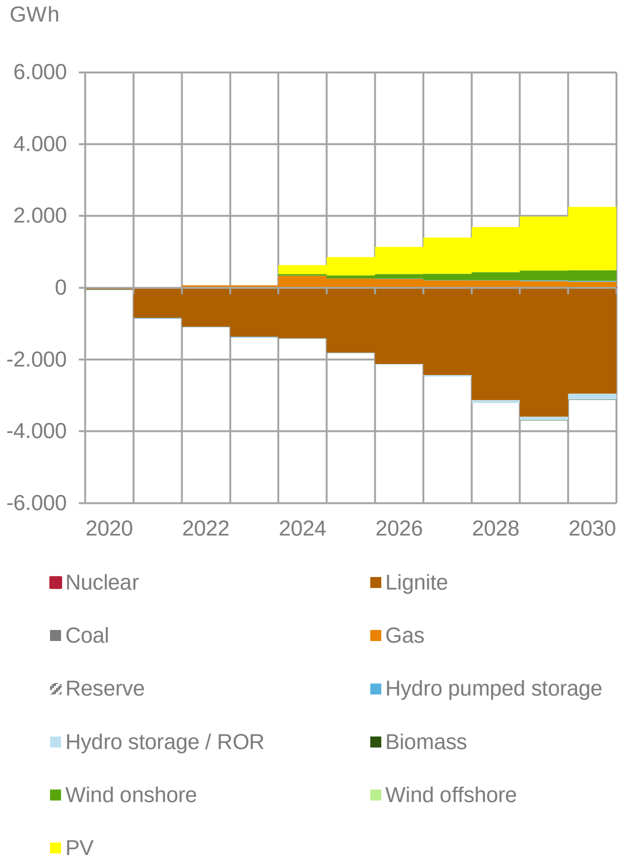


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

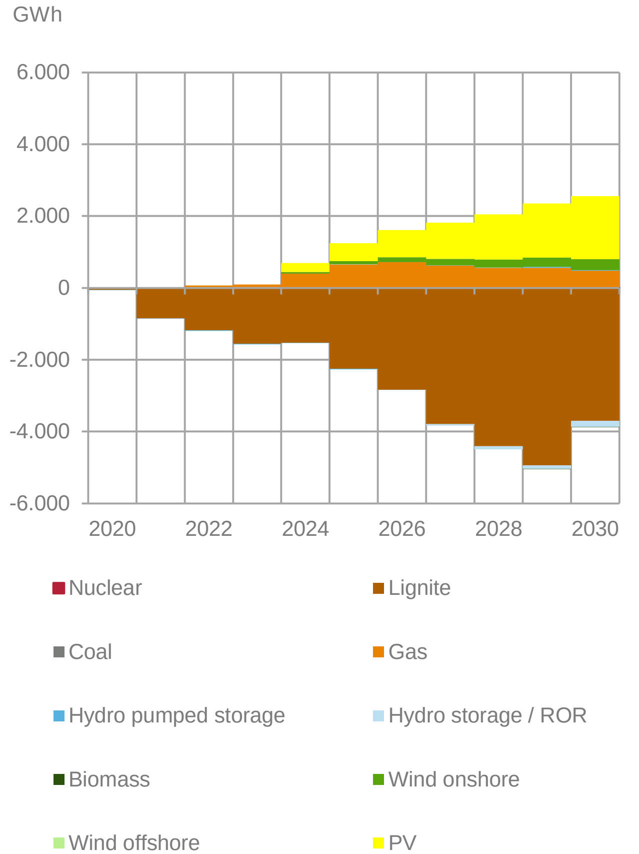
Scenario differences: Power generation in SI

Earlier decommissioning and lower utilization of the remaining coal-fired units trigger temporary increased gas-based generation (mid-term) in both 55 % Market based scenarios. On the long run, coal-based generation is mostly compensated by wind and PV generation, and, in case of the 55 % Market based coal-to-clean scenario, also supplemented with significant gas-based generation by 2030.

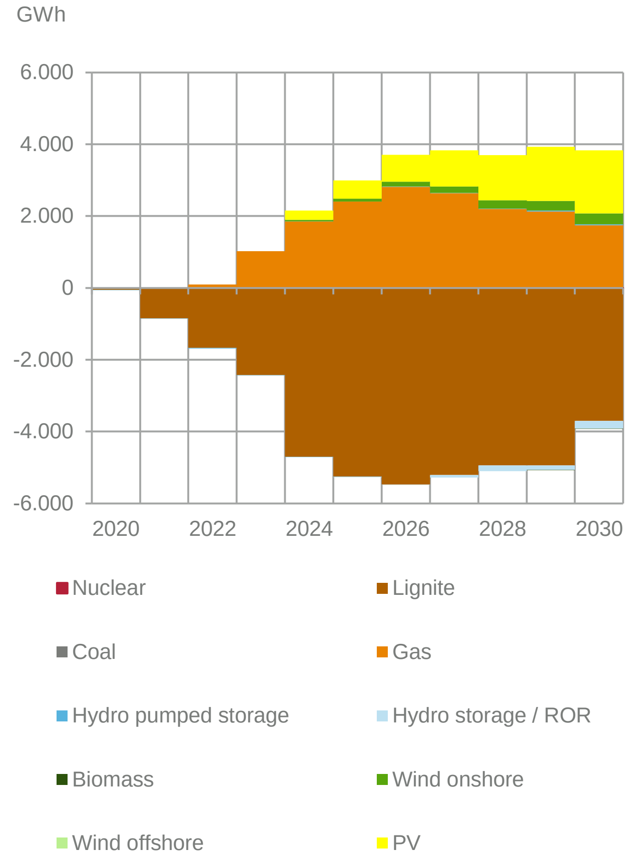
55 % PM



55 % MCE



55 % MCTC



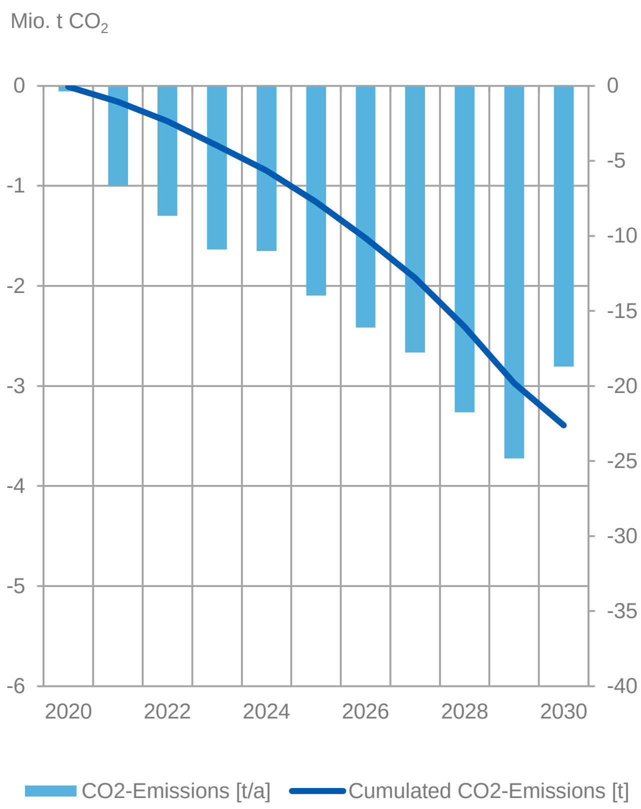
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM).

PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

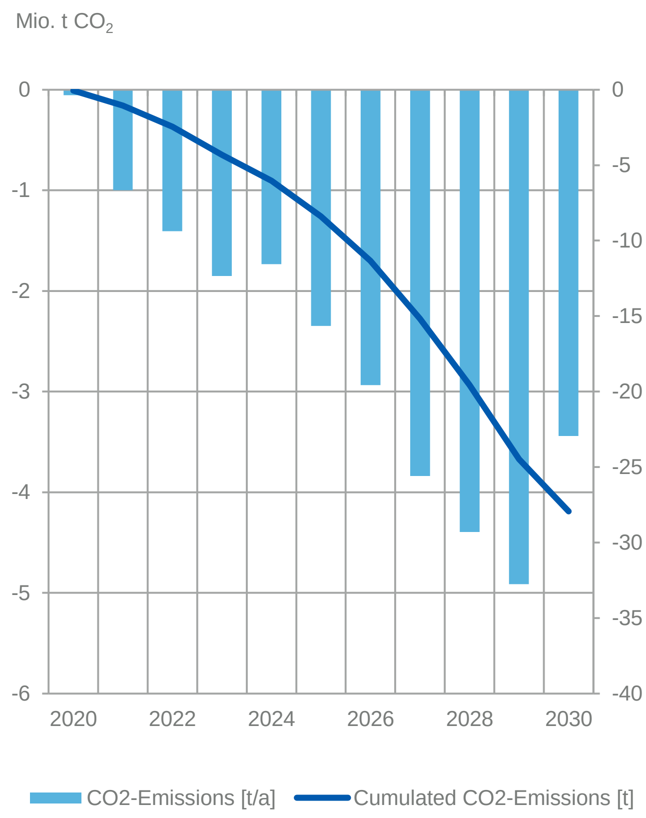
Scenario differences: CO_2 emissions in SI

All 55 % scenarios lead to significant CO_2 savings in Slovenia compared to the 40 % PM scenario. Until 2024, the additional reduction is driven only by the CO_2 price. In total, the 55 % PM scenario results in a cumulative reduction of 23 Mio.t. of CO_2 (market based coal exit: 28 Mio.t.; market-based coal-to-clean: 35 Mio.t.) until 2030 compared to the 40 % PM scenario.

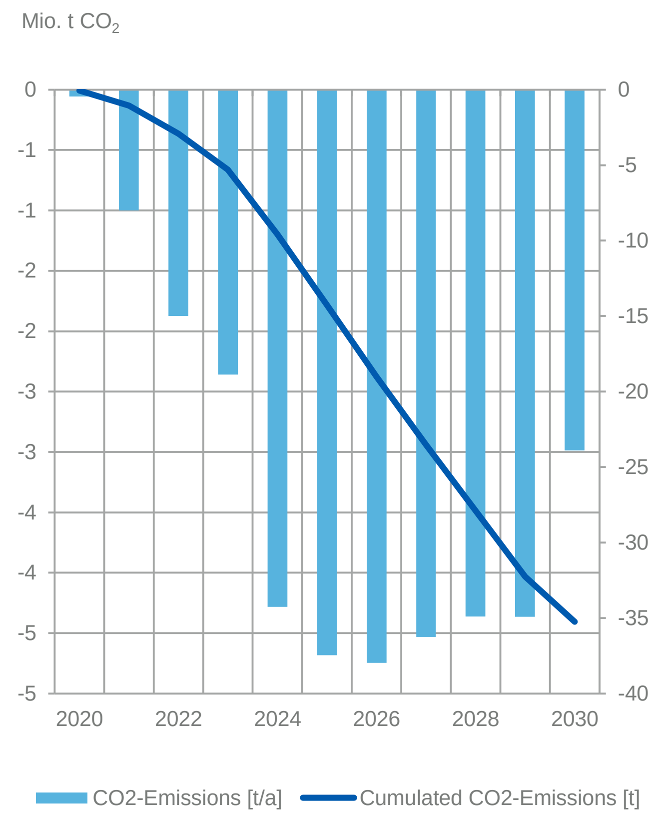
55 % PM



55 % MCE



55 % MCTC

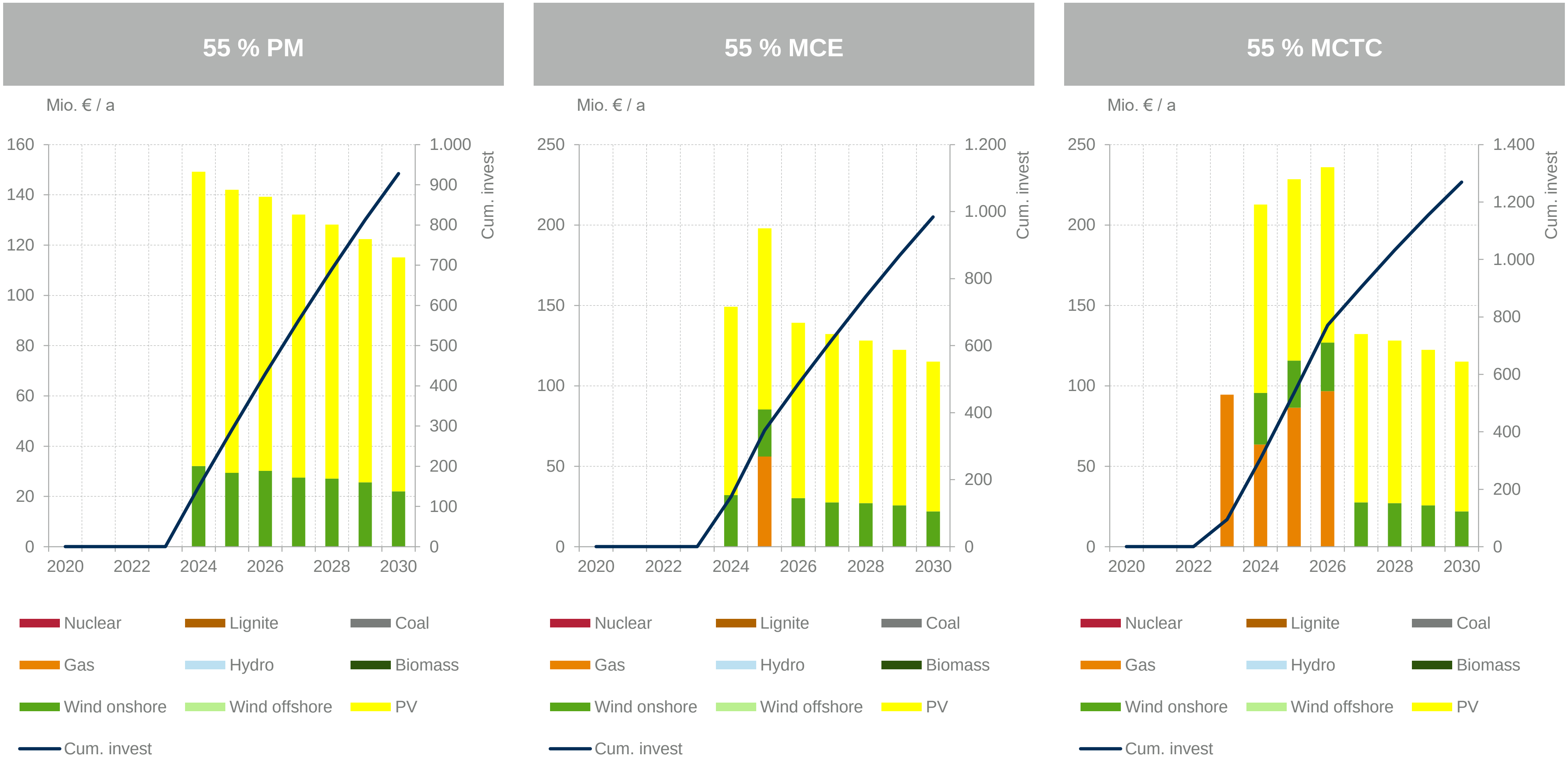


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM).

PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Scenario differences: Investment volumes in SI

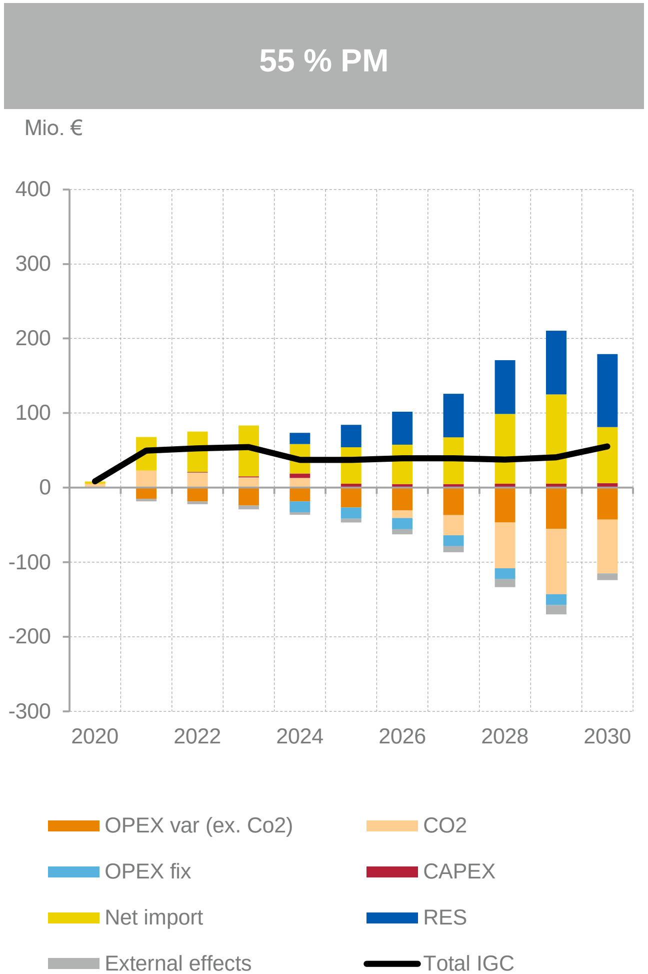
Required additional investments into Slovenia's power-generating infrastructure accumulate to 0.93 bn € (55 % PM), 0.98 bn € (55 % Market based coal exit) and 1.3 bn € (55 % Market based coal-to-clean) until 2030. Investments are mainly channelled towards new PV assets. In the 55 % Market based coal-to-clean scenario, additional investments in gas-based units take place between 2023 and 2026.

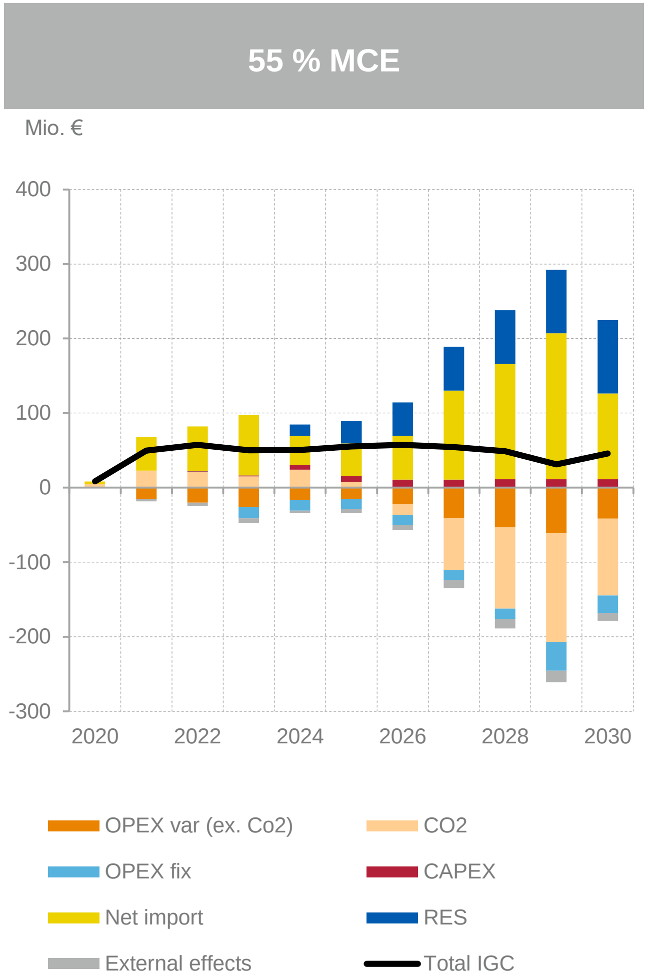


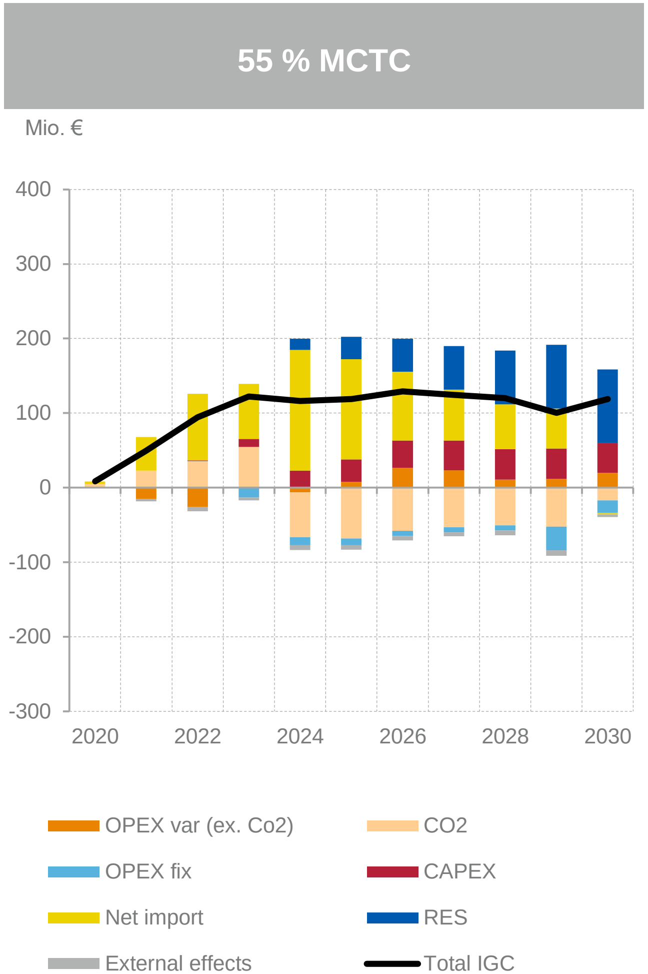
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Scenario differences: Incremental generation costs in SI

Annual incremental generation costs in Slovenia are higher in all 55 % scenarios. Main drivers are higher import and RES costs which dominate diverse savings in OPEX and external effects by the end of the decade. Note: Revenues from auctioned CO_2 certificates can also be seen as a source of income.



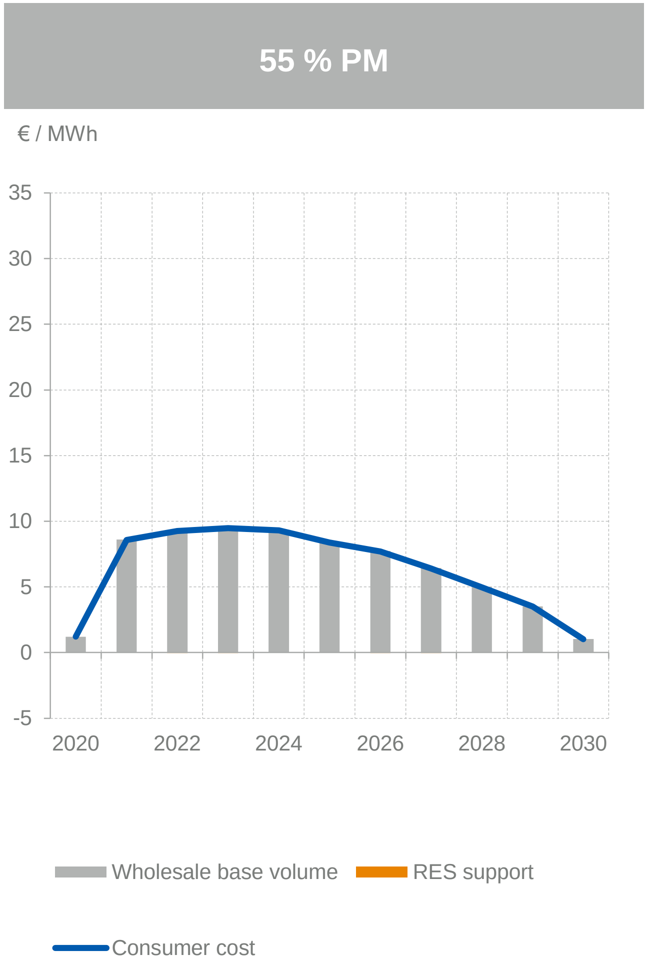


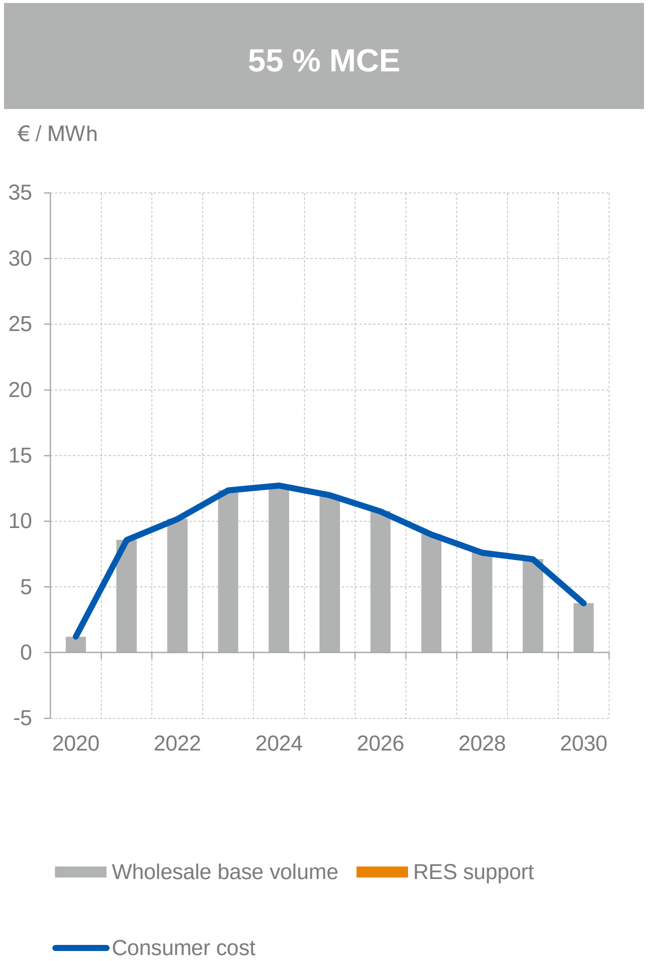


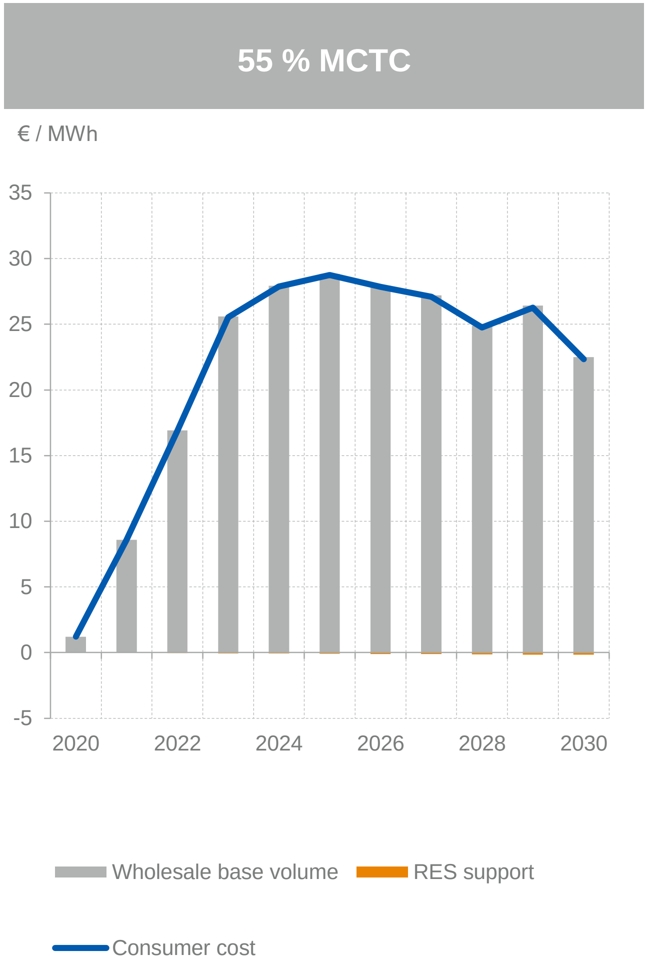
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Scenario differences: Consumer costs in SI

Costs to consumers increase in all 55 % scenarios in Slovenia (in comparison with the 40 % PM scenario) due to higher wholesale price levels, partly driven by higher CO_2 prices and net-imports. The effect is mitigated with increased availability of carbon-free renewable generation towards 2030.





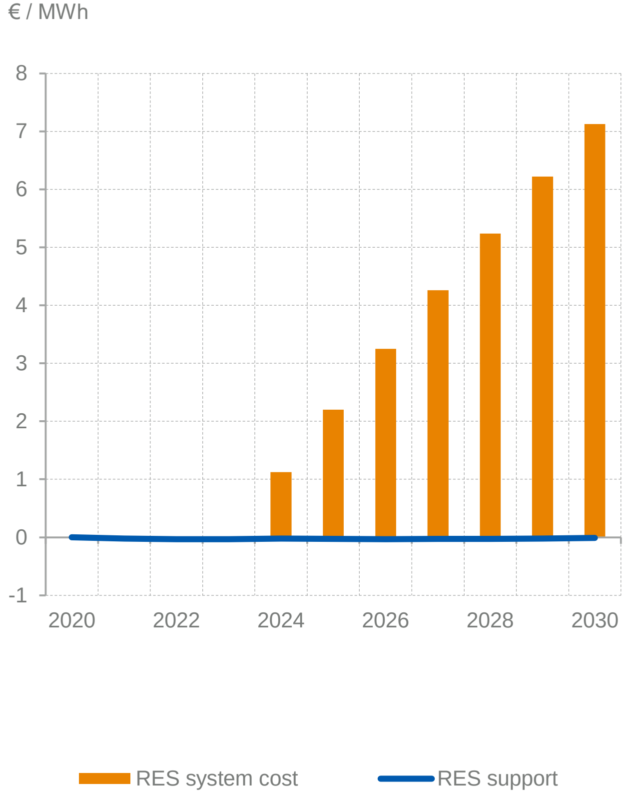


Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

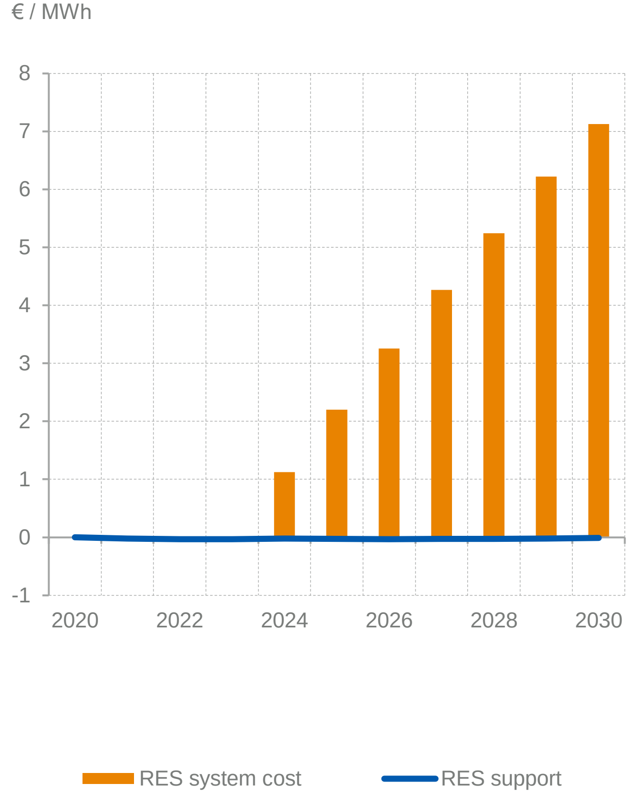
Scenario differences: RES re-financing in SI

The deployment of significant additional RES capacities increases RES system costs in Slovenia in the 55 % scenarios. Higher wholesale prices imply higher market revenues of RES generation and thus decrease support needs. The required additional RES support decreases, especially in the two 55 % Market based scenarios.

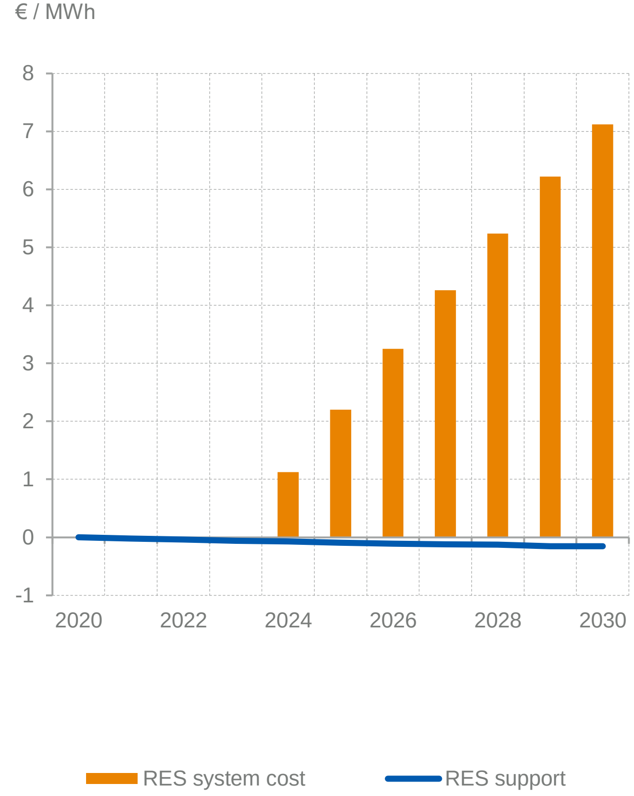
55 % PM



55 % MCE



55 % MCTC



Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM).

PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

METHODOLOGY & MAIN ASSUMPTIONS

Methodology & scenarios

SCENARIO DESIGN
- Definition of political scenarios
- Basis for power market modeling

ASSUMPTIONS
- Techno-economical parameters
- RES, coal trajectories
- CO_2 prices

MODELING
- Power plant dispatch & investment up to 2030
- Development of capacity and generation mix

RESULTS
- Incremental generation costs* (ICG)
- Investment volumes
- CO_2- and other emissions

MODELING APPROACH

EU-27 countries aggregated and major coal-countries as focus group („Coal-6“): BG, CZ, DE, PL, RO, SI

REGIONAL SCOPE

40 % reduction scenario

40 % Policy mix (40 % PM)

Policy mix– “40 % Scenario” implies the former EU 2030 carbon mitigation ambition level. No significant market based coal exit or RES expansion. CO_2 price based on EC Reference 2016 sc. (35 €/t in 2030).

55 % reduction scenarios

55 % Policy mix (55 % PM)

Policy mix - complete **coal exit until end of 2030** and increased, policy-driven RES expansion as well as elevated CO_2 prices (54 €/t in 2030 based on TYNDP2020).

55 % Market based coal exit (55 % MCE)

Market based coal exit - coal exit trajectory resulting from relying on an economic decommissioning of all coal plants driven by the CO_2 price. RES expansion remains policy-driven.

55 % market based coal-to-clean (55 % MCTC)

Market based coal exit and RES expansion - further explores the requirements and implications of a CO_2 price-driven coal-to-clean transformation.

SCENARIOS

* For an economic comparison of scenarios the differences in generation cost are of main relevance. This study look at indicator called “Incremental generation costs”. For a detailed explanation see methodology section.

enervis fundamental model eMP

INPUT
(initial analyses and databases)

Policy / framework

Weather data

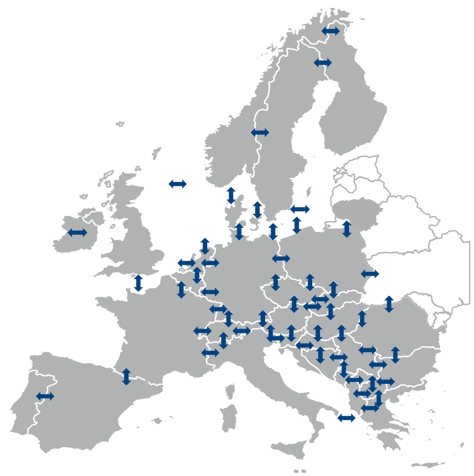
Load development

Interconnections

Commodities
fuel, CO_2, transport costs, exchange rates

European generation capacities

MARKET MODEL
(fundamantal simulation)



fundamental energy market model: eMP

- EU 28 + Switzerland, Norway, Balkan
- hourly resolution
- Power plant blocks > 50 MW
- individual analysis: regions, technologies
- „Off the shelf“ or individual assumptions
- embedded in enervis modelling landscape

RESULTS
(selection)

market prices

- wholesale: spot, intraday
- Capture prices of renewables
- Ancillary services: PCR, SCR, TCR
- Capacity prices
- CO_2 certificate prices
- Revenues of interconnectors

other results

- capacity-/generation development
- commercial exchanges (import/export)
- CO_2-Emissions
- spreads

individual results (examples)

- System costs for generation (econ.)
- market value of renewables (site specific)
- power plant dispatch / valuation

enervis®

Model approach: players and their decision scope

Different players within modeling framework (rows) and their respective degrees of freedom (columns) are shown. The table cells define the model.

	USAGE	EXPANSION	SHUTDOWN
	Marginal cost minimizing dispatch with detailed consideration of technical / economic conditions (OR, gradients, minimum load, CHP…)	• Exogenous expansion • **Economic expansion based on full cost aspect**	• Exogenous shutdowns • Technical lifetimes • **Economic aspects, i.e. for retrofit**
	• Marginal cost minimizing dispatch of interconnectors • **Representation of interconnector cost (for example with bottlenecks)**	• According to current projections of the European TSOs and entso-e • **Market splitting** of electricity price regions can be implemented in the model (i.e. price zone separation Germany-Austria)	
	• Usage according to support scheme (e.g. "market premium model") • **High geographically and temporal resolution** of weather data for availability	• Exogenously and partly politically determined capacity expansion • **Economic expansion possible based on full cost aspect**	• Technical lifetimes
	• Pumped storage, decentralized PV-storage and electric mobility distribute generation / consumption marginal cost minimal or **spread optimal**		
	Other **secondary conditions** (i.a. coal exit) can be defined to represent **political goals** (in particular for the development of emissions)		

Scenario Overview (I)

Three alternatives are modelled for implementing a 2030 EU-wide coal phase-out, quantifying CO_2 prices levels corresponding to and implications of fully market-based coal phase-out and renewable phase-in versus a policy mix.

	40 % Policy mix	55 % Policy mix coal exit	55 % Market based coal exit	55 % Market based coal-to-clean
CO_2 Prices	Ca. **35€/t in 2030** / based on EU Reference Sc. 2016	Ca. **54€/t in 2030** / based on TYNDP 2020 DE Sc.	Heuristical iteration: such that in 2030 all coal units opt for economic decommissioning (2 years of negative net margins), from 2021	Heuristical iteration: such that in 2030 renewable generation at the level of 55 % PM scenario is economically feasible
Exogenous coal trajectory	According to national plans & strategies	Phase-out of all coal capacities **by 31.12.2030** (by age)	According to national plans & strategies	As resulting in 55 % MCE
Economic decommissioning of coal	none		Decommissioning according to economics but max. 2 years earlier than in 55 % PM trajectory	none
Exogenous RES trajectory	Based on NECPs	Ambitious renewable expansion to substitute coal generation (vs. 40 %)		Expansion to the same 2030 generation level as in 55 % PM scenario
Endogenous RES expansion	none	Minor additional market based expansion		

- Energy economic effects of a policy mix (coal phase-out, supported RES, CO_2 price increase)
- What level of CO_2 price can lead to a market based coal phase-out unit 2030?
- What level of CO_2 price can compensate RES support?

Scenario Overview (II)

Three alternatives are modelled for implementing a 2030 EU-wide coal phase-out, quantifying CO_2 prices levels corresponding to and implications of fully market-based coal phase-out and renewable phase-in versus a policy mix.

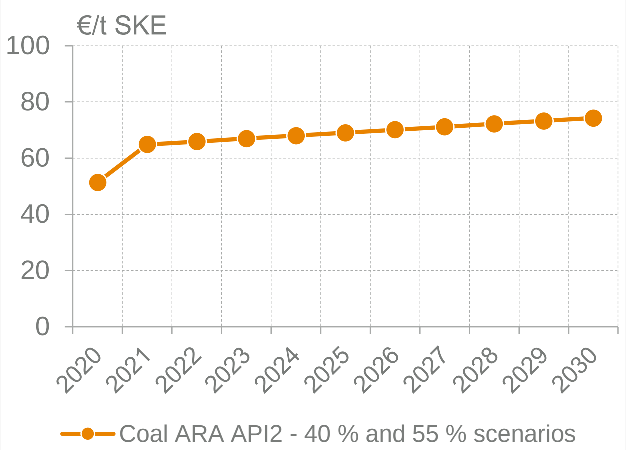
	40 % Policy mix	55 % Policy mix coal exit	55 % Market based coal exit	55 % Market based coal-to-clean
Fuel Prices	Based on WEO 2020 projections			
Gas Capacities	Merchant driven deployment in all regions / partial CHP replacement			
Nuclear Capacities	Existing: According to exit plans or lifetime assumption where applicable / Newly built units not relevant until 2030 or realization not assumed in EU countries			
Demand	According to national projections and sources / NECPs / partial electrification of mobility and heating sectors based on enervis assumptions			
Security of Supply	Peak Load, availability… etc. according to selected sources			
DSM	DSM potential assumed to be 5 % of national peak load			
Interconnection	Based on entso-e data and TYNDP Projects			

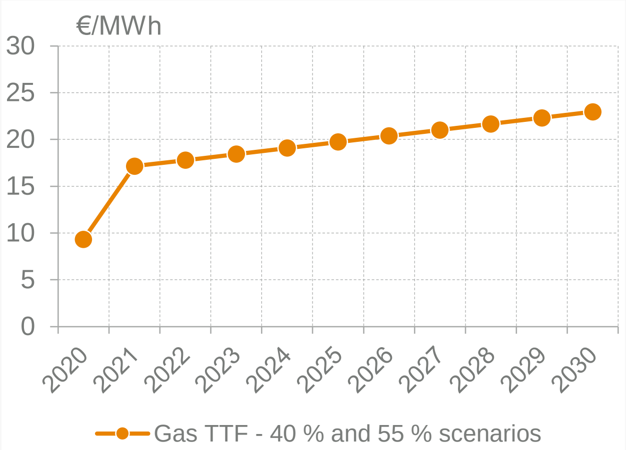
Fuel & CO_2 price* assumptions

Fuel prices are the same across all four scenarios. CO_2 prices are differentiated depending on scenario-specific reduction ambition and implied policy approach.

Coal price

- In all scenarios, 2030 figures are based on WEO 2020 Stated Policies Scenario
- 2020 figure based on historical data
- 2021 figure based on future quotes Jan/Feb 2021



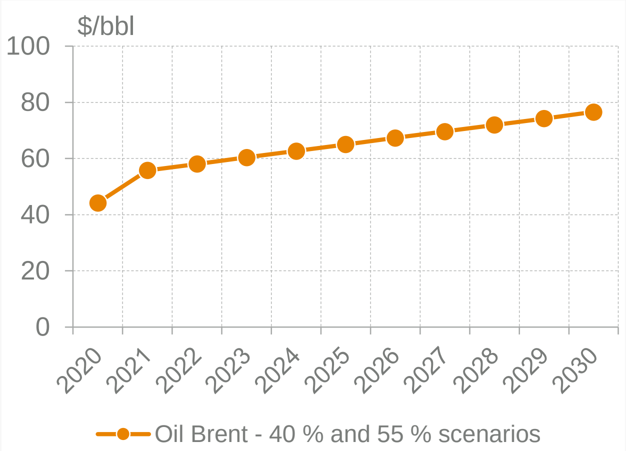


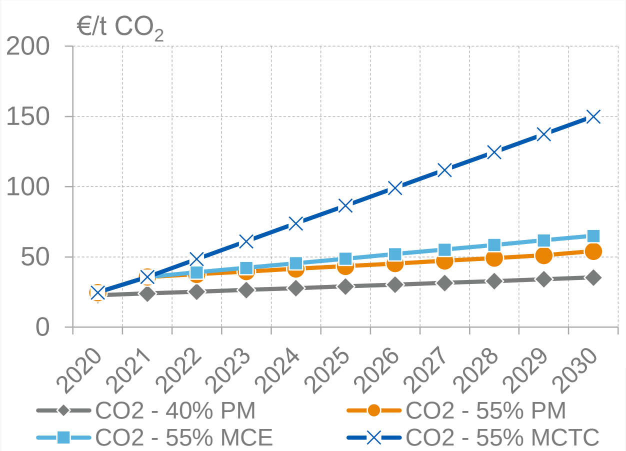
Gas price

- In all scenarios 2030 figures are based on WEO 2020 Stated Policies Scenario
- 2020 figure based on historical data
- 2021 figure based on future quotes Jan/Feb 2021

Oil price

- In all scenarios, 2030 figures are based on WEO 2020 Stated Policies Scenario
- 2020 figure based on historical data
- 2021 figure based on future quotes Jan/Feb 2021





CO_2 price (EU ETS)

- 55 % PM 2030 level based on TYNDP 2020 Distributed Energy Sc.
- 40 % PM 2030 level based on EC Ref. 2016
- 2021 figure based on future quotes Jan/Feb 2021

* all figures real (base 2021)

Incremental generation costs (I)

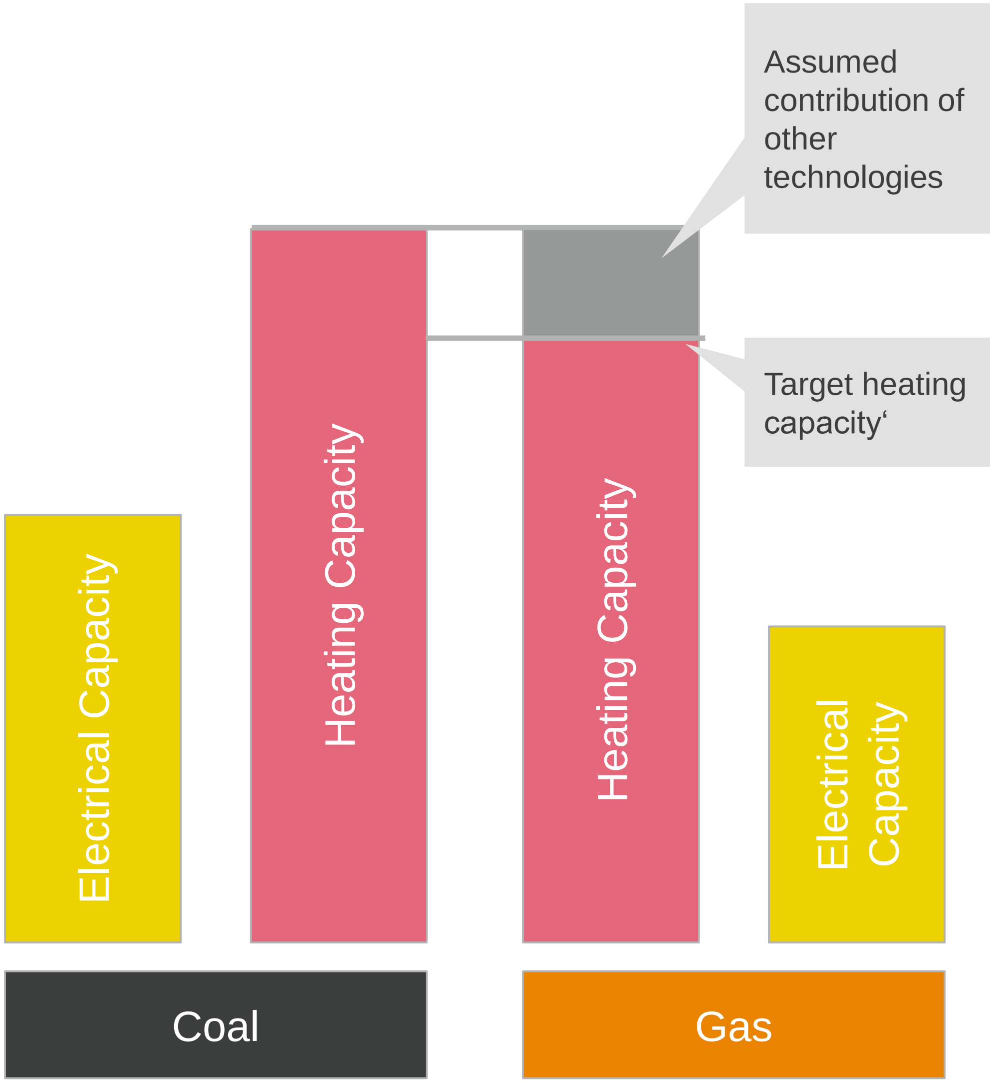
- For an economic comparison of scenarios the differences in generation cost are of main relevance. This study look at indicator called "Incremental generation costs".
- Generation costs are costs that are caused when generating (or importing) power in a country or system. These costs typically include all variable and fixed costs (including costs of capital) for building and operating power generation units.
- Incremental generation costs includes costs that change in between scenarios, whereas all costs that occur in all scenario do not influence "merit" in comparison and are this not necessarily included.
- If generation costs are comparatively lower in one scenario vs. another, this means that power is generated more cost efficiently, which can either reduce end-consumer costs or increase rents ("profits") of power producers by the same amount (or, of course, both partially). Since both producer rents and consumer prices are, from an economic point of view, distributional in nature, economic efficiency is often assessed based on generation costs.

Incremental generation costs (II)

In this project we have defined the following cost elements:

- **Net-Import Costs**: Any increase in net-power import from surrounding market zones has to be taken into consideration and was therefore assessed based on wholesale import prices.
- **External Effects**: External effects (mostly) represent negative health effects caused by pollutants emitted in the context of coal-based power generation, for the sake of comparability, these negative health effects were evaluated in monetary terms and expressed as costs.
- **CO_2 Costs**: This includes all costs caused by procurement of CO_2 certificates within the ETS. Please note, that these costs also create additional income e.g. for governmental institutions.
- **OPEX**: This component covers operational costs of conventional power generation. This includes fuel costs but, in this instance excludes carbon costs, which were addressed separately.
- **CAPEX**: Capital costs caused by conventional power generation. This represents investment and capital costs.
- **RES Costs**: All costs relevant for investing in and operation of renewable energy sources (OPEX and CAPEX of RES).

Assumptions for replacing coal-based CHP plants



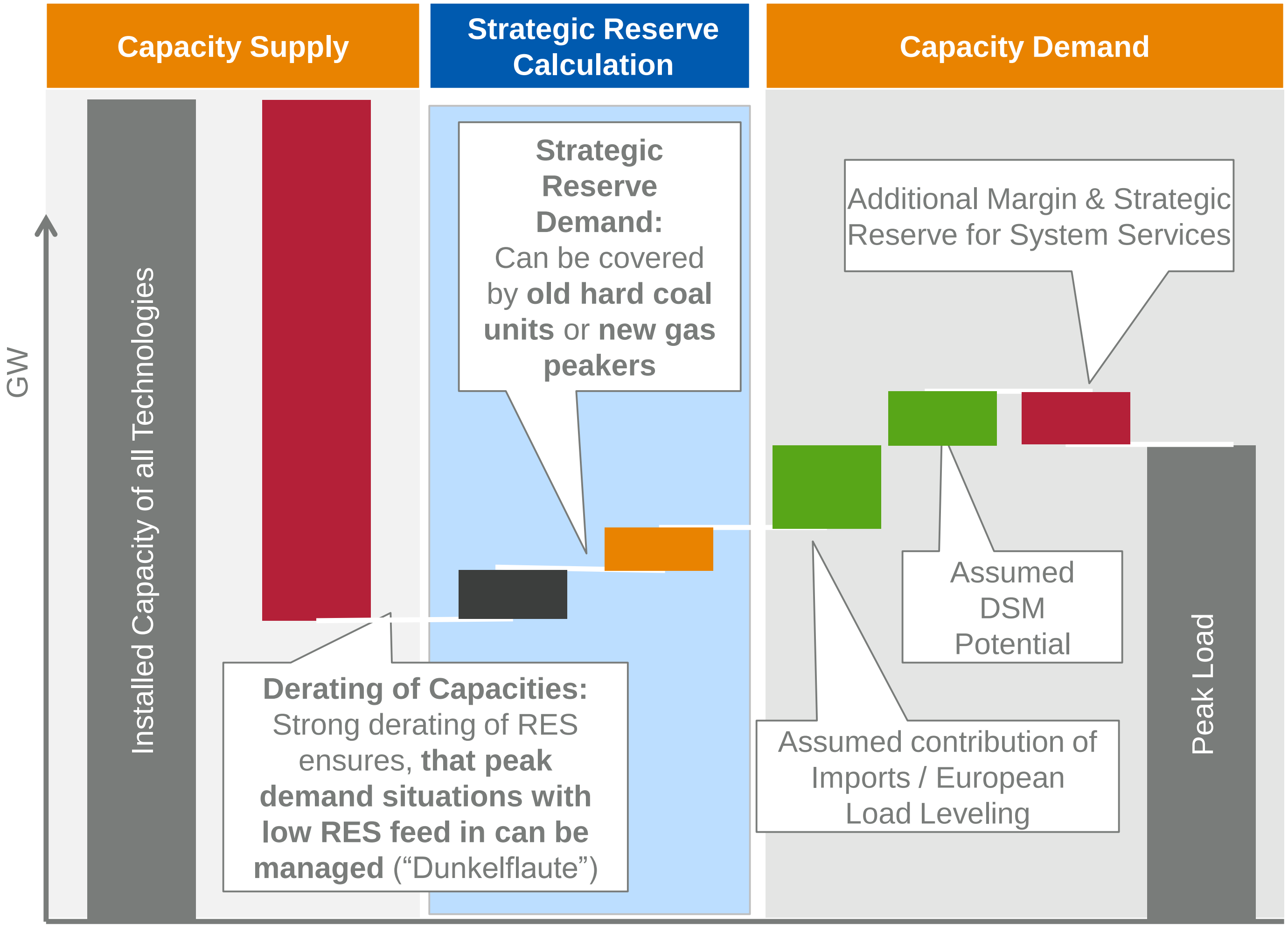
Comments

- **In this project a simplified 'heat capacity balancing approach' was conducted.**
  1. Based on Eurostat data and typical technology parameters of coal CHP plants, heating capacity of coal plants was estimated.
  2. Heating capacity was reduced by a country specific factor representing an assumed contribution of other technologies (e.g. RES heating)
  3. This ‚Target heating capacity' was substituted by heating capacity of gas plants
  4. Based on typical technology parameters of CHP gas plants, electrical capacity of gas plants was calculated.
  5. Actual heat generation to be optimized by the power market model

STRATEGIC RESERVES

Assumptions for deriving strategic reserve capacities

In this project, a “Capacity Balancing Approach” was used to calculate strategic reserve demand on a national level / If these strategic reserves are contracted, even so called “Dunkelflaute” situations should be manageable.

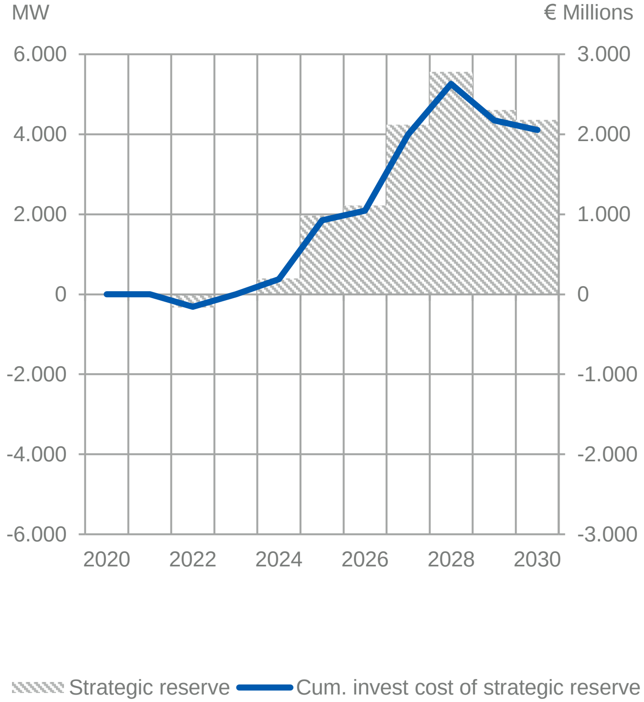


- Calculations are based on the assumption, **that hard coal units can contribute to the strategic reserve for up to 10 years after market exit.**
- **Additional assumptions:**
  - Required Margin on peak load = 9 %
  - DSM can reduce peak load by 5 %
  - European levelling effects can reduce peak load (pro rata) by 7.5 %
  - Capacity credit of RES: PV = 0 %; onshore = 4 %, offshore = 7 %

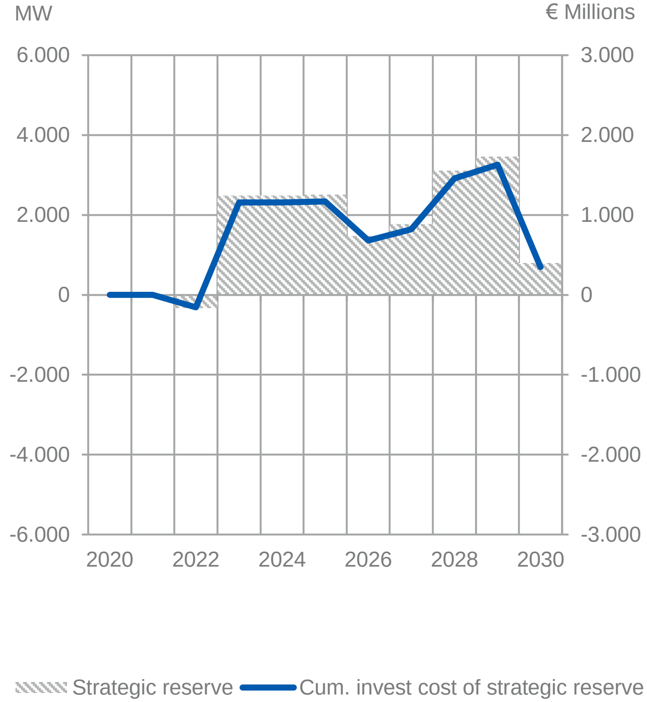
Strategic reserve deltas – Coal-6

In comparison with the 40 % PM scenario, the 55 % scenarios see additional strategic reserve needs* in the Coal-6 countries from the mid-2020s onwards. In the 55 % Market based coal-to-clean scenario, this trend changes, and by the end of the decade (2028 onwards) lower strategic reserve capacities are required due to additional gas & (partially) wind onshore in the power systems.

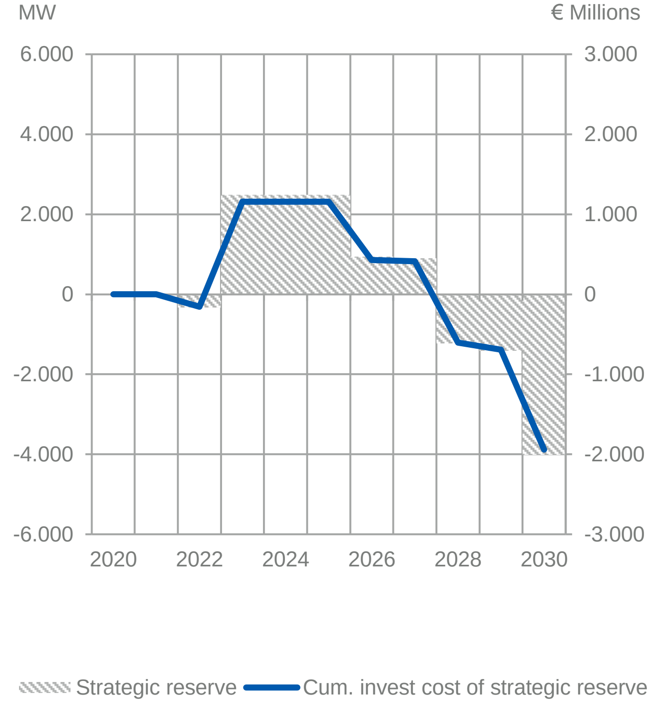
55 % PM



55 % MCE



55 % MCTC

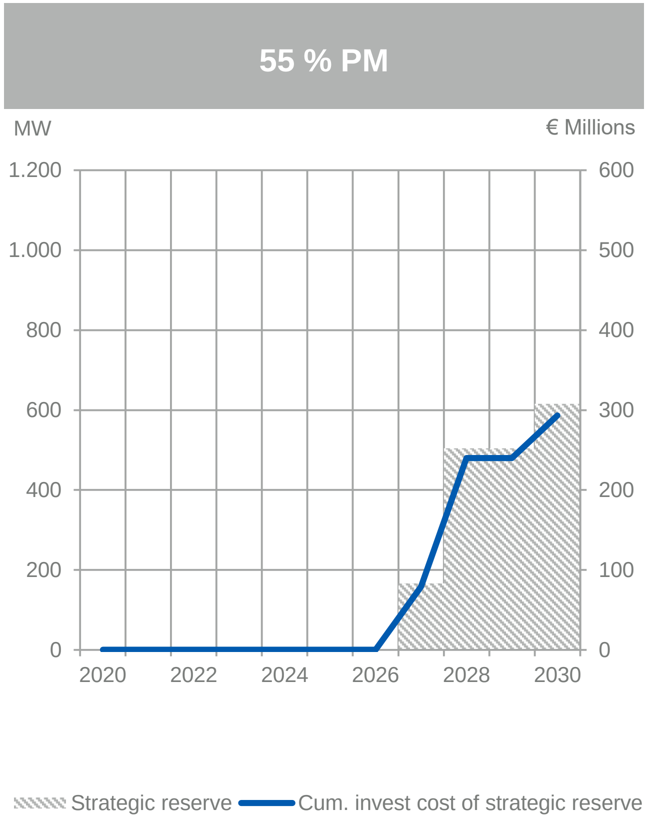


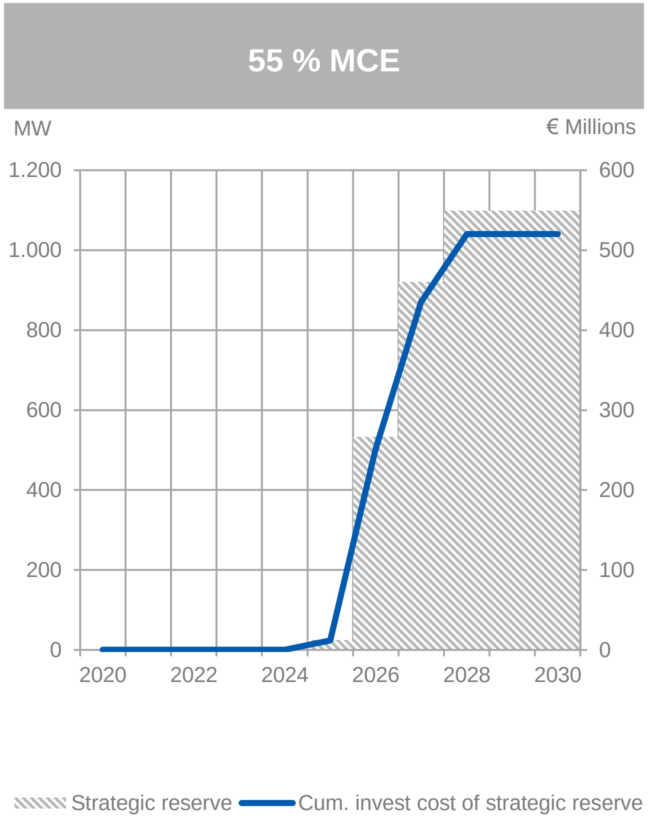
Note: No net demand for newly built strategic reserves is caused if hard coal units decommissioned in the 55% scenarios can be utilized as reserves. Hence costs depicted in this slide represent the costs of reserves if the capacity had to be provided by newly built gas units (OCGT) and hence would be lower in case decommissioned coal would be used instead.

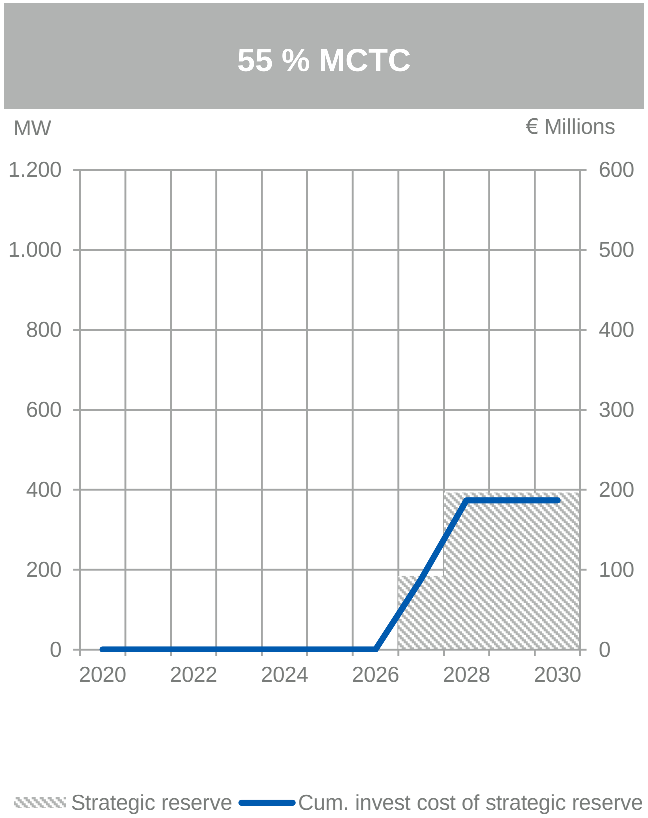
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Strategic reserve deltas – BG

The capacity balancing approach leads to additional strategic reserve requirements for Bulgaria beyond those the power market model would deploy based on market price signals alone. 2026 onwards, additional capacities would be required in all 55 % scenarios for ensuring peak load to be served primarily on a national basis.







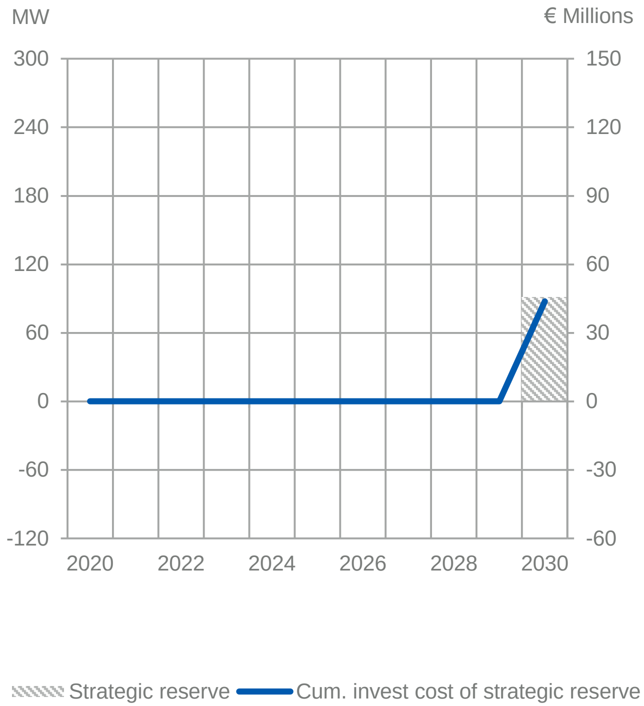
Note: No net demand for newly built strategic reserves is caused if hard coal units decommissioned in the 55% scenarios can be utilized as reserves. Hence costs depicted in this slide represent the costs of reserves if the capacity had to be provided by newly built gas units (OCGT) and hence would be lower in case decommissioned coal would be used instead.

Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

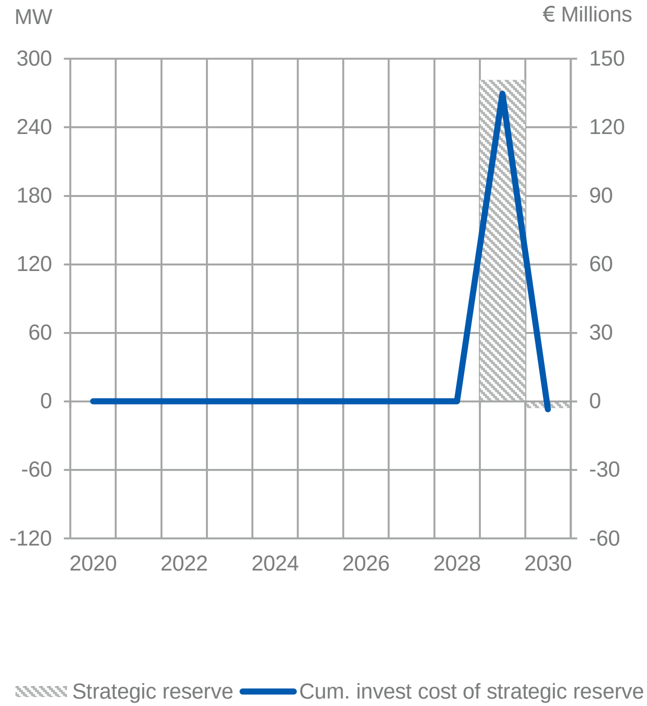
Strategic reserve deltas – CZ

For the Czech Republic, only by the end of the decade some minor additional strategic reserve capacities would be required in the 55 % scenarios for ensuring peak load to be served primarily on a national basis. In the 55 % Market based coal-to-clean scenario however, the trend changes by 2030 where less strategic reserve capacities is required.

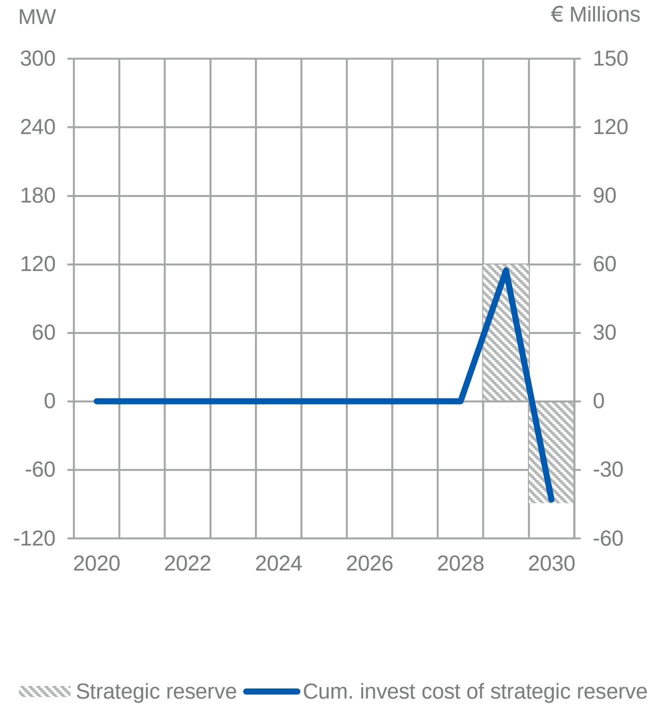
55 % PM



55 % MCE



55 % MCTC

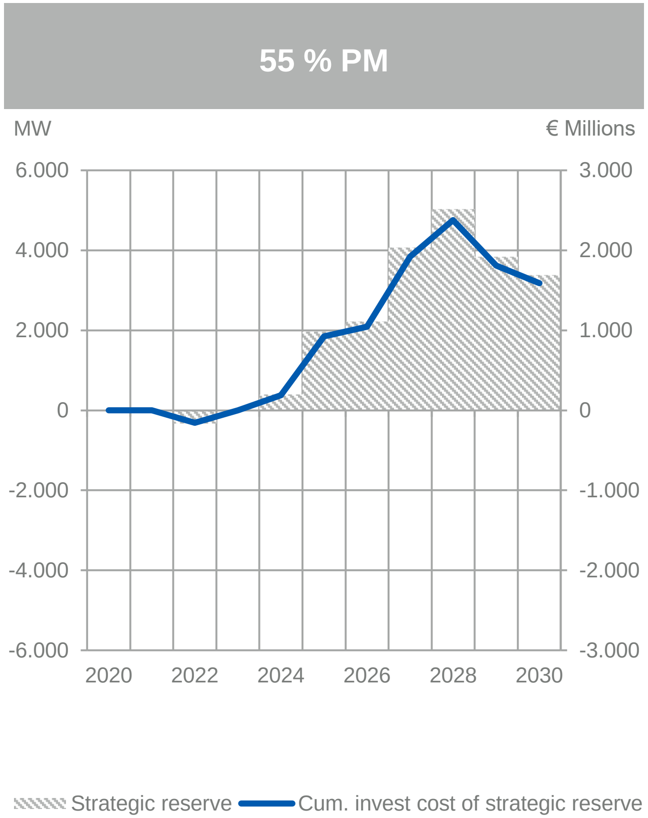


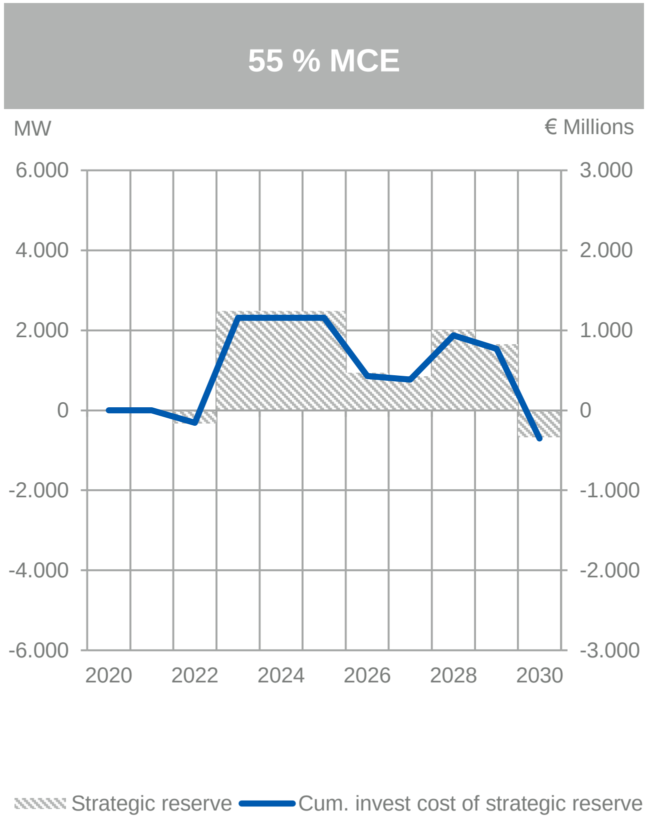
Note: No net demand for newly built strategic reserves is caused if hard coal units decommissioned in the 55% scenarios can be utilized as reserves. Hence costs depicted in this slide represent the costs of reserves if the capacity had to be provided by newly built gas units (OCGT) and hence would be lower in case decommissioned coal would be used instead.

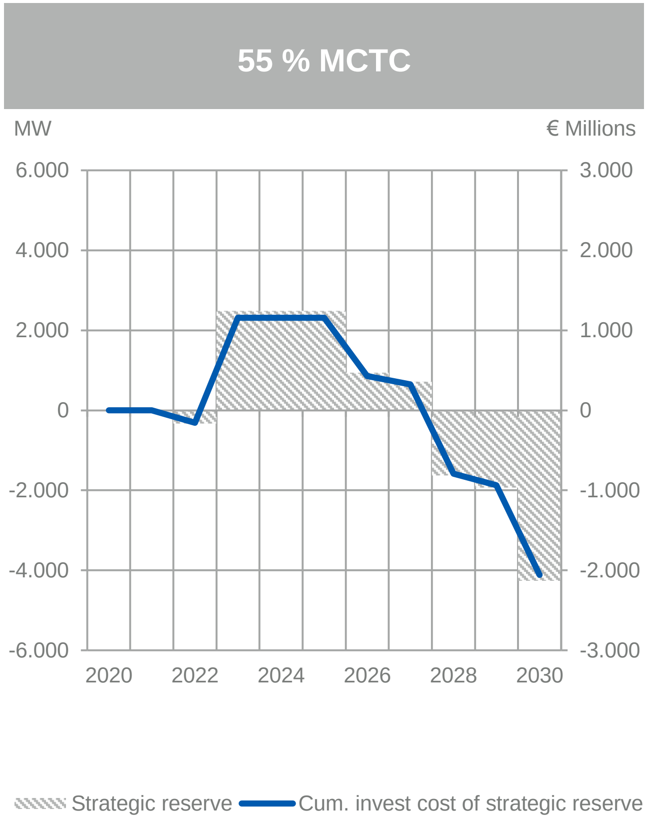
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Strategic reserve deltas – DE

For ensuring peak load to be served primarily on a national basis, additional reserve capacities beyond those the power market model would deploy based on market price signals alone would be required in the 55 % scenarios for Germany. Most of the reserve demand of the Coal-6 concentrates in Germany.







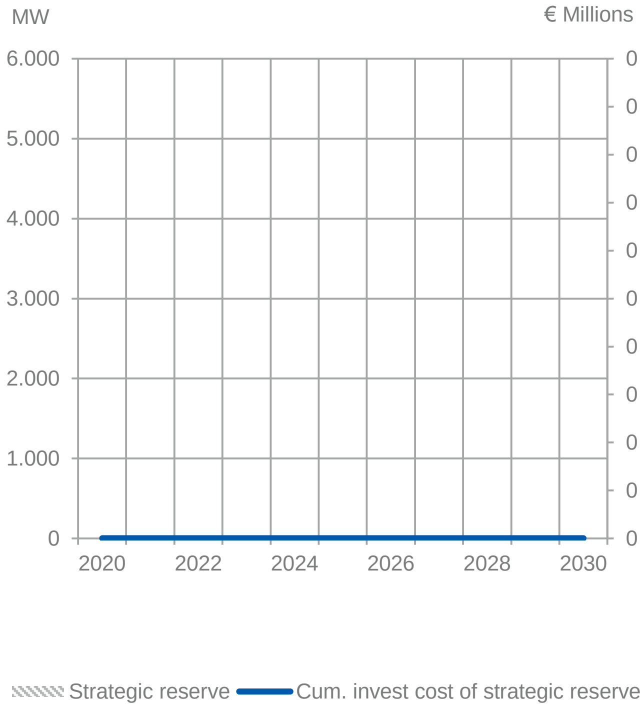
Note: No net demand for newly built strategic reserves is caused if hard coal units decommissioned in the 55% scenarios can be utilized as reserves. Hence costs depicted in this slide represent the costs of reserves if the capacity had to be provided by newly built gas units (OCGT) and hence would be lower in case decommissioned coal would be used instead.

Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

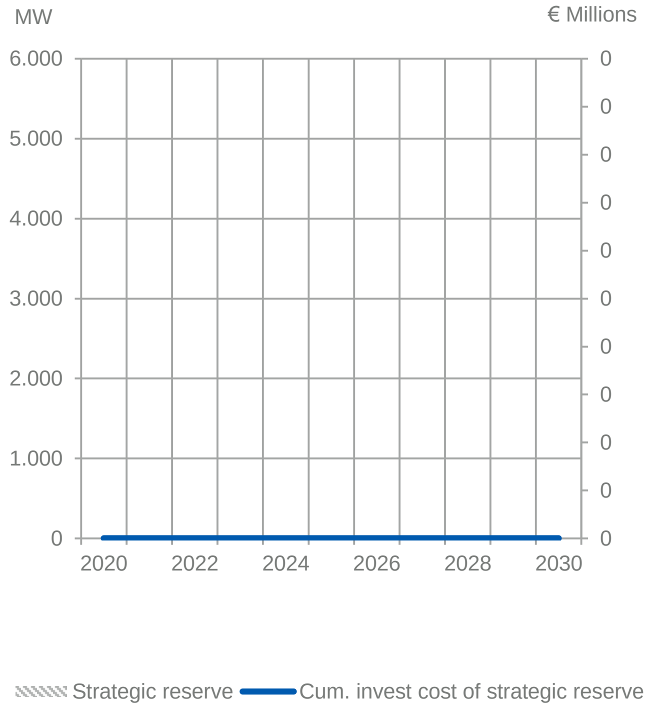
Strategic reserve deltas – PL

For Poland, in all 55 % scenarios no additional strategic reserve capacities beyond those which can be contracted from existing capacities are required to serve peak load on a national basis.

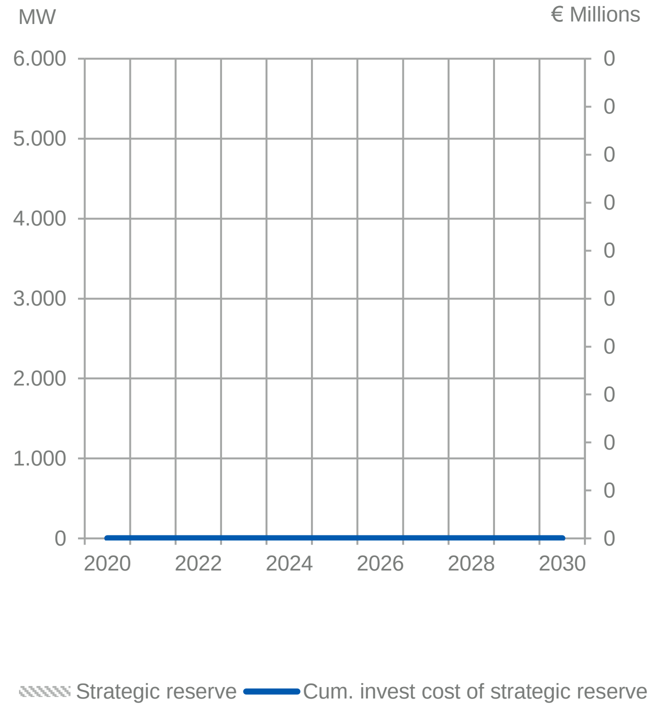
55 % PM



55 % MCE



55 % MCTC

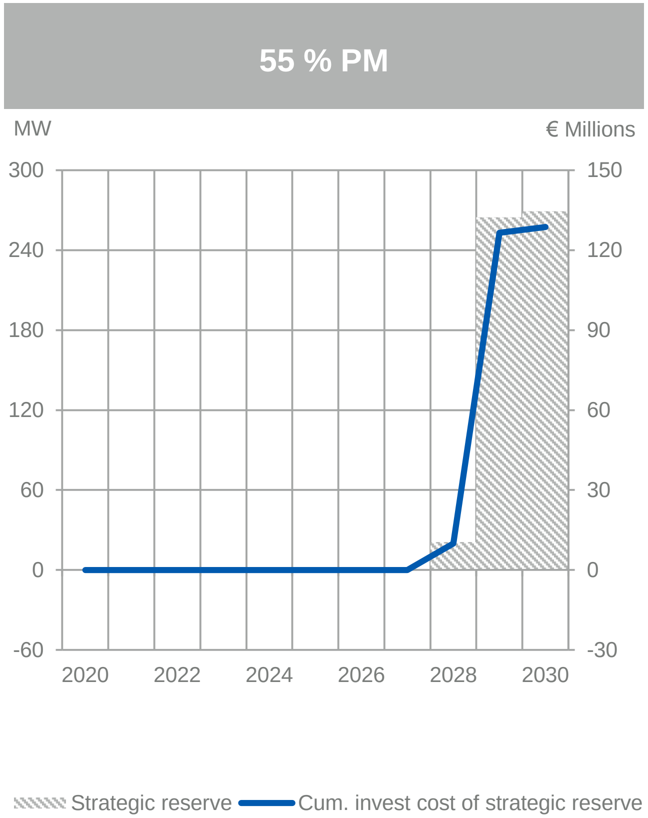


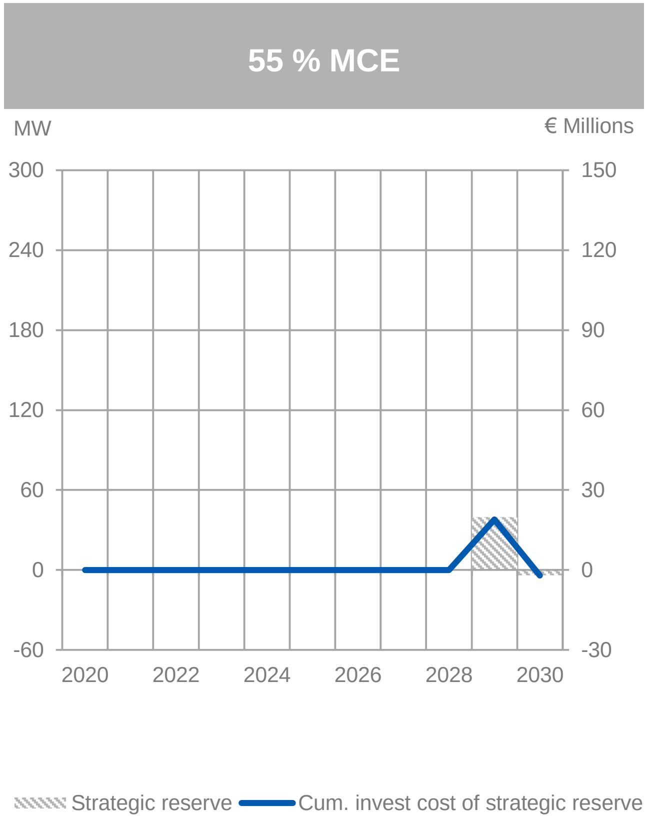
Note: No net demand for newly built strategic reserves is caused if hard coal units decommissioned in the 55% scenarios can be utilized as reserves. Hence costs depicted in this slide represent the costs of reserves if the capacity had to be provided by newly built gas units (OCGT) and hence would be lower in case decommissioned coal would be used instead.

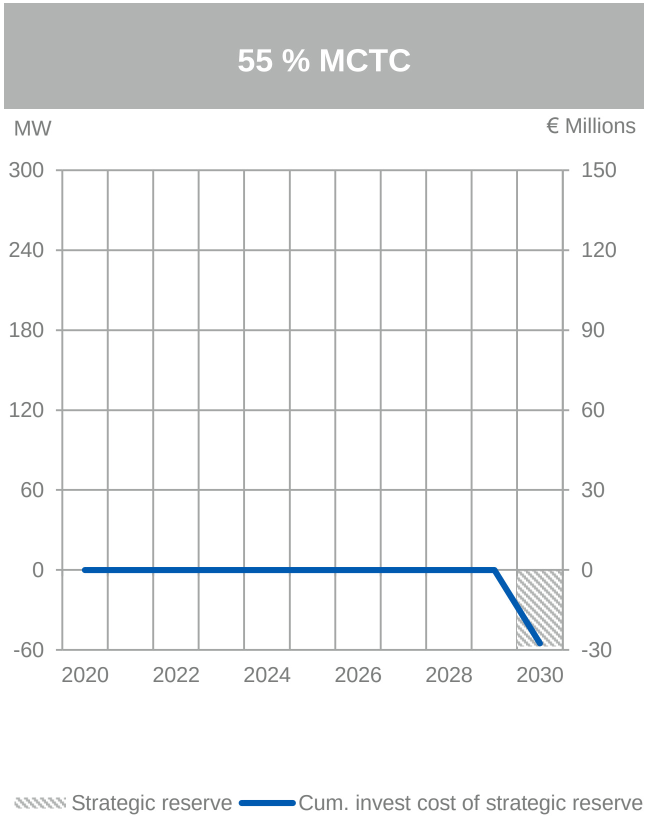
Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

Strategic reserve deltas – RO

In Romania, some additional reserve capacities beyond what the power market model would deploy based on market price signals alone would be required. The applied capacity balancing approach leads to additional „out of the market“ reserves in the in the 55 % Policy & the 55 % Market based coal exit scenario. In the 55 % Market based coal-to-clean scenario, less strategic reserve capacities are required.







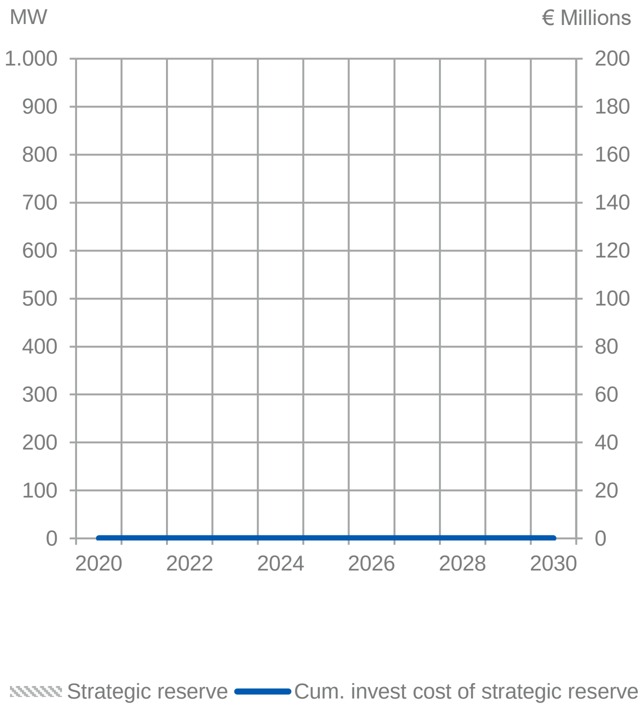
Note: No net demand for newly built strategic reserves is caused if hard coal units decommissioned in the 55% scenarios can be utilized as reserves. Hence costs depicted in this slide represent the costs of reserves if the capacity had to be provided by newly built gas units (OCGT) and hence would be lower in case decommissioned coal would be used instead.

Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

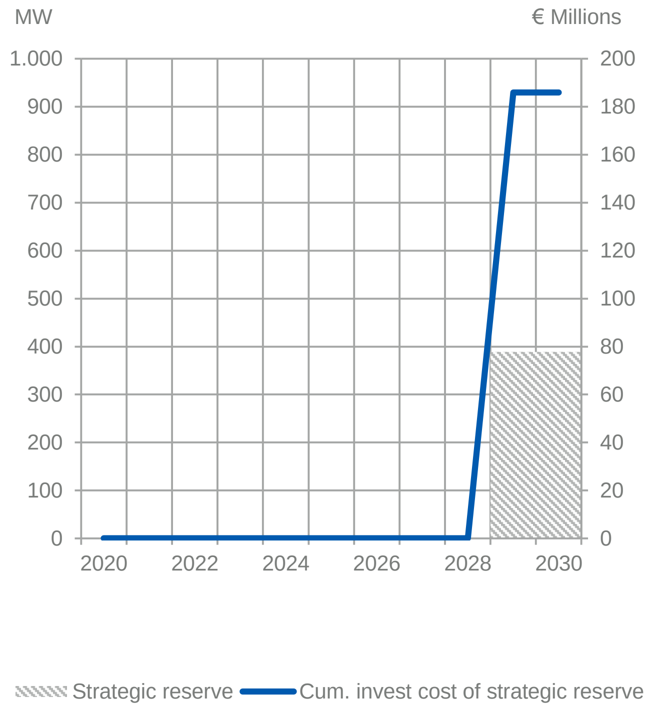
Strategic reserve deltas – SI

In Slovenia, only in the 55 % Market based coal exit scenario some additional strategic reserve capacities beyond what the power market model would deploy based on market price signals alone would be required. The applied capacity balancing approach leads to additional „out of the market“ reserves 2028 onwards.

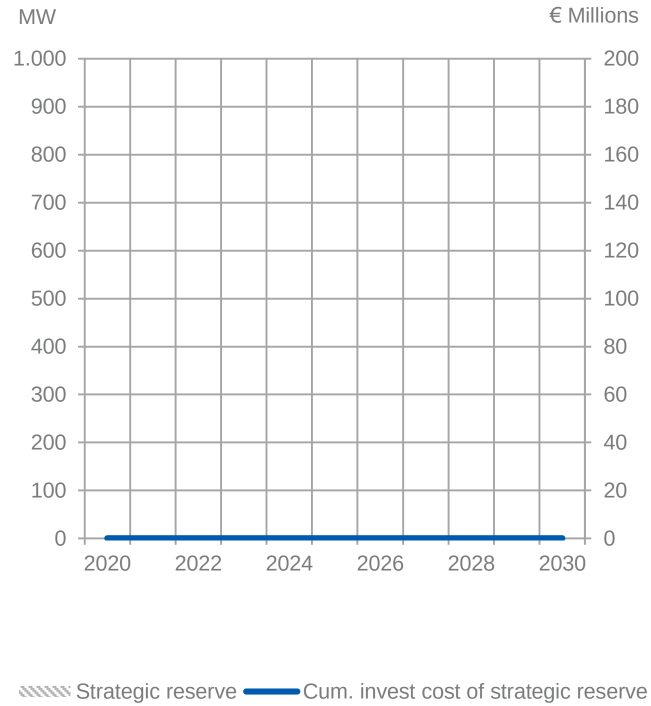
55 % PM



55 % MCE



55 % MCTC



Note: No net demand for newly built strategic reserves is caused if hard coal units decommissioned in the 55% scenarios can be utilized as reserves. Hence costs depicted in this slide represent the costs of reserves if the capacity had to be provided by newly built gas units (OCGT) and hence would be lower in case decommissioned coal would be used instead.

Note: Graphs depict scenario differences to the 40% PM scenario (e.g. 55 % PM minus 40 % PM). PM = Policy mix; MCE = Market-based coal-exit; MCTC = market-based coal-to-clean

www.enervis.de

enervis energy advisors GmbH
Schlesische Str. 29-30
10997 Berlin
Germany
Fon +49 (0)30 695175-0
Fax +49 (0)30 695175-20

E-Mail kontakt@enervis.de