COMPASS LEXECON

Presentation

Impact assessment of a 550 Emission Performance Standard in capacity mechanisms

A study commissioned by EURELECTRIC

26 September 2017

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STUDY CONTEXT AND OBJECTIVES

As part of its **proposal for a new Electricity Regulation**, the European Commission proposes to introduce an Emission Performance Standard (550 g CO2/kWh) for generation capacity participating in capacity mechanisms (CM).

Such threshold will apply to **existing plants 5 years after entry into force of the Regulation** and to **new plants immediately** at the entry into force.

In order to inform the European energy policy debate, EURELECTRIC has commissioned Compass Lexecon to **perform an independent impact assessment of the 550 EPS in European power and capacity markets**.

Compass Lexecon has used its proprietary models to **dynamically model the evolution of the European power sector in two scenarios** :

- The ***Reference scenario*** assumes that all countries modelled have a market-based and market-wide capacity mechanism targeting a 3 hours Loss of Load expectation, to reflect the nature of the legislative proposal.
- The ***550 EPS scenario*** assumes that in all countries an Emission Performance Standard (550 g CO2/kWh) is added to the capacity markets defined in the reference scenario.

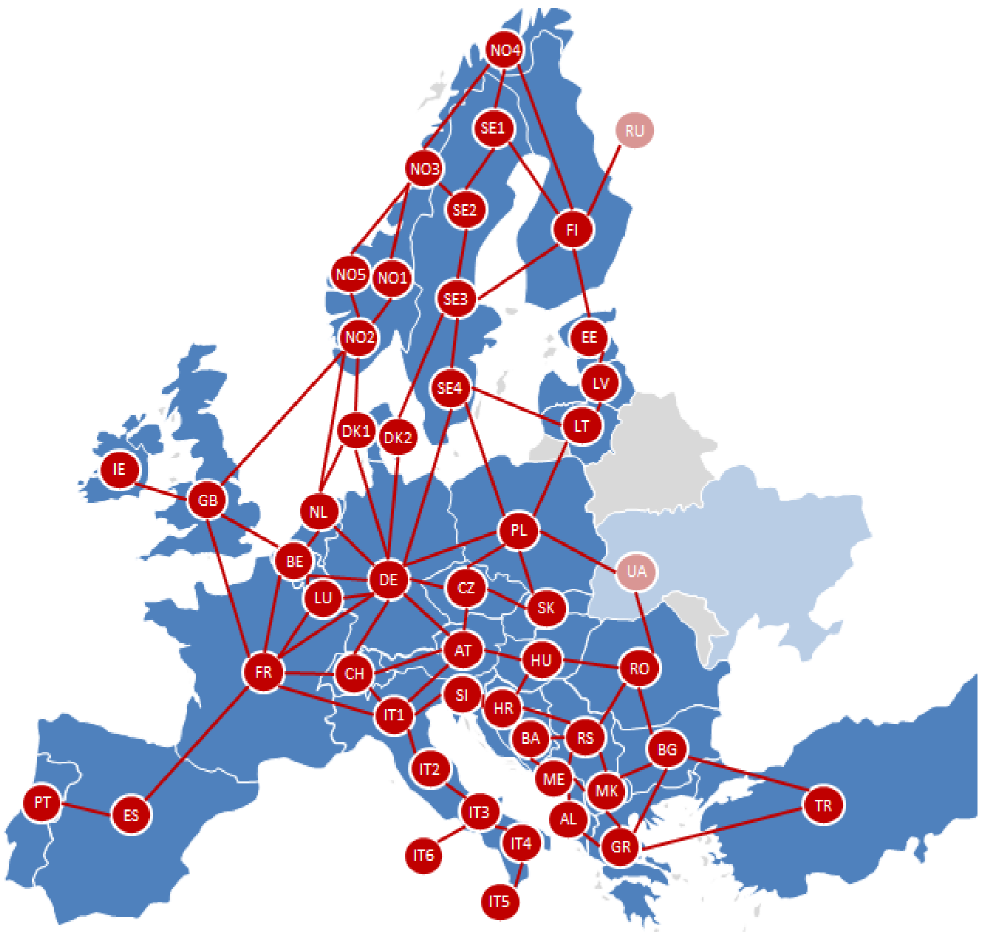
This is an independent study conducted by Compass-Lexecon commissioned by EURELECTRIC. The assumptions and results do not necessarily represent the views of EURELECTRIC's individual members.

MODELLING APPROACH FOR THE IMPACT ASSESSMENT

Modelling approach

- We model all capacity connected to the European power system by technology, age and vintage
- The assumptions (power demand, initial capacity mix, commodity prices, interconnection) are based on a set of public sources: ENTSOE databases and scenarios and the International Energy Agency commodity outlooks
- We simulate plant revenues from both the energy and capacity markets
- The Net Present Value for each power plant determines plant additions / retirements each year and the dynamic evolution of the generation mix over 2020-2040
- The optimisation process assumes perfect foresight from all market participants

Modelling geographic scope



The study results are reported for two regions: Western Europe (Austria, Belgium, Denmark, France, Germany, Italy, Luxemburg, the Netherlands, Portugal, and Spain) and Eastern Europe (Bulgaria, Croatia, Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia)

THE REFERENCE SCENARIO MEETS THE EU RENEWABLES AND CO2 EMISSIONS REDUCTION OBJECTIVES

Environmental objectives

- 49% penetration of RES in electricity in 2030, in line with EU RES objectives
- On track with 2050 CO2 emission reduction trajectory

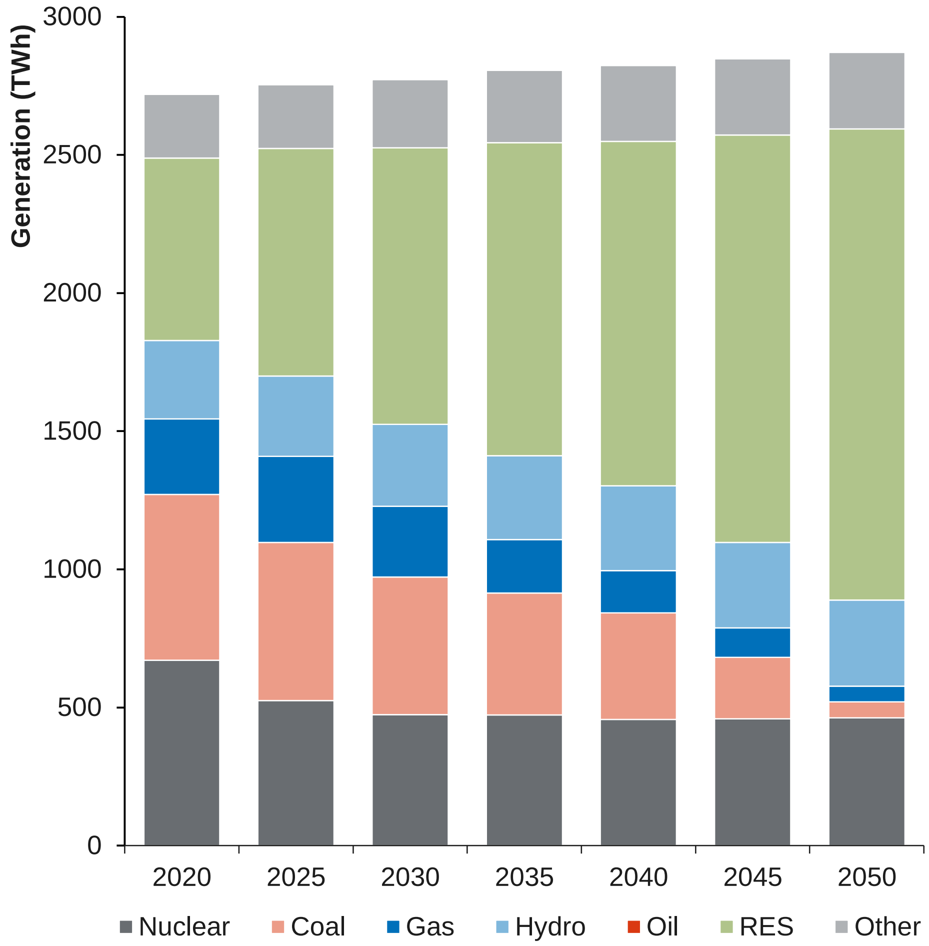
Thermal generation:

- Decrease of thermal generation share to 4% by 2050, delivering a close to carbon neutral power supply
- According to IEA fuel and CO2 prices assumptions coal remains cheaper than gas to generate electricity until 2040

Resulting capacity outlook:

- Thermal plant closure: 102GW of which 88GW baseload and 14GW peaking capacity
- Replaced by more flexible plants …
  - 38GW additional new thermal base capacity
  - 60GW additional new peaking capacity (23 GW battery, 13GW DSR, 24 GW thermal)
- … and 275GW new RES over 2020- 2040 reaching a total of 565GW in 2040

Reference scenario generation outlook including DSR and battery



Note: Other includes small distributed thermal non-renewable generation. RES includes wind, solar, biomass and small distributed renewable generation

THE REFERENCE SCENARIO SEES A KEY ROLE FOR DEMAND RESPONSE AND BATTERIES FROM 2030 ONWARDS

New technologies take up

- DSR continues to grow throughout the modelling horizon;
- Batteries become competitive in the late 20s, with a material roll-out in the 30s.

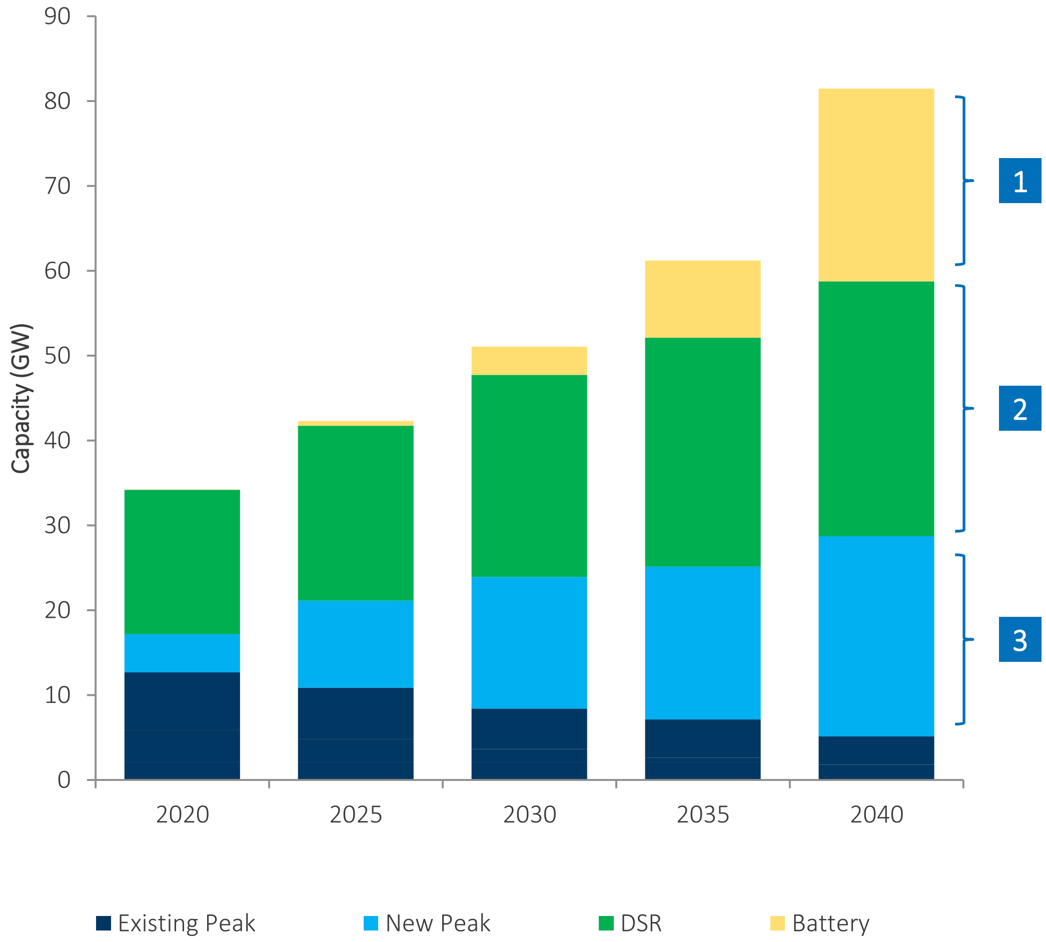
Installed peaking capacity in 2040

1 Batteries: 23GW

2 DSR: 30GW

3 New thermal peaking capacity: 24GW

Reference peaking capacity EU wide, 2020 - 2040

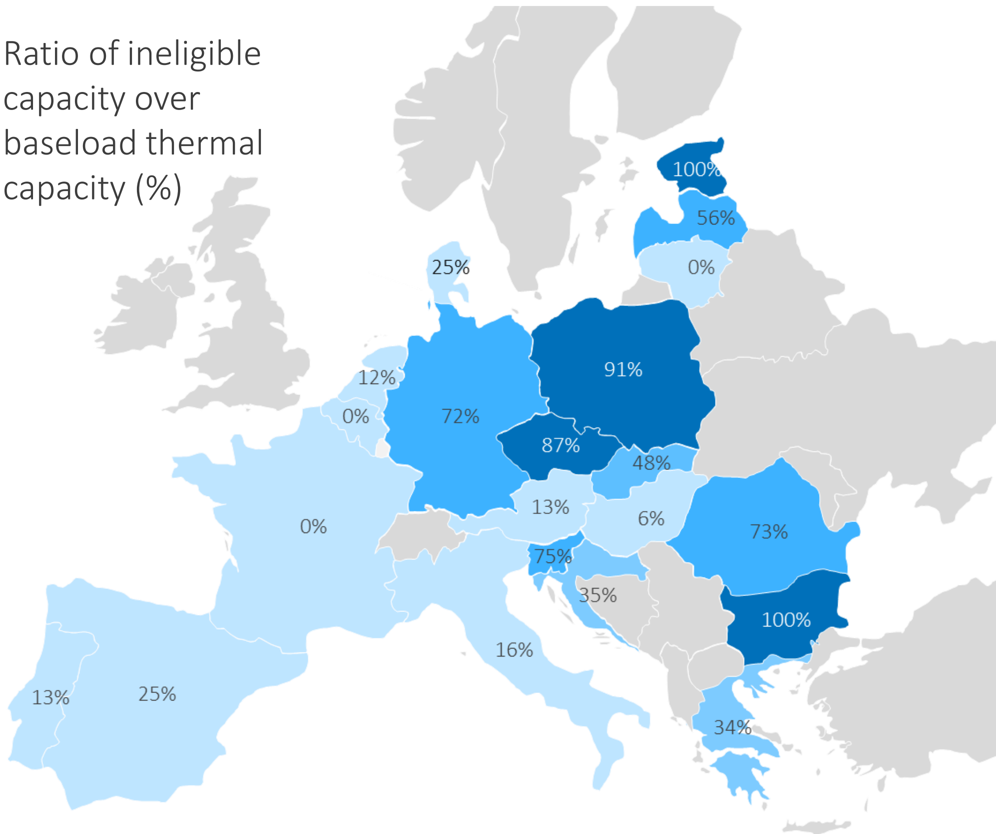


Note: (1) New technology roll out depends on CAPEX assumptions. More / less aggressive battery cost reduction would lead to earlier / later battery roll out.

THE 550 EPS SCENARIO IMPACTS HEAVILY BASELOAD THERMAL CAPACITY IN EASTERN EUROPE AND GERMANY AND ALMOST ALL THERMAL PEAKING PLANTS

Uneven 550 EPS impact on thermal baseload plants

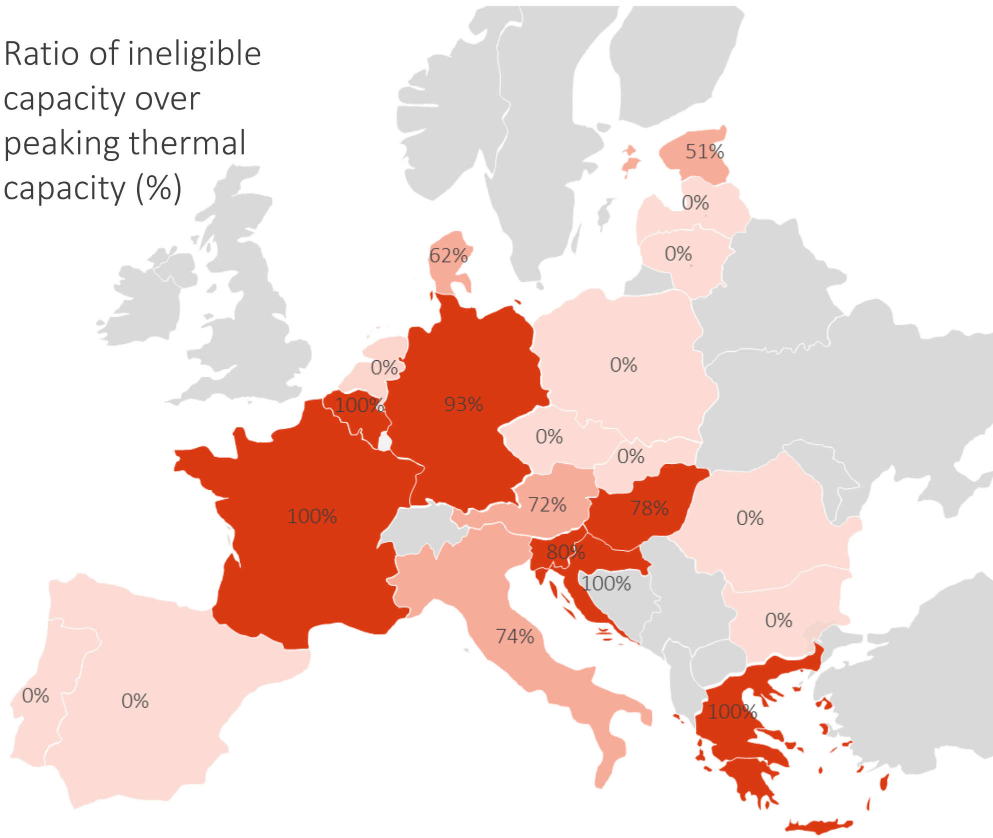
Ratio of ineligible capacity over baseload thermal capacity (%)



- 24% of baseload thermal capacity in Western Europe is ineligible for capacity payments (ranging from 0% in France to 72% in Germany)
- 41% of baseload thermal capacity in Eastern Europe is ineligible in the 550 EPS scenario (91% in Poland)

550 EPS impacts almost all thermal peaking plants

Ratio of ineligible capacity over peaking thermal capacity (%)



- 12.6GW of peaking thermal capacity in Western Europe is ineligible for capacity payments
- 2.5GW of peaking thermal capacity in Eastern Europe is ineligible for capacity payments

Note: Baseload capacity includes CCGT, coal and lignite plants and excludes nuclear plants; Thermal peaking capacity includes OCGT, and oil plants
Eligibility is based on nameplate power production efficiency and excludes heat for CHP (cf. appendix slide 19)

THE 550 EPS WOULD LEAD TO 19GW OF ADDITIONAL THERMAL BASELOAD WHICH MAY BECOME STRANDED ASSETS

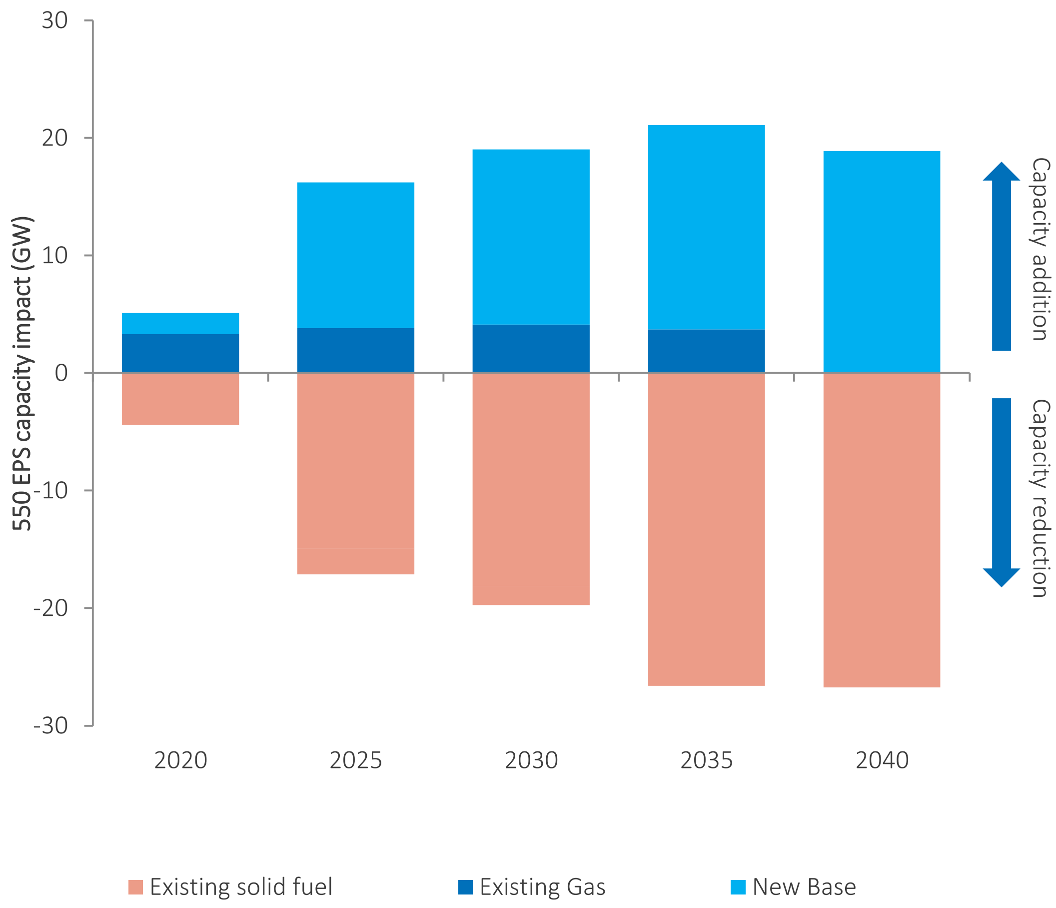
- Baseload plants are p**artially replaced by new peaking capacity** as load factor decreases with increasing RES penetration.

- 550 EPS would lead **to a total of 19GW** (12 GW in 2025) **additional new thermal baseload capacity** to replace the **27 GW of existing plants early closure decision**.

- This would require **€15 billion** *(real 2016)* **additional investments**.

- These new plants have a technical lifetime of 30 years, but to deliver on the power sectors' decarbonisation objectives, their contribution would have to be limited in time. **These plants would therefore likely become stranded assets**

Baseload capacity in 550 EPS compared to reference scenario: Cumulative impact 2020 - 2040



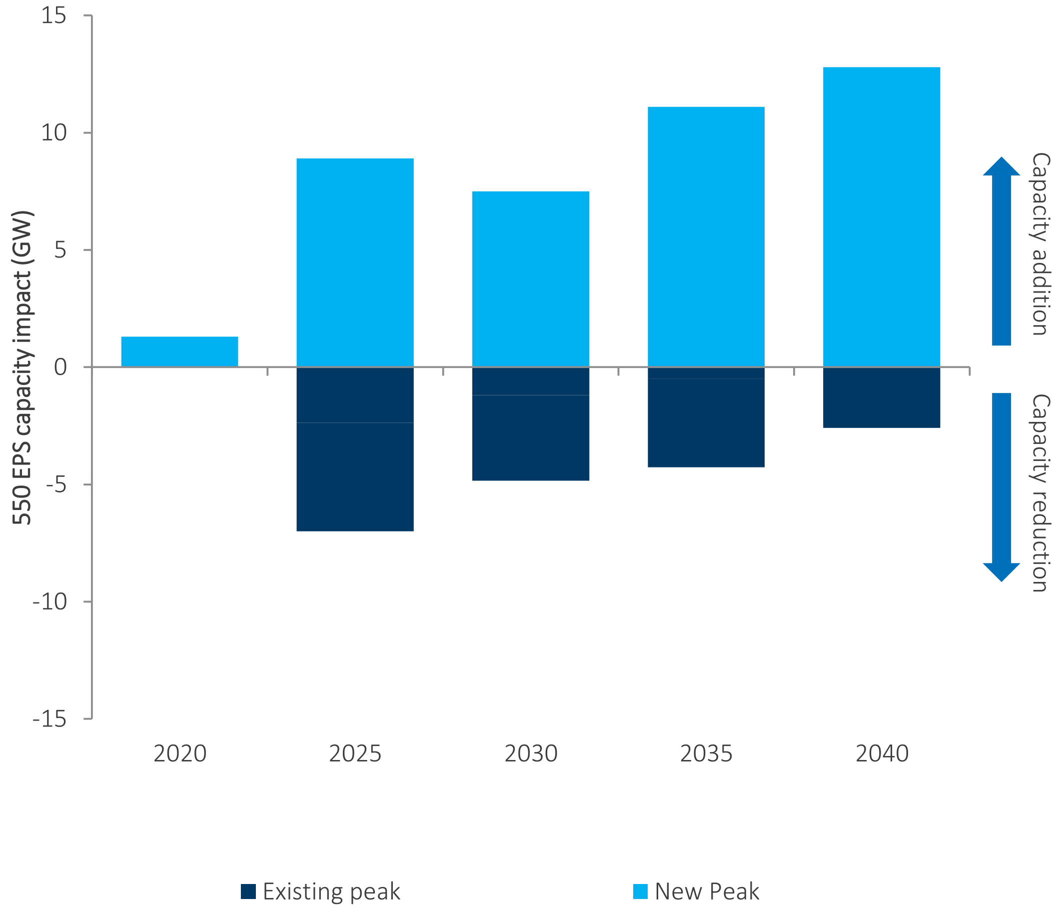
THE 550 EPS WOULD LOCK-IN 9GW OF NEW THERMAL PEAKING CAPACITY BY 2025, ON THE EVE OF BATTERIES AND DSR LARGE-SCALE DEPLOYMENT

- The 550 EPS would lead to a total of **13GW** (9 GW in 2025) **additional new thermal peaking capacity** to replace the existing thermal peaking and baseload capacity.

- By bringing forward the need of new peaking capacity in 2025 compared to the reference scenario, **the 550 EPS would risk locking-in new thermal peaking capacity.**

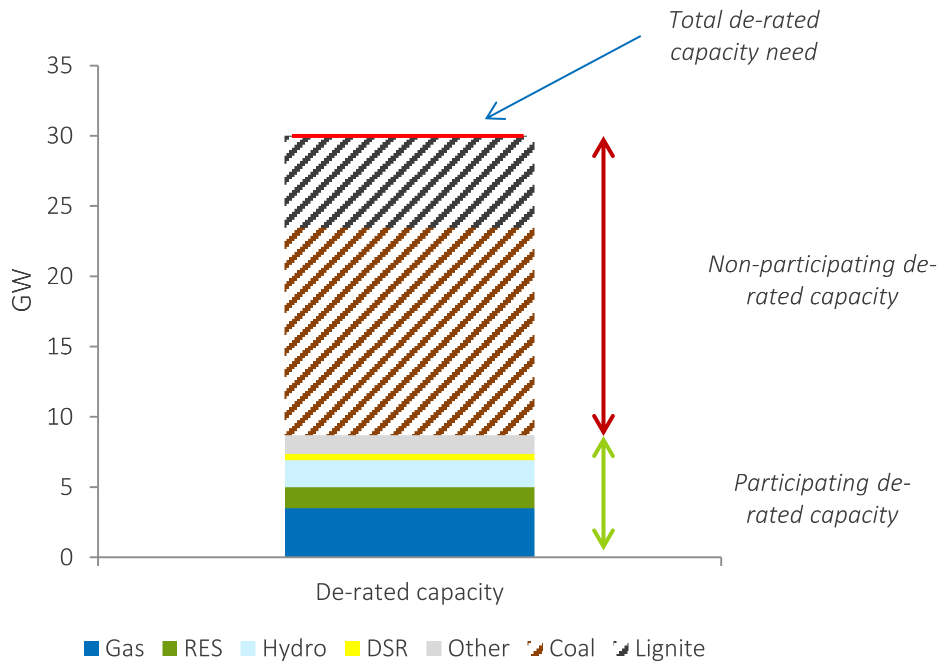
- The additional thermal peaking plants built in 2025 (**€4.5 billion investment,** *real 2016*) **would risk to be stranded** as **batteries and other flexibility sources would become more competitive post 2025**.

Peaking capacity in 550 EPS compared to reference scenario: Cumulative impact 2020 - 2040



THE 550 EPS WOULD LEAD TO SIGNIFICANT UNCERTAINTY ON AVAILABLE CAPACITIES THUS CREATING ADDITIONAL RISKS FOR MARKET PLAYERS

Theoretical case study: Capacity mix with high share of capacities emitting more than 550gCO2/kWh



- **The 550 EPS would create significant uncertainties on the availability of generation capacities.**

In this simple example:

- Need for de-rated capacity of 30 GW to ensure security of supply
- 21 GW cannot participate in the capacity market
- If these ineligible capacities are economic and remain in the system, only 9 GW needs to be procured in the capacity market
- However, it is uncertain whether these ineligible capacities might close as they cannot be contracted in the capacity market
- **These uncertainties may create additional risks for market players and lead to additional costs**

THE 550 EPS WOULD INCREASE ENERGY COST BY €73 BILLION OVER 2020-2040

- By replacing cheap solid fuel generation by more expensive gas-fired generation, the 550 EPS would increase the frequency of gas-fired power plants setting the price, leading to an increase of energy cost.

Additional energy cost in the 550 EPS scenario over the reference scenario	**2020 - 2040**
Western Europe	€53 billion (*real 2016*)
Eastern Europe	€20 billion (*real 2016*)

- The additional energy cost would hamper the competitiveness of electricity versus other energies and could slow down electrification of transport and heating &cooling which is necessary to decarbonize the European economy.

CAPACITY MARKET REVENUES FOR NEW PLANTS IN THE 550 EPS WOULD INCREASE BY AT LEAST €35 BILLION

The 550 EPS would impact capacity costs through:

Capacity price impact:

- The 550 EPS would increase the average capacity price by around **2€/kW in Western Europe** as only a small proportion of the mix is impacted and **4€/kW in Eastern Europe** with significant variation between countries depending on the need for new investment.

Capacity cost impacts:

- In the 550 EPS, **32GW additional new investments** are needed to ensure security of supply:
  - Capacity market revenues for new plants would increase by **€35 billion (real 2016) over 2020-2040** compared to the reference scenario.

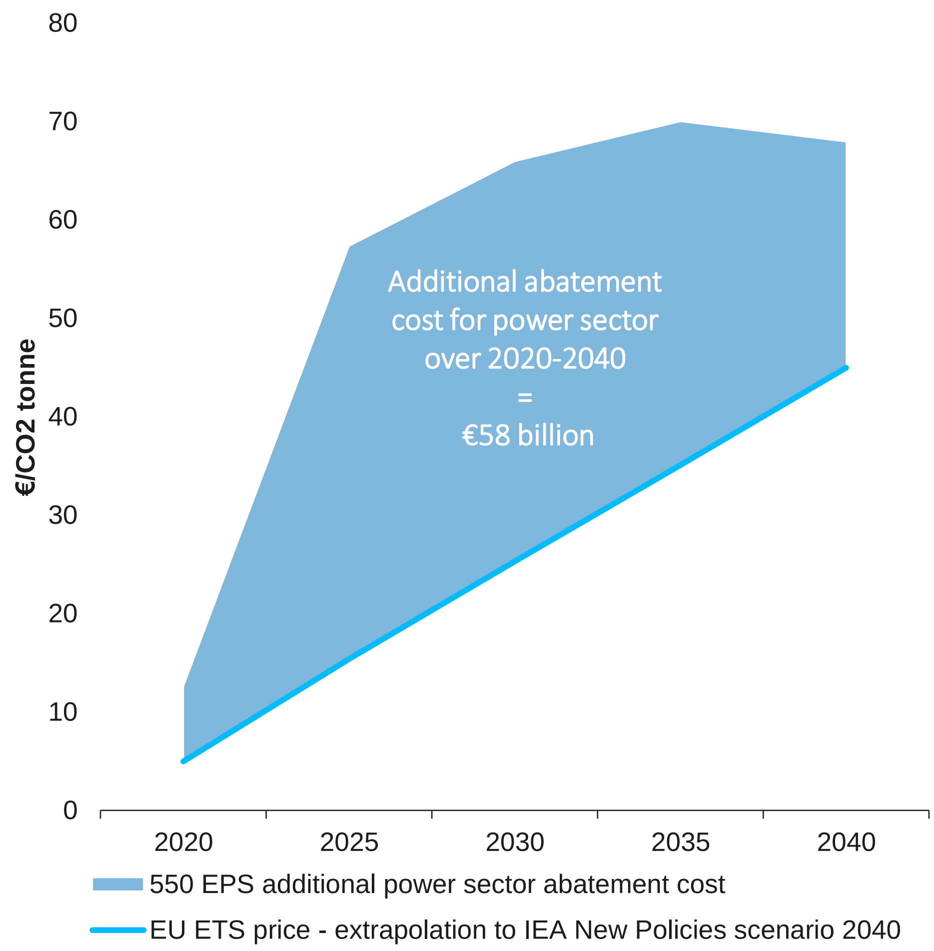
- 550 EPS would introduce significant uncertainty and lead to **2 types of volume effects** on the capacity market:
  - On the one hand **existing ineligible plants will not receive capacity market revenues** which would have a downwards effect on the total capacity costs.
  - On the other hand **implementation issues** associated with the difficulties to anticipate ineligible plants' decisions to stay or retire could lead to additional new capacity being contracted in the capacity market triggering increased costs.

THE 550 EPS WOULD LEAD TO €58 BILLION OF ADDITIONAL CO2 ABATEMENT COST

- The 550 EPS would not achieve its policy objective of supporting decarbonisation as **total EU CO2 emissions covered by the ETS cap would remain unchanged.**
  - In addition, increased energy cost could hamper electrification leading to less CO2 emission reduction in transport, heating and other sectors.
- The additional power sector CO2 emission reductions in the 550 EPS come at an **abatement cost higher than the ETS carbon price.**
- The 550 EPS leads to **socially inefficient emission abatement** as more emission reductions could be achieved for the same cost.
- **The 550 EPS overlaps with the EU ETS would likely undermine the ETS** as prime driver of the EU's decarbonisation.
- The **complexity of the interference between the 550 EPS and the ETS** would be a source of ETS market uncertainty and could lead to **possible unintended consequences**

Note: Similarly to capacity cost, capacity market implementation issues introduce uncertainty on total additional abatement cost.

Additional CO2 abatement cost for power sector in 550 EPS over reference scenario, 2020-2040



IN 550 EPS, POWER SECTOR GAS CONSUMPTION WOULD INCREASE BY 40% RAISING CONCERNS ON GAS IMPORT DEPENDENCY

550 EPS would materially **increase the power sector gas consumption** throughout Europe:

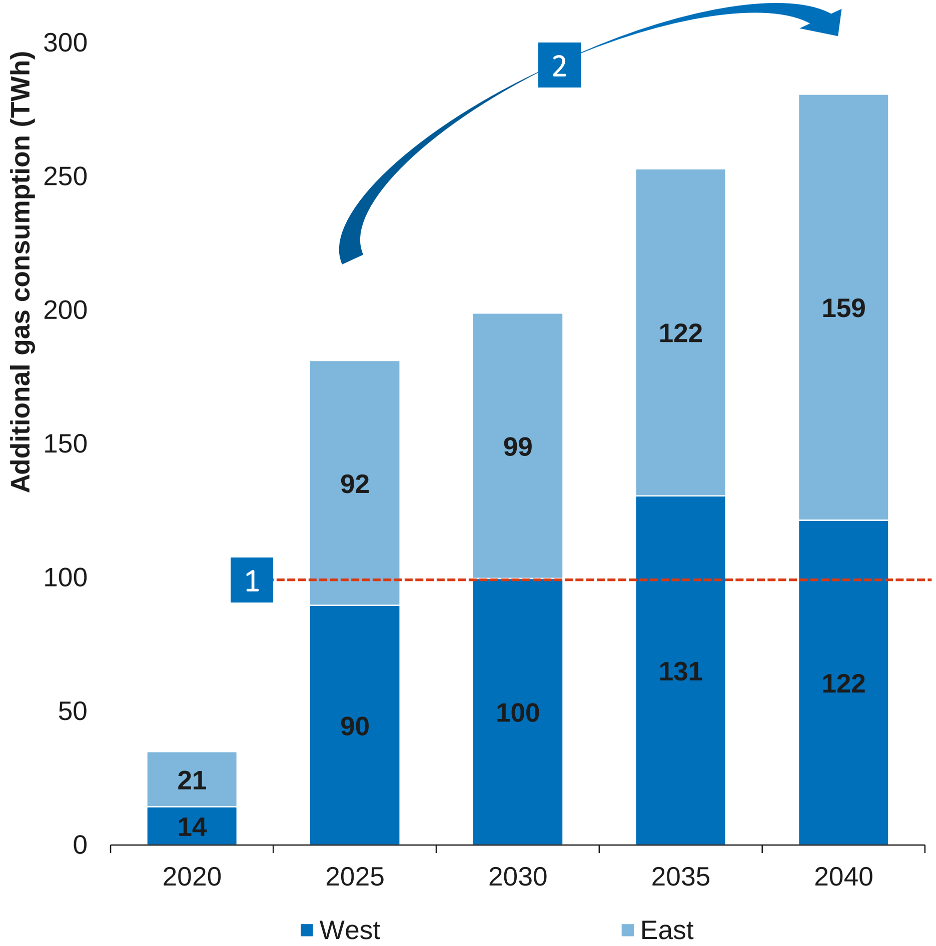
1. In Western Europe, gas consumption would **increase by c100TWh per year**, maintaining gas consumption above 400TWh until 2035.

2. In Eastern Europe, gas consumption would steadily increase **by 90TWh per year in 2025 to 160TWh per year in 2040**.
   - 50% of the annual gas consumption increase in 2040 would come from Poland, putting significant constraints on its gas supply and network.

Over 2020-2040, total power generation related gas consumption would **increase by an average of 40%.**

550 EPS would lead to **significant gas infrastructure investment** requirement and raise **concerns on gas import dependency** for a number of countries.

550 EPS impact on annual power sector gas consumption compared to reference scenario over 2020-2040



SUMMARY OF KEY FINDINGS

The 550 EPS would not achieve its policy objective of supporting decarbonisation

- Total EU CO2 emissions covered by the ETS cap would remain unchanged
- But additional emission reductions compared to the reference scenario would come at an average premium of €32/tonne CO2 on top of the ETS price, representing a total additional cost of €58 billion (*real 2016*) over the outlook.
- 9GW of new thermal peaking capacity would be locked in, on the eve of batteries and DSR large- scale deployment

The 550 EPS would increase customer cost by €108 billion (*real 2016*) over the period 2020-2040

- Energy cost would increase by €73 billion over 2020-2040 and new plants' capacity market revenues by at least €35 billion (*real 2016*)
- In addition, €20 billion *(real 2016)* of investments in new thermal plants risk being stranded
- Overall, these additional costs would hamper the competitiveness of electricity and slow down electrification

The 550 EPS would create additional risks on security of supply and increase gas import dependency

- The risk that ineligible plants would retire would create significant uncertainty on how to ensure security of supply leading to additional risks for market players
- Significant increase of gas consumption and gas import dependency in some countries

Further studies could shed light on critical unaddressed aspects of the Commission's proposal

- In practice, how does the EC propose to implement the 550 EPS?
- What is the rationale of the proposed implementation dates?
- Why is the approach uniform at the EU level when the impact is strongly differentiated across regions and member states?

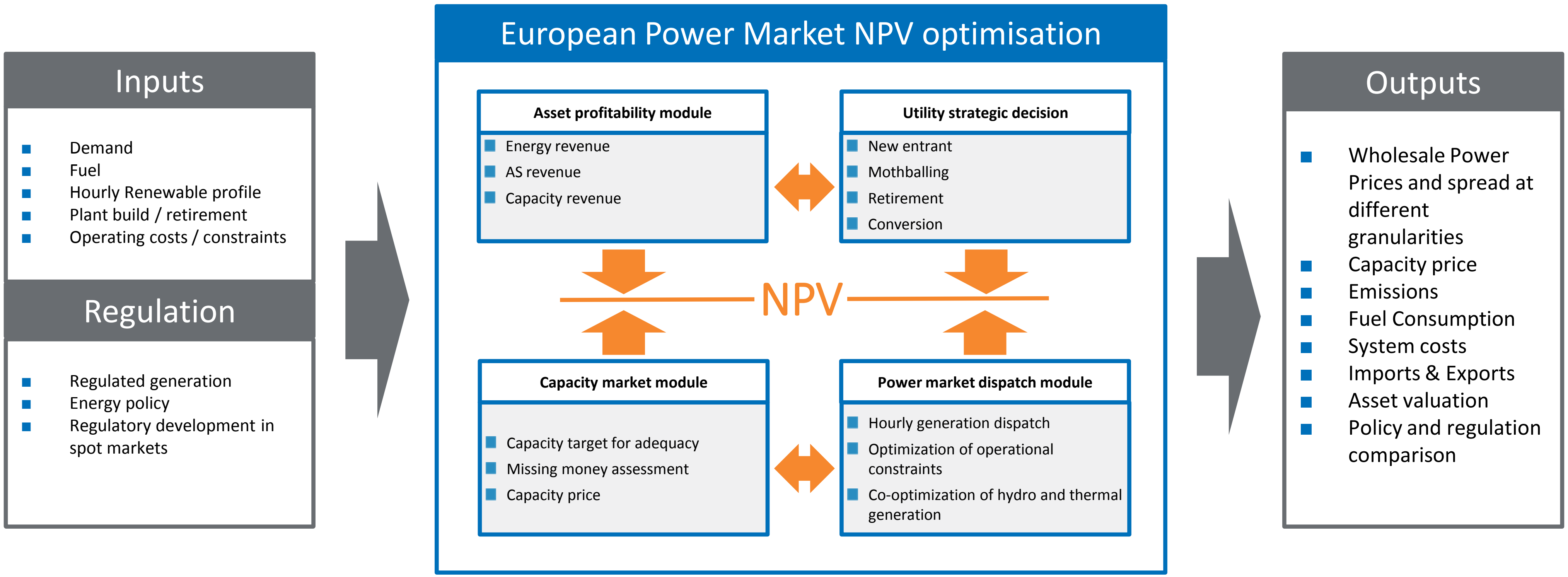
Appendix - Key modelling assumptions

CL'S MODELS DYNAMICALLY MODEL THE EVOLUTION OF THE GENERATION MIX

Overview of CL's NPV optimization for plant additions and decommissioning

- The future power markets installed capacity mix is optimized based on a NPV calculation of expected revenues and costs throughout the modelling horizon.
- Therefore, decisions to retire, mothball or invest depend on the expectation of future revenues and costs over the next years.
- This NPV methodology enables to dynamically build the optimal future capacity mix.

CL's modelling approach (input, modules and output)



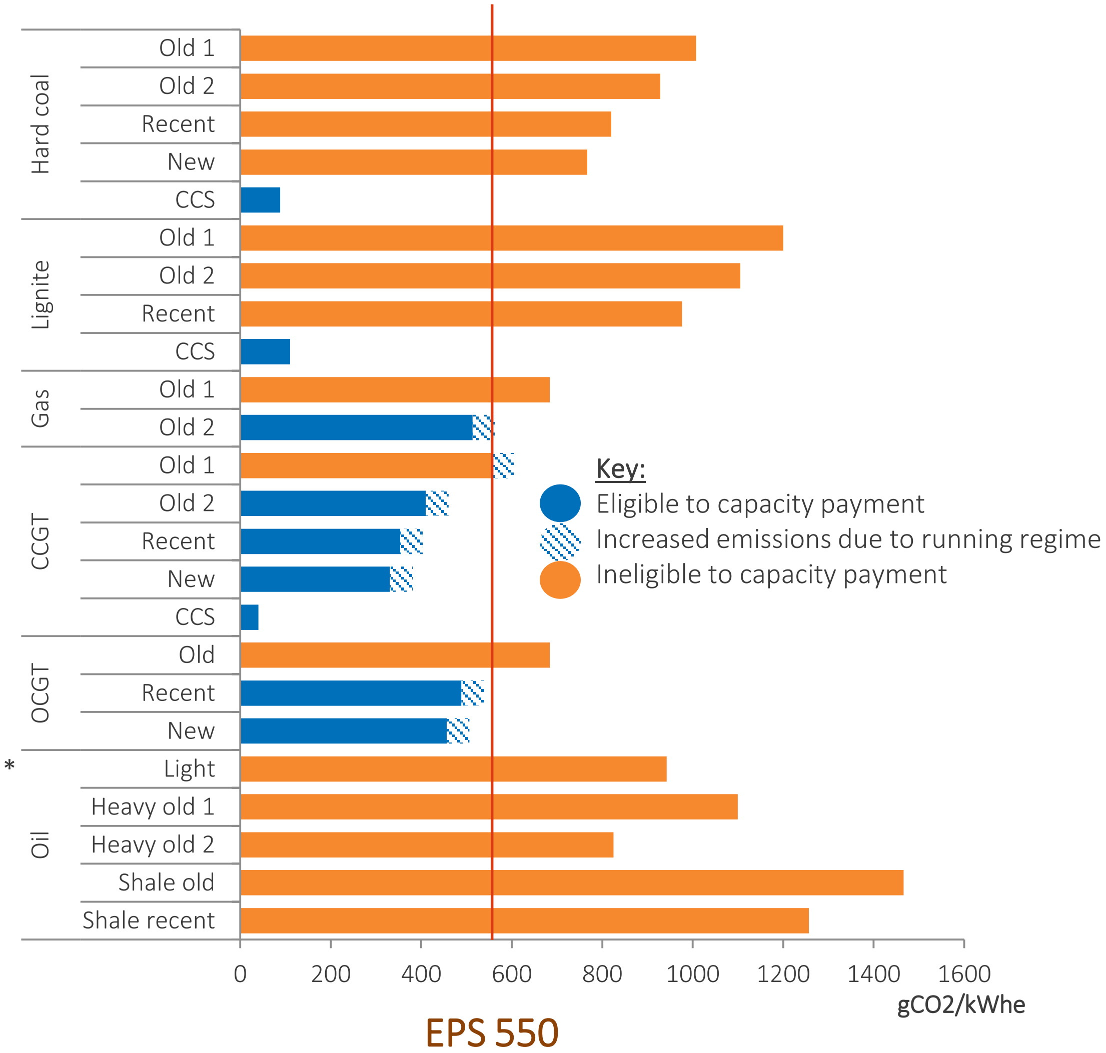
THE REFERENCE SCENARIO IS BASED ON THE LATEST ANNOUNCEMENTS FROM TSOS, REGULATORS AND MARKET PLAYERS

Key power price driver	Sources
Demand	
Power demand	■ Latest TSOs' reference scenario outlooks ■ ENTSO-E MAF 2016 Expected progress scenario (2020,2025) ■ Median long-term Vision 2 & 3 of ENTSOE TYNDP 2016
Supply	
RES capacity	■ Latest RES National plans ■ Meet EU objective of 49% RES-E penetration share by 2030
Nuclear capacity	■ Latest National plans on phase-down or phase-out ■ Latest announcement on plants' life extension and new projects ■ Compass Lexecon best estimates where national plans are not finalized
Thermal capacity	■ Latest announcements from operators and National plans on phase-out or conversion to biomass ■ Latest announcement on refurbishment and new projects in the short-term ■ Dynamically optimised in the longer term based on NPV of anticipated costs and revenues
Commodity prices	
Gas NBP	■ Forwards until 2020, converge to IEA WEO 2016 New Policy by 2040
Coal ARA CIF	■ Forwards until 2021, converge to IEA WEO 2016 New Policy by 2040
CO2 EUA	■ Forwards until 2021, converge to IEA WEO 2016 New Policy by 2040
Interconnections	
Interconnection	■ ENTSO-E MAF 2016 outlook for new interconnections and existing interconnections' reinforcement

Note: (1) MAF: Medium term adequacy forecast; (2) TYNDP: Ten Years Network Development Plan; (3) WEO: International Energy Agency World Energy Outlook

550 EPS IMPACT ON CAPACITY – SIGNIFICANT UNCERTAINTY ON THE DEFINITION OF ELIGIBLE UNITS

CO2 emissions per technology subtypes



* Light oil includes turbines burning a majority of oil derivative fuels versus gas derivative fuels.

CO2 emissions calculation

- The CO2 emissions per technology subtypes is calculated as follow:

$$CO2\ emission = \frac{Fuel\ CO2\ content}{Average\ efficiency}$$

- As shown on the chart, an Emission Performance Standard of 550 gCO2/kWhe would impact:
  - **Baseload plants:**
    - All coal-fired plants;
    - All lignite-fired plants; and
    - Old CCGTs and boilers characterized by low efficiencies
  - **Peaking plants:**
    - All oil-fired plants; and
    - Old OCGTs characterized by low efficiencies

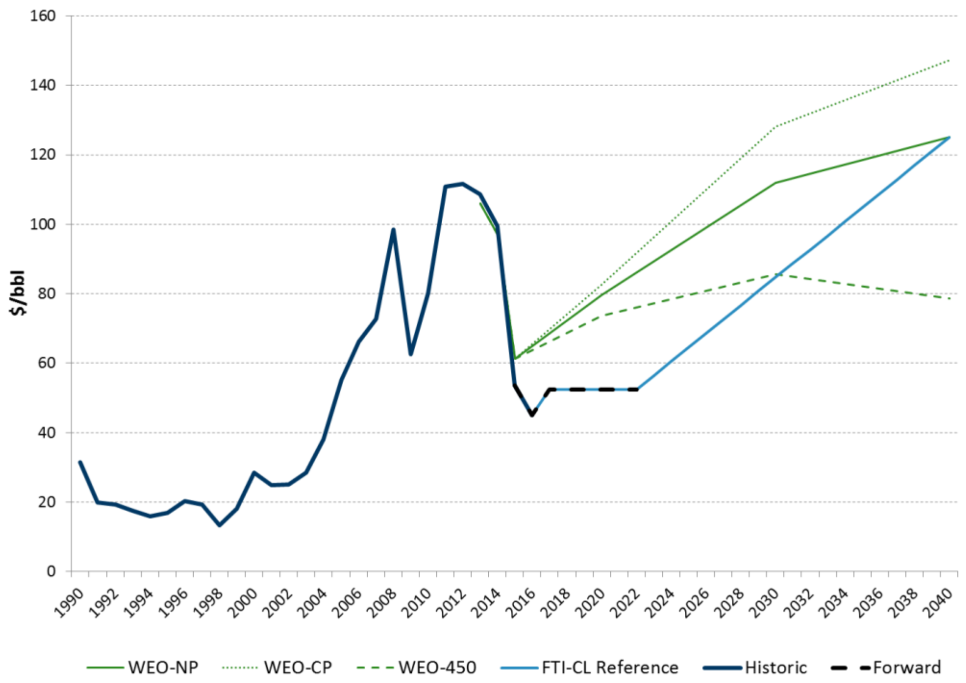
Comment: Using the nameplate efficiency is a conservative metric regarding real CO2 emissions, as the running regime and size of the plant could have a negative effect on the operational efficiency, and materially increase the CO2 emissions per KWhe.

Note: As shown on the chart, the running regime could impact the plants eligibility.

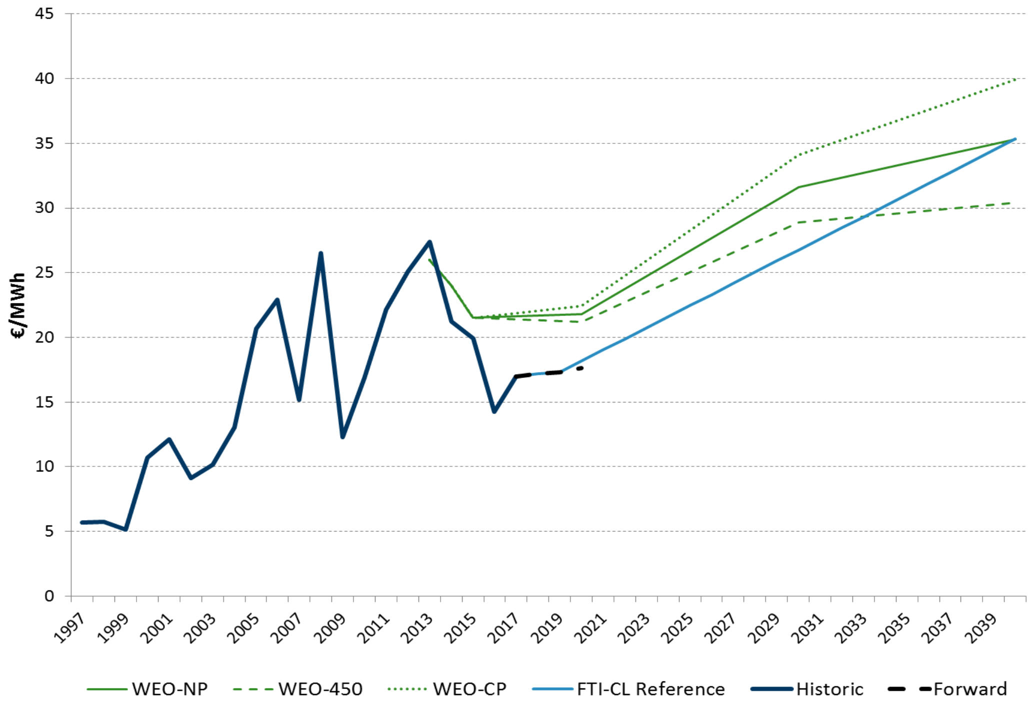
For CHP plants, including the heat production in the definition of eligibility threshold would result in having most CHP plants eligible.

OUR OIL AND GAS PRICE OUTLOOKS ARE BASED ON THE IEA PROJECTIONS

Brent crude oil outlook to 2040, real 2016



Gas NPB outlook to 2040, real 2016

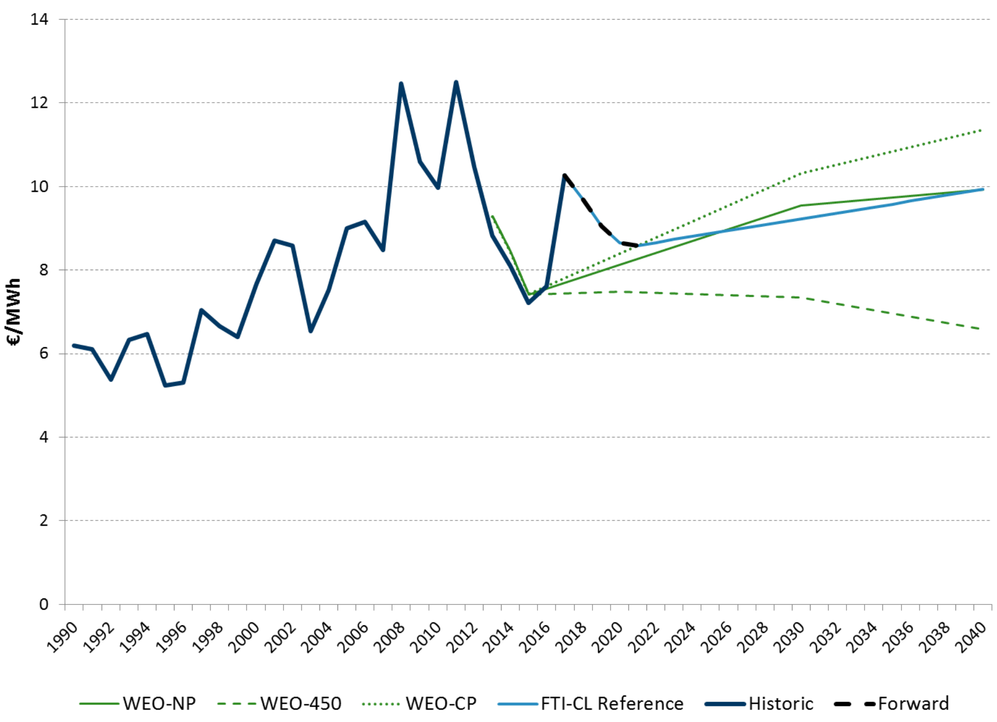


We rely on an external source (IEA WEO) as reference assumption which is used as well in the EC 2016 scenarios and ENTSOE scenarios: our outlooks use the latest forward prices until 2020 and converge towards IEA WEO New Policy scenario by 2040.

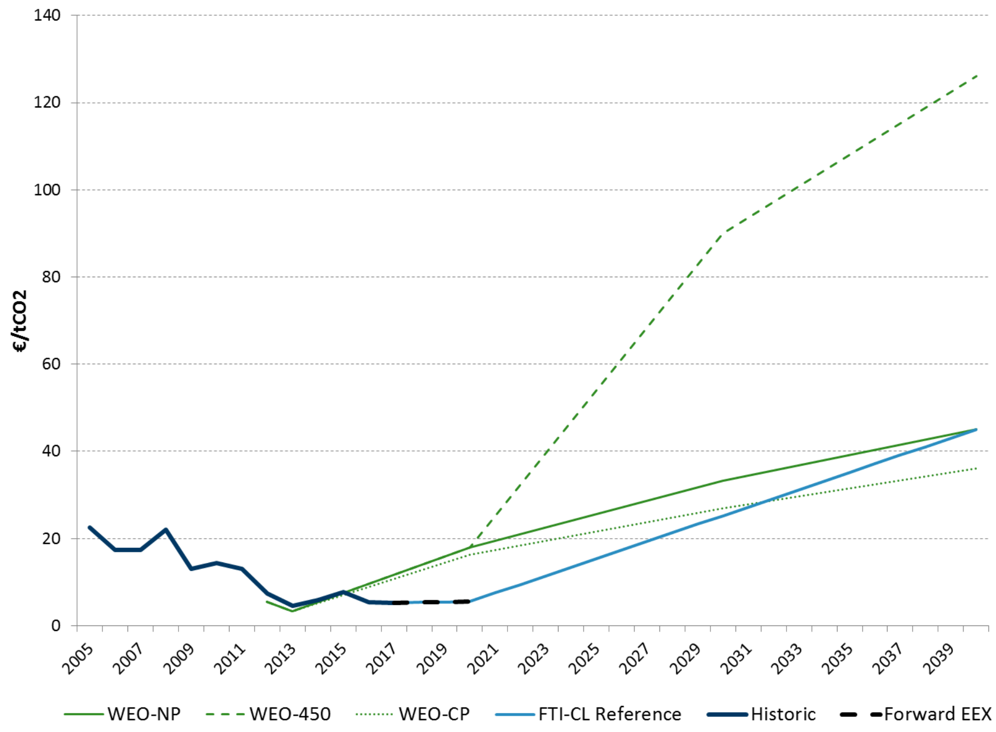
Source: FTI-CL Energy based on Bloomberg and IEA World Energy Outlook

OUR COAL AND CO2 ETS PRICE OUTLOOKS ARE BASED ON THE IEA PROJECTIONS

Coal ARA CIF outlook to 2040, real 2016



CO2 EU ETS outlook to 2040, real 2016

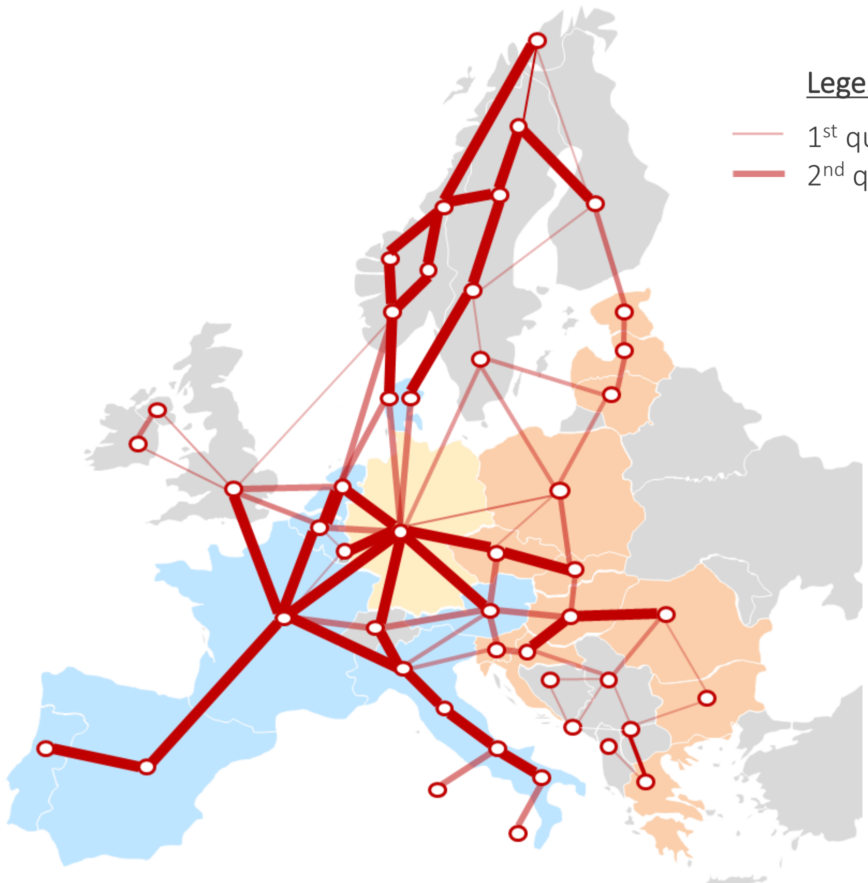


We rely on an external source (IEA WEO) as reference assumption which is used as well in the EC 2016 scenarios and ENTSOE scenarios: our outlooks use the latest forward prices until 2020 and converge towards IEA WEO New Policy scenario by 2040.

THE EU TRANSMISSION NETWORK DEVELOPMENT IS ASSUMED TO FOLLOW ENTSOE MAF AND TYNDP 2016 SCENARIOS

- The European transmission network assumptions including Net Transfer Capacity and new project commissioning date are based on ENTSOE MAF and TYNDP 2016. The network development is in line with the 10% import capacity EU target.

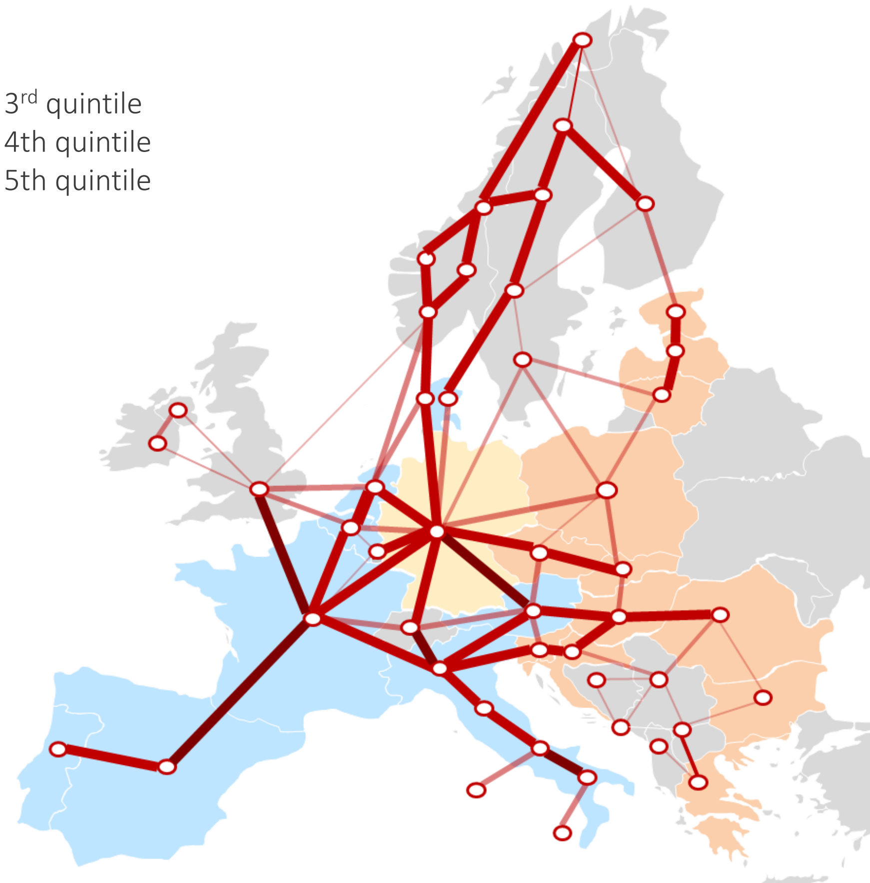
EU transmission network - 2020



Legend:

1st quintile
2nd quintile
3rd quintile
4th quintile
5th quintile

EU transmission network - 2030



SHORT AND LONG TERM PRODUCTION COST ASSUMPTIONS ARE BASED ON ENTSOE DATA, DIW AND INDUSTRY SOURCES

	Short term production assumption			Long term production assumption				
	Efficiency HHV (%)	CO2 content (tCO2/MWh)	VO&M (€/MWh)	FO&M (€/kW)	Refurbishment // life extension (€/kW)	New build CAPEX (€/kW)	Lifetime (years)	WACC (%)
Hard Coal old 1	33%	0.336	3	40	200 // 100		40 + 10 + 10	9%
Hard Coal old 2	36%	0.336	3	40	200 // 100		40 + 10 + 10	9%
Hard Coal recent	41%	0.336	3	45			40 + 10 + 10	9%
New Hard coal	44%	0.336	3	45		1600	40	9%
CCGT old 1	33%	0.185	2	20			25	8%
CCGT old 2	45%	0.185	2	20			25	8%
CCGT recent	52%	0.185	2	20			25	8%
New CCGT	56%	0.185	2	20		800	25	8%
OCGT old	27%	0.185	3.5	10			25	8%
OCGT recent	38%	0.185	3.5	10			25	8%
New OCGT	41%	0.185	3.5	10		500	25	10%
DSR	N/A	N/A	500 // 1000 *			30 to 40 per year ***	N/A	10%
Battery	90%	N/A		5		240€/kWh in 2020 to 110€/kWh in 2025 **	10	10%

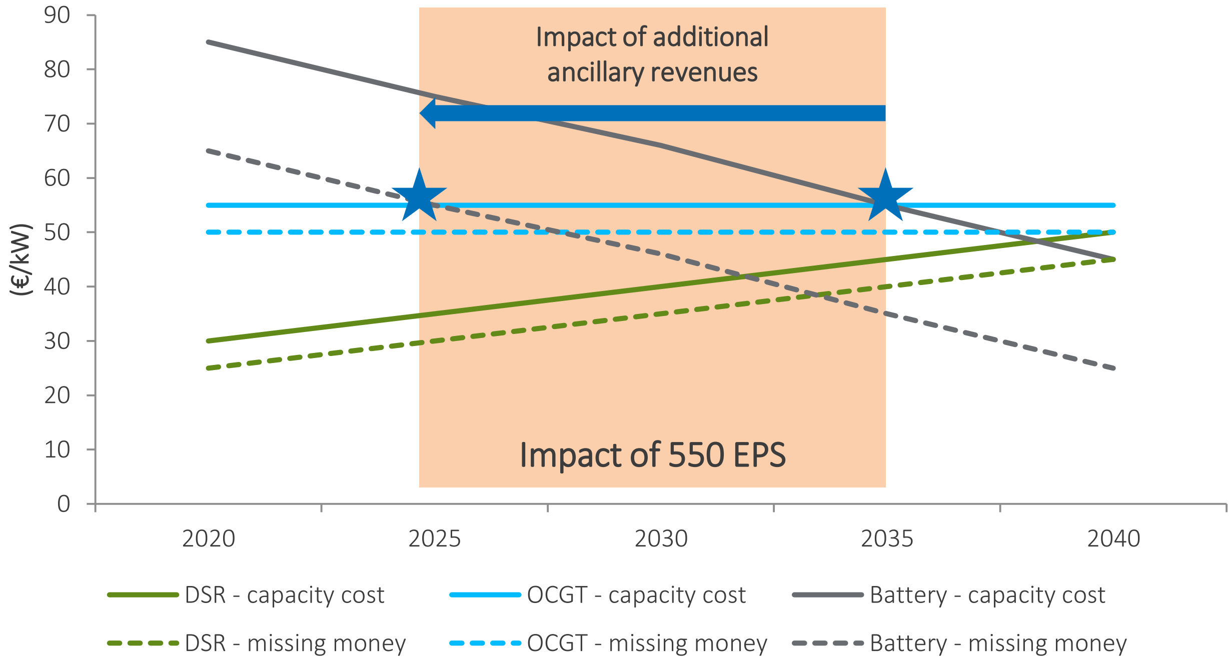
* The figures correspond to the activation cost on the wholesale day-ahead market.
** Cost reduction from todays' €400/kWh, based on ETRI 2014 and market leaders outlook.
*** DSR annual development cost increase as incremental DSR potential is accessible at a higher cost

IN THE SHORT TERM DSR AND OCGT ARE THE MOST ECONOMIC PEAKING TECHNOLOGIES, BUT BATTERY COST REDUCTION MAKES THEM MORE COMPETITIVE IN THE 2020s

Capacity cost outlook for peaking technologies

- While DSR potential remains limited, DSR volumes are more economic than new built OCGT.
- New build OCGT capacity cost is assumed to remain stable throughout the modelling horizon.
- With battery cost reduction, battery becomes more competitive in the mid 2020s. The competitiveness of the battery is strengthened by its capability to capture additional revenues from ancillary services

Capacity cost and missing money outlook 2020 - 2040



Note:
(1)The illustrative missing money takes into account the impact of additional revenues from ancillary services but doesn't account for potential energy revenues which should strengthen the competitiveness of OCGT and batteries vs DSR as their SRMC would be lower and therefore let them capture infra-marginal rents.
(2) DSR capacity cost increases as incremental DSR potential is accessible at a higher development cost.

Thank you for your attention

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