Phasing out coal in the EU's power system by 2030

A policy action plan

IMPULSE

Agora Energiewende

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Preface

Dear reader,

The European Climate Law has entered into effect. It obliges the EU institutions and Member States to take all necessary measures to reduce net domestic greenhouse gas emissions in Europe by at least 55 percent by 2030 based on 1990 levels. Hard coal and lignite power plants are one of the biggest greenhouse gas emitters in the EU. 16 EU Member States are already or will be coal free by 2025; however, to stay on a cost-efficient net zero pathway, coal will need to be completely out from the EU's electricity system by 2030.

To provide a foundation for a fact-based discussion on completely phasing out coal in the EU power system, we tasked the consultancy enervis energy advisors to develop 2030 coal phase-out scenarios. These scenarios allow us to identify a suitable mix of enabling measures that phase out coal, ensure security of supply, minimise costs to consumers and avoid new fossil fuel lock-ins.

With the EU-wide coal phase-out just 9 years ahead, we took insights from the modelling to develop an action plan that we hope will guide EU and national decisions in the months to come.

Enjoy the read!

Dr. Patrick Graichen
Executive Director, Agora Energiewende

Key findings at a glance:

1. **The EU's 2030 climate target of –55 percent requires a complete coal phase-out in the power system by 2030.** A 2030 coal phase-out provides a CO_2 emission reduction potential of 1 billion tons beyond the 40 percent emissions reduction scenario at little additional cost to consumers (wholesale prices rise by 0.5 cent/kWh).

2. **Coal should be replaced by renewables.** The required emission reduction of the power sector can only be achieved if coal is overwhelmingly replaced by solar PV and wind energy. A phase-out of the remaining 38 GW coal capacities in the six countries that do not have a 2030 phase-out date yet (Bulgaria, the Czech Republic, Germany, Poland, Romania and Slovenia) must be met with 100 GW of PV and wind.

3. **Additional gas capacities will be needed, along with an overall decrease in the rate of utilization.** The coal phase-out may require additional deployment of 15 GW of gas plant capacity to safeguard security of supply – while gas-fired power generation needs to fall 15 percent by 2030 in the EU. To avoid stranded assets, all new fossil gas investments should be hydrogen ready.

4. **To achieve the EU wide coal phase out at least cost, a policy mix is required.** The EU ETS should be tightened as proposed by the European Commission. Several Member States should quickly develop or accelerate their plans for national coal phase-out, potentially complemented by a national carbon floor price. Member States should rapidly scale renewables.

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I An action plan for an accelerated EU coal phase-out (written by Agora Energiewende)

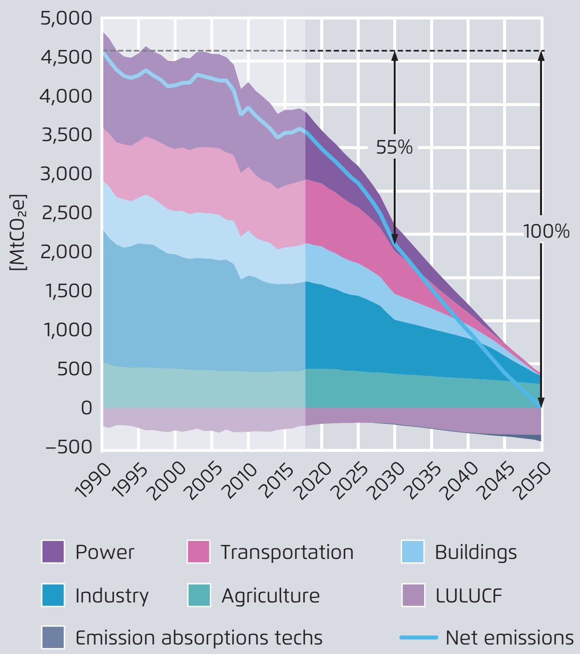
1 The –55 percent emission reduction target requires a complete coal phase-out in the EU power system by 2030

Most EU countries have planned an end date for coal use in the power sector between now and 2040 or are considering one. For the EU as a whole, however, this phase-out is not happening soon enough to be in line with the EU's 2030 and 2050 climate targets.

The EU has recently set itself a more ambitious climate target: a binding 55 percent reduction in net GHG emissions by 2030 relative to 1990 levels. The target increase is an important building block to achieve another EU climate target: becoming climate neutral by 2050. All studies show that quickly decarbonizing the power sector is an important enabler for meeting the 2030 target in a cost-effective way and setting the course for a climate-neutral Europe (see Figure 1).

The main scenario of the EU Commission's Impact Assessment[1] regarding the EU 55 percent target shows a fall in emissions of the electricity sector by 700 Mt or 71 percent compared to 2015, which is half of the needed EU-wide GHG reductions from 2015 to 2030. This is achieved by reducing the share of coal generation in the electricity mix from the current 15 percent to less than 2 percent by 2030, while increasing the share of renewables (RES) in electricity generation from 39 percent to 68 percent. Thus, a significant further acceleration of the ongoing coal-to-clean energy transition is required.

Sectoral emission reductions to reach a climate-neutral Europe by 2050 — Figure 1



McKinsey (2020)

These findings are supported by the recent IEA net zero pathway study that suggests a phase-out of unabated coal capacity in advanced economies by 2030 and a net zero electricity sector in the EU by 2035.[2]

Many member states have already decided to phase out coal-based power generation before 2030. Only six countries – Bulgaria, the Czech Republic, Ger-

1 https://ec.europa.eu/clima/sites/clima/files/eu-climate-action/docs/impact_en.pdf

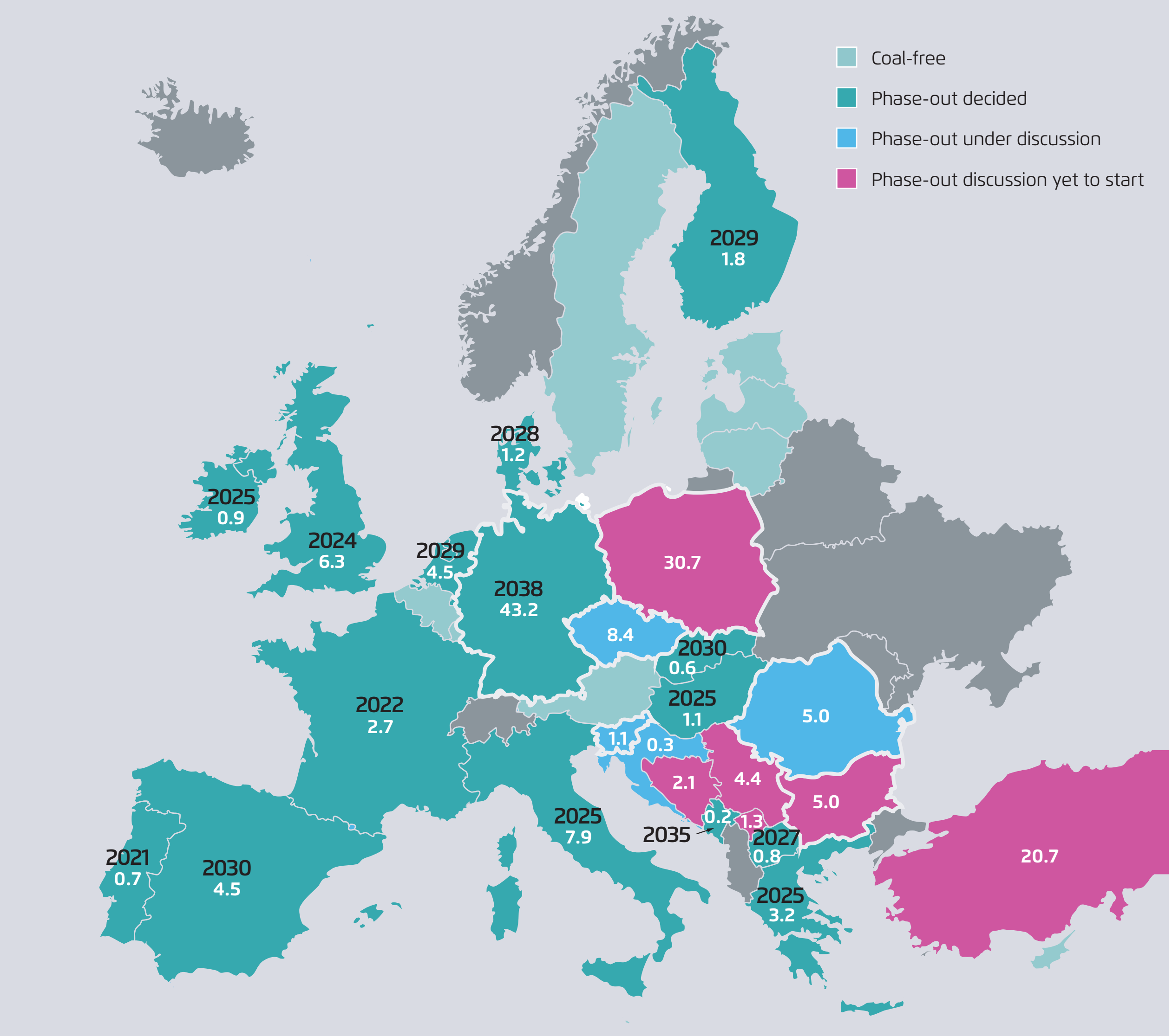
2 Modelling for this project started in late 2020 focusing on the feasibility of a 2030 coal phase-out. It did not consider pathways to a net zero electricity system by 2035 as suggested in the IEA's NetZero Roadmap in May 2021.

many, Poland, Romania and Slovenia (referred to here as the "Coal-6") – have not yet set a date for phasing out coal by latest 2030 (see Figure 2). Combined, the "Coal-6" accounted for 74 percent of coal-based power generation in the EU in 2018.

Against this background, we tasked the consultancy enervis energy advisors with the modelling of different 2030 coal phase-out scenarios for Europe. The main findings of their modelling effort are summarised in Part II of this paper.

The scenarios help to understand how carbon pricing, renewables deployment policies and measures to ensure security of supply interact in the context of a 2030 coal phase-out.

Coal phase-out dates and remaining coal capacities in [GW] | Figure 2



Europe Beyond Coal (2021)

The proposed action plan for achieving an accelerated EU-wide coal phase-out by 2030 presents a policy mix to ensure security of supply and keep costs low. Some of the actions need to be taken at the EU level, while others require national decision-making. It is of vital interest to stakeholders, particularly in the "Coal-6" countries, to develop as a matter of priority concrete national coal phase-out plans.

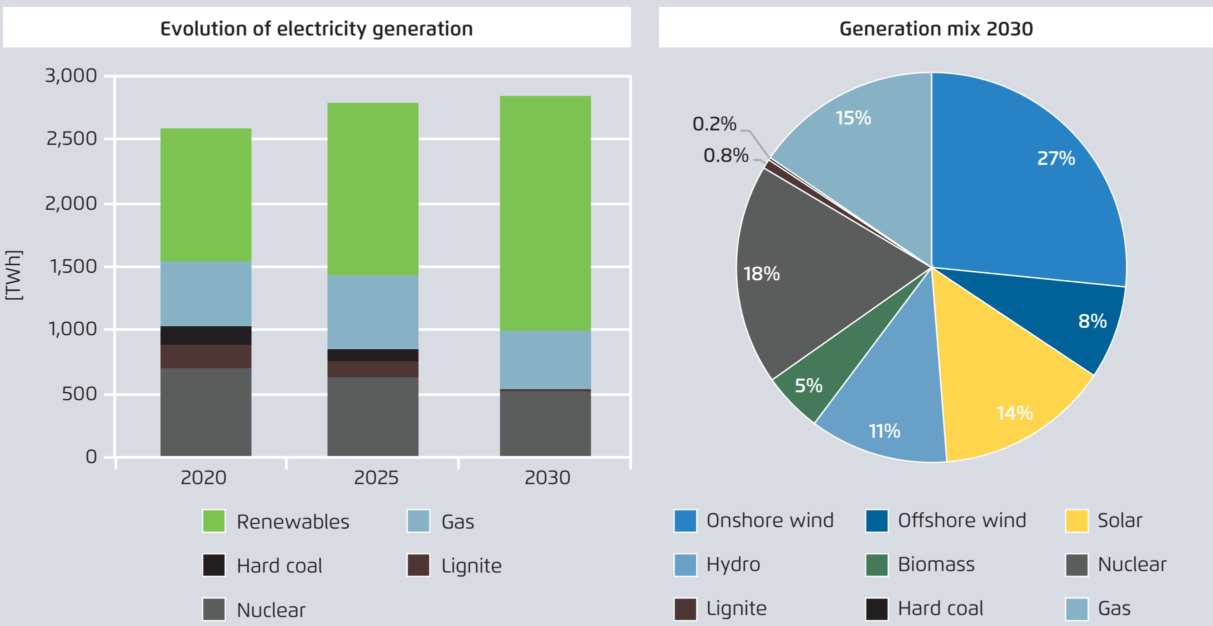
2 A policy mix to phase-out coal, scale up renewables and enable a just transition

A phase-out of the remaining 38 GW of coal capacities in the "Coal-6" will require 100 GW of additional wind and solar PV.

To ensure security of supply during the ramping-up of renewables, an additional 15 GW of gas power plant capacities would be required across the EU during the coal phase-out (see figure 9 for full load hours of gas plants). If policy makers aim to meet domestic peak loads solely with national capacities, around 4 GW of strategic reserves would be necessary – 600 MW for Bulgaria, 100 MW for the Czech Republic, 3.4 GW for Germany, and 300 MW for Romania. For Poland and Slovenia, no additional strategic reserve capacities are needed. The strategic reserves would not be dispatched during average weather years.

Additional costs to the consumer of an accelerated EU coal phase-out remain limited, with an average of 0.5 cent per kilowatt hour and should be balanced through broader reforms of taxes, levies and charges on end consumer electricity prices that shift the burden from increasingly clean electricity to fossil fuels. Low costs for wind and solar PV will keep the additional costs for consumers low. Figure 3 shows the generation mix of an EU power system that phases out coal by 2030.

Net generation in the EU's power system — Figure 3



enervis (2021)

There are three main policy levers for a 2030 coal phase-out:

i) increased ambition in the EU ETS as proposed by the EU Commission as part of its July Fit for 55 package[3];
ii) national policies that mandate a coal phase-out, a just transition and regional economic diversification strategies; and
iii) accelerated deployment policies for renewables.

With its Fit for 55 package, the EU Commission proposed a further strengthening of the EU ETS to reduce CO_2-emissions from installations under the scheme in line with the EU's increased 2030 climate target.

After the December 2020 decision of EU heads of state and government to increase the 2030 climate target to at least 55 percent net domestic greenhouse gas reduction, prices for ETS allowances have already moved from around 20 euros to around 60 euros per tonne of CO_2 in September 2021, anticipating a further tightening of the system.

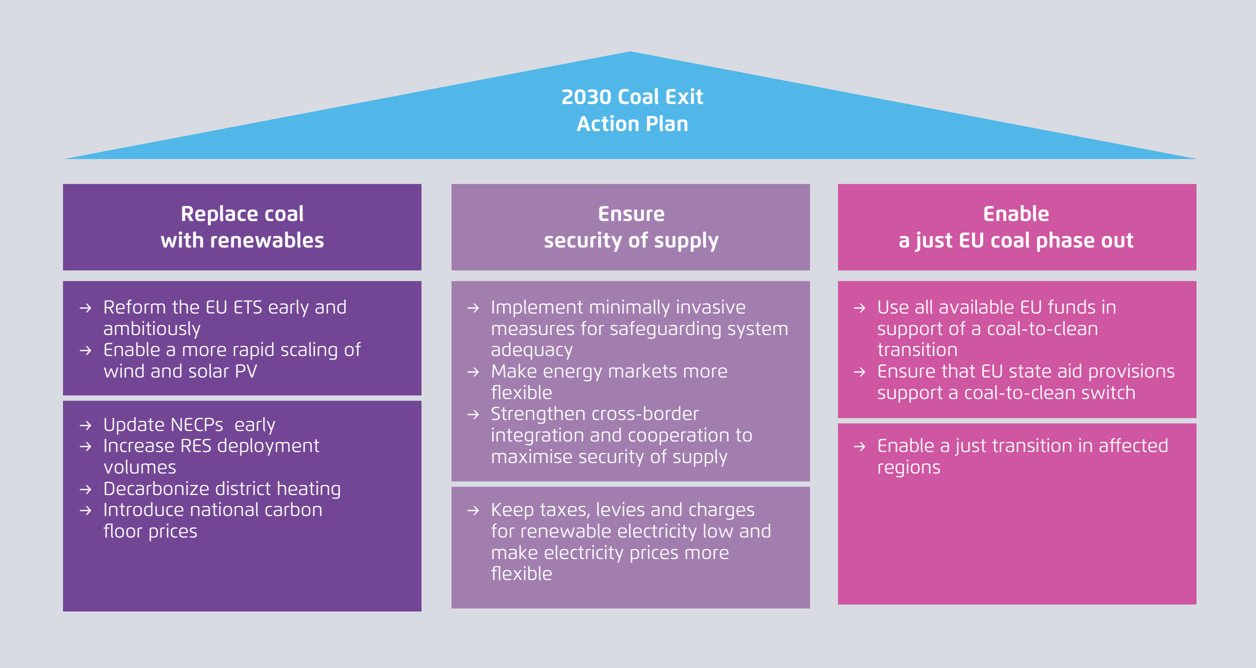
The modelling indicates that sustained prices above 65 euros per tonne of CO_2 are needed for a fully market-driven coal phase-out, but carbon prices would have to increase to 150 euros per tonne of CO_2 in order for market signals alone to achieve both a coal phase-out and a renewables phase-in.

Even the highest projections by the EU Commission remain well below this level (up to 80 euros per tonne of CO_2)[4], and an ETS price of around 150 euros per

3 https://ec.europa.eu/commission/presscorner/detail/en/IP_21_3541

4 https://ec.europa.eu/info/sites/default/files/revision-eu-ets_with-annex_en_0.pdf (page 177)

Policy elements of the EU accelerated coal phase-out action plan — Figure 4



Agora Energiewende (2021)

tonne of CO_2 by 2030 would raise a host of political concerns (e.g., industry, distributional impacts). Therefore, there is a strong case for market responsive revenue stabilisation mechanisms for new renewable power capacity needed to replace coal. Even if competitive auctioning may result in zero cent bids, revenue stabilisation mechanisms act as a safety net that reduce risks for investors and thereby keep costs low.

Early planning and preparation for a coal phase-out by 2030 is essential to ensure a just transition in regions most affected by the phasing out of coal mining and coal use and to monitor and potentially safeguard security of supply. Furthermore, robust coal phase-out plans and territorial just transition strategies enable regional governments to access support from the EU's just transition mechanism or the EU's platform for coal regions in transition.

Against this background, an action plan for an accelerated European-wide coal phase-out by 2030 should include an interrelated set of national and EU-level elements (see Figure 4).

EU-level actions

→ Replacing coal with renewables
- Reform the EU ETS early and ambitiously to provide a firm carbon price signal in support of a coal phase-out by 2030
- Enable a more rapid scaling of wind and solar PV capacities for power production

→ Ensuring security of supply with the generation portfolio, flexible markets and cross border integration
- Implement minimally invasive measures for safeguarding system adequacy
- Make energy markets more flexible
- Strengthen cross-border integration and cooperation to maximize security of supply

→ Public funding to enable a socially just EU coal phase-out by 2030
- Use all available EU funds in support of a coal-to-clean transition in affected regions
- Ensure that EU state aid provisions support a coal-to-clean switch

National level actions

→ Enable a just transition in affected regions
→ Update National Energy and Climate Plans early
→ Increase RES deployment volumes and eliminate RES planning and permitting barriers
→ Decarbonize district heating
→ Keep taxes, levies and charges for renewable electricity low and make electricity prices more flexible
→ Introduce national carbon floor prices

2.1 EU-level actions

2.1.1 Replacing coal with renewables

2.1.1.1 Reform the EU ETS early and ambitiously to provide a firm carbon price signal in support of a coal phase-out by 2030

The EU Commission's proposal for amending the EU ETS would, if adopted, lead to a largely market-driven phase-out of coal by 2030, while providing additional financing for just transition strategies in low-income Member States through a proposed increase to the Modernisation Fund. Although the EU carbon market is already pricing in the ETS update, an early adoption of ambitious amendments to the ETS is politically important.

Specifically, the EU Commission proposes[5] to tighten the CO_2 emissions cap for 2030 by 61 percent compared to 2005 levels. It would achieve this through a combination of a one-off reduction of the overall emissions cap by 117 million allowances and an increase in the factor by which the cap is reduced year after year, from 2.2 percent to 4.2 percent. To more quickly absorb the historical surplus of ETS allowances, the EU Commission proposes to continue the Market Stability Reserve intake rate of 24 percent of surplus allowances in any given year and to limit the number of allowances in the reserve that will not be invalidated to a maximum of 400 million allowances.

ETS allowance prices reached around 60 euros per tonne of CO_2 in September 2021.[6] Such an ETS price is driving installations with lower marginal abatement costs out of the market, coal plants in particular. However, the modelling indicates that sustained prices above 65 euros per tonne of CO_2 are needed for a fully market-driven coal phase-out. For planning security, countries should thus consider putting in place an adequate carbon floor price, complementing the ETS price signal (see national actions below).

5 COM (2021) 551 final of 14.7.2021.

6 https://ember-climate.org/data/carbon-price-viewer/

2.1.1.2 Enable a more rapid scaling of wind and solar PV capacities for power production

For the six countries that do not yet have a plan to phase out coal by 2030 (the "Coal-6"), our modelling points to the need for an additional 100 GW wind and solar PV capacity by that date. The full and effective transposition of planning and permitting obligations in the current Renewable Energy Directive and measures to make the electricity market more flexible will enable the necessary accelerated scaling of renewable power capacity at low cost. These regulatory measures need to be supported by EU State Aid rules.

Replacing electricity from coal-fired power plants primarily through renewables is important to ensure the necessary reduction in CO_2 emissions while avoiding a new lock-in of fossil gas installations (when exceeding the necessary additional 15 GW of gas), which would likely turn into stranded investments.

As part of the Fit for 55 package, the EU Commission proposed an increase of the EU's 2030 renewable energies target from a 32 percent share of renewables in gross final energy consumption to an at least 40 percent share. This implies around 70 percent of renewable electricity in the mix by 2030 – the bulk of which will come from new solar PV, onshore and offshore wind capacity and a tripling in the annual deployment of new renewable power capacity throughout this decade as compared to 2010–2020.

The current EU Renewable Energy Directive that had to be transposed by summer 2021 includes all the elements necessary for achieving a much faster deployment of renewables. Particularly relevant are its provisions on national planning and permitting, as well as on new market participants such as prosumers, communities and industrial consumers; indeed, the latter can now contribute to the necessary investments through a power purchase agreement.

A contentious point in some national coal phase-out debates will be the potential conversion of coal plants to biomass use. Biomass use for power production is not sustainable, either environmentally or economically. Indeed, all climate neutrality scenarios show that biomass is a scarce resource that must be prioritized for applications, particularly in industry, for which non-emitting alternatives do not (yet) exist. In the power sector, wind and solar PV are the superior alternative. Notably, the EU Commission has proposed in the Renewable Energy Directive update to phase out support for biomass for electricity-only production by 2026.

Last but not least, the EU Commission should signal that it will apply EU State Aid rules in support of regional coal-to-clean strategies (see also below). Particularly when linked to regional just transition strategies (e.g., installing large-scale PV in former lignite mines)[7], it must be possible for Member States to undertake technology-specific auctions.

2.1.2 Ensuring security of supply with the generation portfolio, flexible markets and cross-border integration

2.1.2.1 Implement minimally invasive measures for safeguarding system adequacy

Additional 15 GW of flexible gas power plant capacity will be needed across the EU to phase out coal by 2030, while the overall gas electricity production decreases by 15 percent. In case of national resource adequacy concerns (4 GW additional gas capacity needed to ensure resource adequacy nationally), Member States should first apply strategic reserves outside energy and balancing markets and introduce in-market capacity mechanisms only where wholesale market signals and strategic reserves do not provide sufficient adequacy levels.

For strategic reserves and capacity mechanisms, the provisions set out in the Electricity Regulation apply. These include the threshold of 350 kilogrammes of CO_2 on average per year per installed kW for power plants eligible for capacity mechanisms; the requirement to allow for cross-border capacity in order to bid; or the need for an EU-wide Resource Adequacy Assessment. Member states should base their resource adequacy assessments solely on the European Resource Adequacy Assessment to fully benefit from cross-border cooperation.

Europe's energy transition needs to build on an increasingly flexible mix of resources to evolve along a cost-effective pathway. Increasingly, then, safeguarding system adequacy is a dynamic issue: It is not only about how much capacity is needed, but also about what kind of capacity.

Our scenario analysis suggests that a 2030 EU power system with zero coal and 65 percent RES-E in the generation mix is possible with additional deployment of around 15 GW of flexible gas power plant capacity across the EU. These additional gas capacities would operate mainly in a mid-merit and peak-load mode (see figure 9). Any new gas-fired power plant will also have to be hydrogen-ready, so that they can be converted from using fossil gas to hydrogen in the future and located strategically where hydrogen supply and infrastructure is likely to be ramped up soon. To ensure a smooth shift and provide employees a transition period, some coal plants may be moved into strategic reserves for a limited period. They would, however, not be utilized during normal weather years.

Regarding capacity mechanisms, the EU Commission just authorized the first of such mechanisms (for Belgium) under the new rules of the Clean Energy for All Europeans package. Any new capacity mechanism should therefore be planned in combination with decarbonization measures to avoid negative impacts for scaling up of renewables and demand-side measures in view of meeting the 2030 targets.

7 https://publications.jrc.ec.europa.eu/repository/handle/JRC116679

2.1.2.2 Make energy markets more flexible

Reduce intraday gate closure times at the EU level, strengthen intraday auctions and implement 15-minute products on the day-ahead market.

The increasing need for flexibility in the system potentially provides a business opportunity for those able to offer flexibility, be it in demand response, storage or flexible clean generation. However, this necessitates setting an adequate price signal, reducing barriers for demand-side response and increasing the credibility of scarcity prices. The Clean Energy for All Europeans package, especially its revised Electricity Market Regulation[8], has already significantly improved the design of short-term markets. However, several improvements in its implementation are necessary:

- → Reducing gate closure times: the Electricity Market Regulation foresees a gate closure time of maximum one hour for cross-border intraday markets. Progressively reducing this gate closure time would help maximize the utilization of the power market based on the most recent weather forecasts.
- → Strengthening cross-border intraday auctions: Cross-border intraday auctions are critical for flexibility in efficient cross-border trade. They should be performed more frequently.
- → Implementing 15-minute time units in the day-ahead market as required by the Electricity Regulation: This aligns the product traded in the day-ahead market with the time unit in which actors need to balance their demand and supply. This would help to better integrate variable wind and solar PV already in the day-ahead market.

8 https://eurlex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0943&from=EN

2.1.2.3 Strengthen cross-border integration and cooperation to maximize security of supply

Ensure that European targets for physical cross-border interconnection are met and that the transition to flow-based cross-border capacity calculation increases available capacities.

A geographically widespread expansion of wind and solar PV helps to mitigate the effects of weather variability. Different weather regimes across Europe serve as the basis for smoothing effects at the generation side. At the European level, the instantaneous total wind power output is generally much less volatile than on local level and is not characterized by extremely high and low values.[9] Sufficient interconnection capacities allow for balancing the power system with high shares of wind and solar PV at lower costs. It is thus crucial to achieve the European interconnections targets (15-30 percent of peak demand or installed RES generation). The Projects of Common Interest for electricity are key to reaching those targets. It would therefore be important to earmark a majority of funds available under the Connecting Europe facility for electricity transmission projects as part of the ongoing TEN-E revision.

It is also essential to fully use the available interconnection capacities. Therefore, the minimum targets on offered capacities (70 percent rule) need to be met, and the flow-based capacity calculation needs to increase available cross-border capacities in the day-ahead and intraday markets.

9 Fraunhofer IWES (2015): The European Power System in 2030: Flexibility Challenges and Integration Benefits. An Analysis with a Focus on the Pentalateral Energy Forum Region. Analysis on behalf of Agora Energiewende.

2.1.3 Public funding to enable a socially just EU coal phase-out by 2030

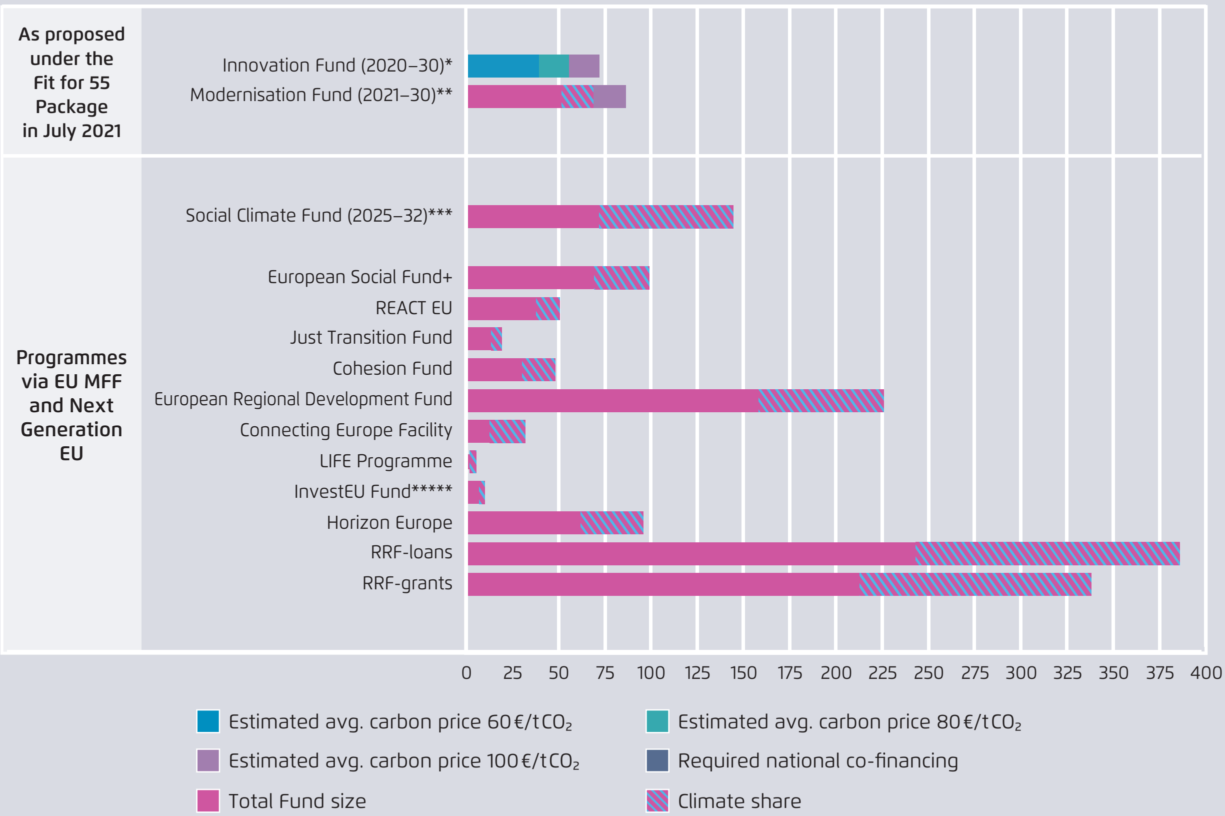
2.1.3.1 Use all available EU funds in support of a coal-to-clean transition in affected regions

Since the proposal of the Clean Energy for All Europeans package in November 2016, the EU Commission has developed a wide range of tools to support coal regions in transition.[10] This includes significant funding that expressly aims to support these regions or that could be used to this end.

10 https://ec.europa.eu/energy/topics/oil-gas-and-coal/EU-coal-regions/initiative-for-coal-regions-in-transition_en

Total fund sizes and minimum climate shares of selected EU funding instruments
in € bn, current prices

Figure 5



* Modernization Fund: Incl. increase through the auctioning of an additional 2.5% of allowances as foreseen under Fit for 55
** ETS Innovation Fund: Estimate, including the top up with 50 million allowances and 150 million allowances from the new system covering emissions from road transport and buildings as foreseen under Fit for 55 proposal. Not depicted: additional allowances which would otherwise be allocated for free to industry sectors covered by the Carbon Border Adjustment Mechanism will be auctioned and added to the Innovation Fund under the current Fit for 55 proposal.
*** Climate Social Fund (EUR 144 bn): As proposed by the Commission, 72 bn EUR in the new fund would need to be matched 1:1 with national funds.
**** Some other sources say it's 61%, but it is not clearly stated on CEF website: 61% (https://www.lamoncloa.gob.es/lang/en/gobierno/news/Paginas/2021/20210708_connecting-eu.aspx)
***** The InvestEU guarantee amounts to €26.2 billion, with provisioning from the Multiannual Financial Framework (MFF) and Next Generation EU resources. The overall investment to be mobilised on this basis is estimated at more than €372 billion.

Climate & Company (2021)

Specifically in support of coal regions in transition is the so called Just Transition Mechanism, with a 17.5 billion Euro Just Transition Fund at its core.[11] While the Just Transition Fund seeks to cushion the effects of the transition, several other EU programmes available to EU Member States can be used to build what will come after. The 750 billion euro Recovery and Resilience Facility specifically encourages Member States to use funds for additional renewables investments under the POWER UP flagship. In the aggregate, though, the EU recovery plans are far off the aspirational 200 GW of renewables (on top of what was planned under the National Energy and Climate Plans). Cohesion spending continues its low-carbon earmarking of the last spending period with more focus on communities and on expanding into high GDP regions. The 30 percent overall climate mainstreaming across the new EU budget for 2021–2027 allows for climate related investment ranging from research to upskilling to renewables investments in agriculture to the tune of at least 500 billion euros – including for renewables upscaling.

The support for affected regions and households was further expanded as part of the Fit for 55 package, with a proposal for a 144 billion euro Social Climate Fund and more firepower for both the Innovation and Modernization Funds – which together would increase to 70 billion, assuming an estimated 50 euro ETS allowance price. The proposed additional 9.6 billion euros attributed to the Modernization Fund would support 10 Eastern European countries, Greece and Portugal in their efforts to decarbonize, in particular for heating and cooling.

2.1.3.2 Make EU State Aid provisions support a coal-to-clean switch

The current State Aid Guidelines may be not enough to encourage a coal-to-clean transition; revenue stabilisation for renewables, especially small-scale projects and innovative technologies, remains important. State Aid for the closure of coal production sites should only be approved in context of a 2030 coal phase-out commitment.

The EU Commission is currently preparing revised Climate, Energy and Environment Aid Guidelines that aim to ensure that the rules under which EU Member States can give State Aid is aligned with the EU Green Deal. New categories of aid show that this reorientation is being taken seriously. They include aid for closure of coal, oil shale and peat; aid for rehabilitation and biodiversity; and admission of carbon contracts for difference to cover the operational cost gap.

It seems highly unlikely, however, that the proposed approach, with a catch-all category for GHG-reducing technologies and subsidies based on avoided CO_2, will encourage a switch from coal to renewables rather than a switch from coal to gas. Modelling suggests that renewables investment will need targeted revenue stabilisation until at least 2030, particularly in less attractive markets and for less mature technologies. Revenue stabilization can be designed to be market responsive in line with the principles of the 2019 Renewables Directive. This must be fully reflected in the new state aid framework. It is to be noted that the intended downward adjustment of volumes in auctions if a tender is undersubscribed seems to penalize renewables. As such, it is not helpful for EU member States that will need to triple renewables capacities between now and 2030, and it would be worth reflecting on whether the auction is an appropriate tool in this case.

Lastly, the planning of a transition from a coal-powered to renewables-powered electricity system must allow Member States to steer certain renewables technologies, e.g., via a technology-specific auction, if only to avoid supply issues, create a balanced energy portfolio and maintain technology leadership.

Another contentious issue concerns State Aid for decarbonizing heat grids, which often are supplied by

11 https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/finance-and-green-deal/just-transition-mechanism/just-transition-funding-sources_en

combined heat and power coal plants. Here, the Commission should consider that the options for competitive price determination are limited, mainly due to the complexity of the individual heat grids. As there are around 6,000 district heating networks in Europe, the continued use of case-by-case notification will slow down the decarbonization of heat grids. An accelerated procedure is needed.

With regard to aid for closure of coal production sites, the draft Climate, Energy and Environmental Aid Guidelines rightly stipulate that such aid should only be handed out if it results in an accelerated coal phase-out. In addition, aid should be only allowed if it advances previous plans and thus alters legitimate expectations with the year 2030 as a firm benchmark. With ETS prices currently above 60 euros and the EU Climate Law in force, the extent of forgone profits is likely to be limited, and it should be ensured that a review takes place and potential repayment is guaranteed if market prices are higher than anticipated. State aid should also not take away environmental and social duties from an operator, again as already stipulated in the draft guidelines.

2.2 Actions at the Member State level

2.2.1 Enable a just transition in affected regions

Politicians need to be honest about the fact that a coal phase-out is only 9 years ahead and enable stakeholders in regions still depending on coal mining and coal use to immediately develop a shared vision and concrete plans for a just transition.

Phasing out coal is a profound structural change. It is thus imperative that stakeholders from affected regions develop a consensual vision and concrete plans for phasing out coal.[12]

12 Phasing Out Coal in Chile and Germany: A Comparative Analysis, 2021.

An accelerated coal phase-out will speed up the employment impacts of the coal-to-clean transition. The EU is still the largest lignite producer in the world and hard-coal mining remains a significant source of high paid employment in Poland. In 2018 a total of 237,000 people in 41 regions located in 12 EU Member States were employed in the coal sector, with coal mining accounting for 185,000 jobs, half of which were in Poland.[13] The economic modelling used in the EU Commission's impact assessment of the –55 percent climate target projects that employment in the broader coal sector in 2030 will fall to around 65,000 jobs. While the impact on total employment differs across the EU, the ongoing transition will nevertheless have severe implications for some coal-reliant regions and local communities.

Economic re-structuring programmes should support the transformation of traditional mining regions. These measures should incentivize additional private investment, especially in the industry sector. The modernization of mining regions encompasses the expansion of renewables as well as the replacement of old generation assets with alternative generation, storage and PtX technologies. The acceleration of planning processes and the investment in transport, digital infrastructure and local research to enhance regional competitiveness can facilitate innovation in former mining areas. Mining regions can be developed into model regions for regulatory purposes, in which new industrial processes and systems can be tested and developed. Those directly employed in the coal industry should be supported by targeted labour market policies.[14][15]

13 https://op.europa.eu/en/publication-detail/-/publication/de175603-896a-11e8-ac6a-01aa75ed71a1/language-en/format-PDF/source-87944594

14 Agora Energiewende and Aurora Energy Research (2019): The German Coal Commission: A Roadmap for a Just Transition from Coal to Renewables.

15 https://publications.jrc.ec.europa.eu/repository/handle/JRC117938

2.2.2 Update National Energy and Climate Plans early

With the coal phase-out only 9 years ahead, the "Coal-6" countries should swiftly update their National Energy and Climate Plans.

The National Energy and Climate Plans (NECPs) of Member States include an integrated and consistent set of measures for achieving the national and EU climate and energy targets. For the "Coal-6" countries, a coal phase-out by latest 2030 implies major changes to their respective NECPs.

The updated NECPs need to be fully consistent with the respective higher targets on emission reductions, renewable energy and energy efficiency, as well as integrating just transition planning. Since NECPs are a main reference point for complementary EU instruments - including accessing EU funds, filling gaps in renewables deployment and infrastructure planning – governments of the "Coal-6" countries should update their respective NECPs well before the formal deadline.[16]

2.2.3 Increase RES deployment volumes and eliminate RES planning and permitting barriers

Deployment volumes for RES need to be increased. Revenue stabilisation mechanisms such as market premium payments, feed-in support (in certain cases, and in line with the provisions of the Renewables Directive) and auctions are needed at least until 2030 to help de-risk RES investments. Permitting bottlenecks should be eliminated. Unallocated funding under the Recovery and Resilience Facility and other EU programmes such as structural and cohesion funding can be used to triple the deployment speed of renewables.

Market-based instruments for revenue stabilisation for RES investments paid through premiums on market prices will remain key in the period until 2030, and deployment volumes will need to be increased. Other support schemes, such as feed-in tariffs, may still be useful to support small-scale projects or less mature technologies.

Robust policy and financing environments for de-risking RES investments reduce renewable energy project costs to levels comparable or lower than those of fossil fuel investments. These de-risking frameworks have a considerable impact on RES financing costs. For example, they lower the levelized cost of energy (LCOE) of onshore wind projects in Greece by 20 percent.[17] Lowering the cost of capital for an onshore wind project from 12 percent (Southeast Europe average) to 3.5 percent (Germany) would mean that twice as much onshore wind generation capacity could be built with the same amount of investment capital.[18]

Member States are also explicitly allowed to use their financial allocations under the Recovery and Resilience Facility for renewables support schemes. Given that the submitted plans in many cases do not foresee significantly increased deployment, this should be corrected when the outstanding amounts are being allocated and plans for cohesion, just transition and social funds are being set up.

Key provisions in the recent clean energy package – specifically those relating to markets and permitting – could accelerate renewables uptake and contribute to de-risking RES investments. It is important to correctly transpose and implement the

16 The draft NECP updates are due by 30 June 2023 and final NECP updates are due by 30 June 2024.

17 New Climate Institute (2019): De-risking Onshore Wind Investment – Case Study: South East Europe. Study on behalf of Agora Energiewende.

18 Agora Energiewende (2018): Reducing the Cost of Fi-nancing Renewables in Europe. Report of a multi-stakeholder dialogue on the proposed EU Renewable Energy Cost Reduction Facility.

provisions from RED II and the Electricity Market Regulation at the Member State level to eliminate permitting bottlenecks so that project pipelines can absorb the significant climate funding already available. Transparent zonal planning procedures need to be implemented that ensure enough land availability for wind and solar PV projects and that in turn enable accelerated permitting.

2.2.4 Decarbonize district heating

Plan and implement the transition to heat pumps, solar thermal, and geothermal for district heat generation. Avoid stranded assets by carefully considering where fossil gas is still needed and plan the transition to hydrogen. Energy efficiency improvements need to be considered in the dimensioning of the systems.

District heating grids are a key technology for decarbonising the building sector. District heating is faced with two challenges: In addition to a required expansion of heating grids, the heat generation itself must also be decarbonized. Coal-fired combined heat and power (CHP) plants are still important for delivering heat in several EU Member States. A coal phase-out would require the replacement of these plants. To a certain extent, fossil gas-fired CHP plants will replace coal CHP plants. Nevertheless, given the long-term decarbonization objectives, the switch from coal-fired to fossil gas-fired CHPs should be kept to a minimum.

Wherever possible, heat provision in existing coal-based district heating grids should come from heat pumps and renewables (geothermal and solar thermal, a limited amount of biomass), and heat demand should be minimized through a focus on energy efficiency. New fossil gas-fired CHP plants should be permitted only if the plant can technically use hydrogen as a fuel as well.[19]

19 https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021_02_Gebaeudekonsens/A-EW_220_Gebaeudekonsens_Summary_EN_WEB.pdf

2021: High electricity prices in the EU

In todays power markets, gas power plants typically set the market price on wholesale electricity markets. CO_2 prices and global gas prices are drivers for bids from gas power plants. The integrated European electricity market, based on the marginal pricing concept, provides signals for short-term consumption and long-term investments. Higher prices, set by gas power plants due to strongly rising gas prices, also increase revenues of wind and solar PV power plant operators and decrease market premiums needed to support wind and solar PV. This should make investments in wind and solar PV more attractive, which in turn reduce wholesale prices.

To alleviate the impact from high wholesale prices on consumers, politicians should mainly consider lowering taxes on electricity and increasing the deployment rate of renewables, e.g., by increasing auction volumes.

Vulnerable consumers can be protected either by considering power prices in the welfare system, potentially linking social benefits to electricity prices or by offering government supported power tariffs.

2.2.5 Keep taxes, levies and charges for renewable electricity low and make electricity prices more flexible

Low and time-varying taxes, levies and charges incentivize investments in flexible assets and help decarbonize the economy.

With rising renewable generation, dependent on wind and solar PV conditions, electricity market prices will become increasingly variable. In an electricity system with variable generation, demand needs to adapt to the generation. Consumers are incentivized to act system-supportive by varying costs for electricity. End consumer electricity prices comprise the wholesale price, taxes, levies and charges. The wholesale price is set in the internal electricity market and fully reflects the variable generation. However, in most countries, taxes, levies and charges are fixed per kWh and constitute a significant part of the end consumer electricity price, thereby dampening the wholesale market price signal. To strengthen the wholesale market price signals and incentivize flexible consumption grid tariffs, charges and levies should vary depending on the wholesale price.

Electricity is also key to decarbonizing mobility, heating and industry appliances. Overall lower taxes, levies and charges on electricity will make the switch to electric solutions more attractive. Conversely, carbon-intensive technologies should be taxed more heavily.

As the decarbonization of mobility, heating and industry appliances progresses, consumption will become increasingly flexible. To utilize these additional flexibility assets, flexible tariffs will be increasingly relevant.

2.2.6 Introduce national carbon floor prices

Introduce a minimum price for CO_2 emissions reaching at least 65 euros per tonne of CO_2 to ensure the closure of remaining coal plants by 2030.

Introducing a national carbon floor price for the power sector provides planning security for the necessary reduction of coal-fired power plant capacity. Despite the already increasing CO_2 prices, a carbon floor price reduces downward variability and provides a firm signal to plant operators and investors. This national floor price "secures" the EU ETS price. A floor of 65 euros per tonne of CO_2 by 2030 could be targeted, as this price ensures the closure of coal plants.[20] It also lowers support needs for renewables.

20 See the market-based coal exit scenario in Part II.

II Power System Scenarios for an EU Coal Exit (written by enervis)

This section presents scenarios for reaching a coal exit in the EU power system by 2030, in line with the overall EU climate target of –55 percent.

1 Modelling approach

All modeling in this study is conducted with enervis' proprietary power market model *emp*. The model optimizes dispatch and deployment of generation technologies for all European power markets based on a comprehensive set of assumptions and input data in high temporal and regional resolution.[21] The resulting developments of capacity and generation of technologies provide a basis for quantifying among others price effects, costs and emissions. This allows for a comparison of the three energy policy scenarios and allows an integrated assessment of policy implications.

Specifically, the following results were modelled and compared between the scenarios:

- Capacity & generation of power market technologies. This is used to quantify the annual phase-out of coal capacities as well as additional RES or gas capacities
- Necessary investment volumes per technology
- Incremental generation costs (IGC) as a core indicator of general economic efficiency of scenarios
- Consumer costs
- System costs of renewable energy sources (RES) and necessary re-financing volumes

21 Input data for the availability of renewables is based on historical weather data in minscale temporal resolution and km-scale spatial resolution. Price formation is modelled in hourly resolution and by bidding zone.

2 Power-market scenarios

In total, four power market scenarios were developed and modelled.

The first scenario covers the former climate mitigation ambition level in the EU (a 40 percent emission reduction by 2030 relative to 1990 levels). This scenario serves as a baseline scenario for comparison with the three more ambitious scenarios.

Three scenarios reach the more ambitious 55 percent CO_2 reduction target. All three imply a "coal-to-clean" transition by 2030. This includes a phase-out of all coal capacities by the end of 2030 and a substitution of coal generation with a mix of wind and PV.

These three "55 percent Scenarios" represent different policy scenarios ranging from more national and regulatory policies to a more European and market-based approach. The main variables differentiating them are the assumptions regarding

i) CO_2 prices in the EU ETS,
ii) the (regulatory) coal phase-out trajectory and
iii) trajectories for the phase-in of renewables.

Figure 6 depicts an overview of the four scenarios.

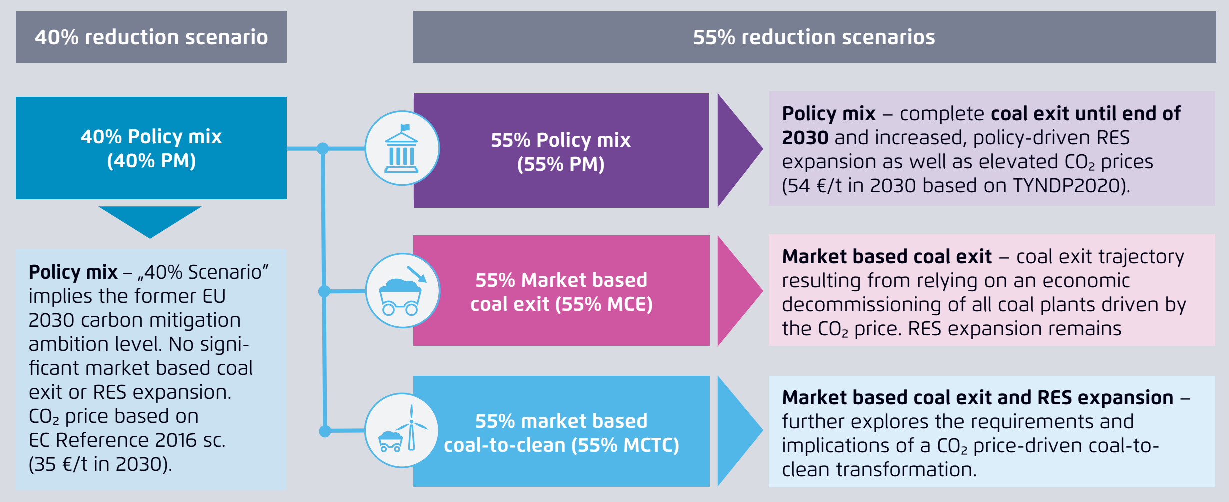
2.1 40 percent policy mix scenario

The "40%policy mix scenario" ("40% PM") implies the outdated European ambition level of a GHG emission reduction of 40 percent by 2030 against a baseline of 1990.

- Against that backdrop, we assumed a CO_2 price trajectory corresponding to this ambition level based on the EU Reference Scenario 2016 (ICCS-NTUA, 2016), with a CO_2 price of ~32 EUR/t in 2030.

Scenario overview

Figure 6



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- → The expansion of renewables and coal-exit trajectories are modelled exogenously based on current national strategies as stated in the National Energy & Climate Plans (NECPs) of the member states.

2.2 55 percent policy mix scenario

In the 55 percent policy mix scenario ("55% PM"), the "coal-to-clean transition" is implemented via a mix of EU-level and national instruments:

- → This scenario assumes a raised ambition for EU ETS, increasing the CO_2 price level to ~53 EUR/t in 2030.
- → An expansion of RES capacity makes up for the reduction in coal generation. We assume that the expansion will be financed by national RES support payments wherever market revenues are not high enough to incentivize expansion.
- → A coal-exit trajectory decommissions coal units by age (oldest plants first) from 2024 onwards such that coal-fired capacity reaches zero by the end of 2030. We assume that this would be implemented via regulatory measures on a national level wherever necessary.

2.3 55 percent market-based coal-exit scenario

The "55 percent market-based coal exit" ("55% MCE") models a coal exit resulting from an economic decommissioning of all coal plants driven by the ETS price.

- → Our modelling indicates that economic decommissioning of the remaining coal fleet in the "Coal-6" would result from a sustained CO_2-price level above 65 EUR/t in 2030.
- → In this scenario, coal units are decommissioned according to a predefined economic criterion under the CO_2 price trajectory.[22]
- → RES expansion and all other exogenous parameters remain as in the 55% PM scenario. The RES expansion remains driven by support payments wherever market revenues are not high enough to incentivize expansion.

22 Units may not retire more than two years earlier than they would in 55% PM, which restricts the economic phase-out trajectory.

2.4 55 percent market-based coal-to-clean scenario

The "55 percent market-based coal-to-clean" scenario ("55% MCTC") explores the requirements and implications of a CO_2 price-driven coal-to-clean transformation. Here we assume that neither a coal exit nor an RES expansion is driven by national policies. Rather, they result from a strong increase in CO_2 prices.

Hence, the EU level of ambition needed to reform the ETS and increase the CO_2 price is the main driver for reaching the emission target.

- → A market-based RES expansion in all EU countries leads to the same level of generation in 2030 as in the policy mix scenarios. This becomes feasible at a CO_2 price of around 150 EUR/t in 2030.[23] Similar levels of CO_2 price have been found in other recent studies investigating an EU-wide coal-to-clean transition by 2030, e.g. (PIK, 2021).
- → The minimum RES expansion is kept at the same rate as in the 55% PM scenario, while allowing for additional market-based expansion incentivized by the higher level in CO_2 prices.
- → The trajectory of market exits of coal-fired units and all other parameters remain the same as in the 55 percent market-based coal-exit scenario.

23 Please note that this level of CO_2 pricing serves as an indication.

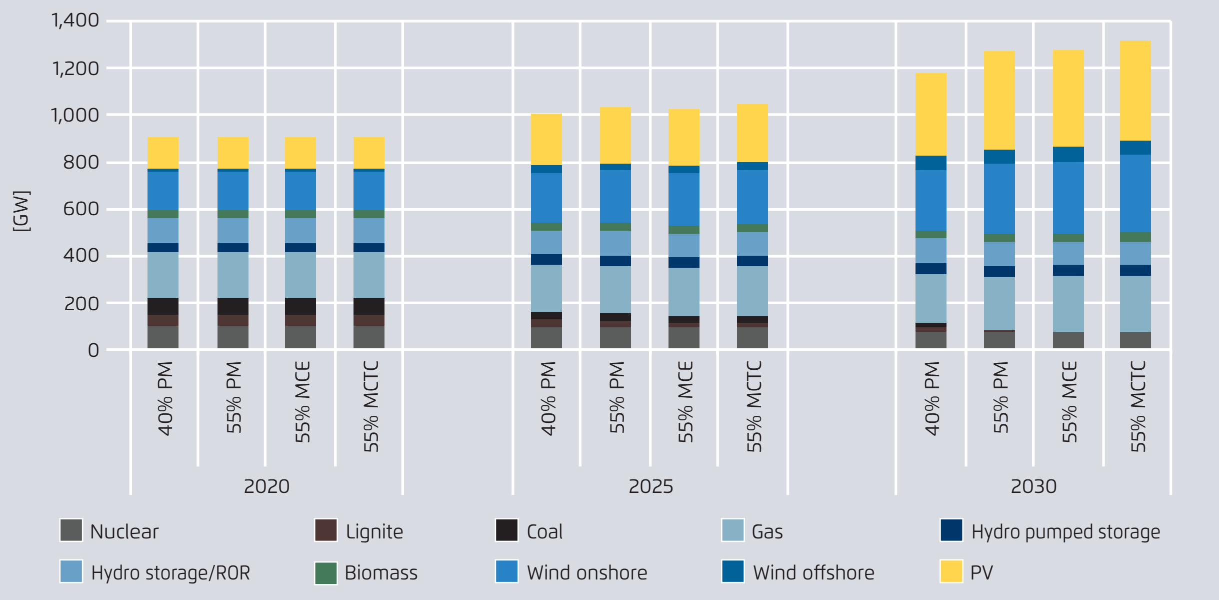
3 The EU power system in 2030: Results

3.1 Development of capacity and generation structures

An overview of EU-level capacities by 2030 in different scenarios is depicted in Figure 7.

Compared with the 40% PM scenario, all 55 percent scenarios see an accelerated reduction of remaining

Installed power plant capacities in the EU until 2030 — Figure 7



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coal capacities, which are substituted with a mix of wind (onshore), PV and some additional gas units for security of supply and flexibility provision.

In the 55% MCE scenario and to a slightly higher degree in the 55% MCTC scenario, additional market-based RES expansion occurs due to higher wholesale prices.

The policy mix (55% PM scenario) reduces the initial 72 GW of hard coal and 45 GW of lignite linearly over time. The capacity difference compared with the baseline coal trajectory amounts to 15 GW for hard coal and 14 GW for lignite in 2030.

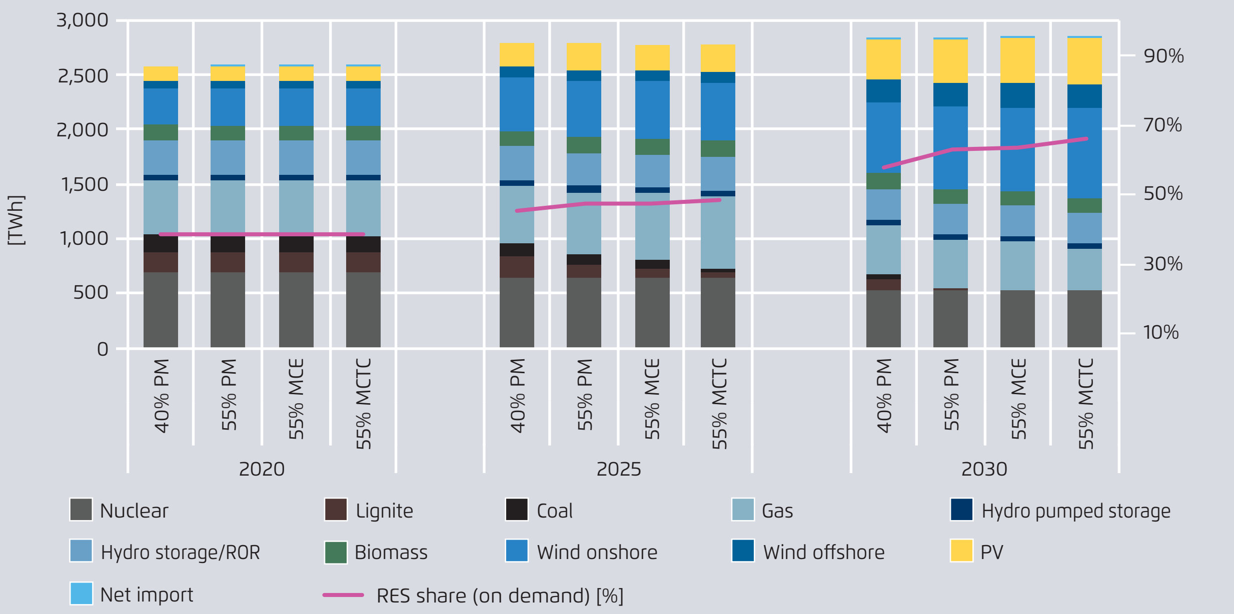
The ETS-driven coal exit scenarios (55% MCE and 55% MCTC) retire some of the units earlier, such that a capacity difference of 10 GW (hard coal) and 15 GW (lignite) relative to the baseline trajectory occurs by 2025. Germany lignite capacity is especially affected, because it is more vulnerable to carbon pricing than hard coal.

By the end of 2030, all coal and lignite units are decommissioned in the 55 percent scenarios, while a total of 18 GW of hard coal and 20 GW of lignite remain online in the "Coal-6" in the 40% PM baseline scenario.

For onshore wind, an increase from 165 GW in 2020 to 213 GW in 2025 occurs in the baseline scenario (40% PM). By comparison, the 55 percent scenarios result in additional expansion to 226 GW (55% PM), 227 GW (55% MCE) and 232 GW (55% MCTC) in the same timeframe. The gap between the baseline and coal exit scenarios further increases towards 2030. Total wind onshore capacities reach 302 GW, 305 GW and 331 GW, respectively, compared with just 260 GW in the 40 percent scenario.

PV sees an even steeper expansion than wind onshore in all scenarios. From an initial 133 GW in 2020, the 40% PM increases installed capacity to 352 GW in 2030. The 55 percent scenarios result in at least a tripling relative to today, to a total of 412 GW (55% PM),

Power generation in the EU until 2030 — Figure 8



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416 GW (55% MCE) and 426 GW (55% MCTC) – at least 60 GW more than in the baseline scenario.

As a consequence, the EU generation mix becomes less carbon-intensive in the 55 percent scenarios, and RES shares (on demand) increase by over 5 percentage points by 2030 against the baseline. Figure 8 displays the generation mix for the EU through 2030.

In the 55% MCTC, RES shares increase by an additional 3 percentage points in comparison with the other 55 percent scenarios, since higher CO_2 price levels incentivize an increased deployment of RES units. The earlier decommissioning and lower utilization of the remaining coal-fired units additionally trigger a temporary increase in gas-based generation in the medium term.

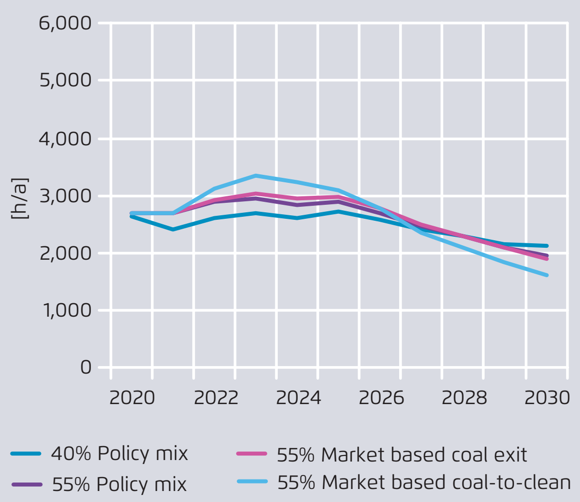
Despite a higher deployment of gas capacities in the 55 percent scenarios compared with the 40 percent scenario, these provide less generation than in the 40 percent scenario. The average utilization of gas-fired units in the EU increases until 2023 to between 3000 and 3400 yearly full-load hours due to a sustained fuel-switch. The generation from these capacities then decreases gradually in all scenarios to around 2000 full-load hours (see Figure 9), because most demand can be met with increasingly available RES capacities. Thus, gas predominantly contributes capacity in times with low renewable generation and covers flexibility demands of the system. In the long term, the share of gas decreases in the market-based 55 percent scenarios as a result of higher market prices for CO_2 allowances and generation costs. The results illustrate that a coal exit offset by additional renewables does not necessarily lead to additional gas-based generation.

3.2 CO_2 emissions

All 55 percent scenarios lead to significant CO_2 savings compared to the 40% PM scenario. Figure 10 shows the avoided cumulated CO_2 emissions relative to the 40% PM scenario by the year 2030.

Annual CO_2 emissions of the ETS amounted to 1.53 billion t in 2019 (DEHST, 2020). Savings of up to

Utilization of gas-fired units in the EU (annual full-load hours) Figure 9



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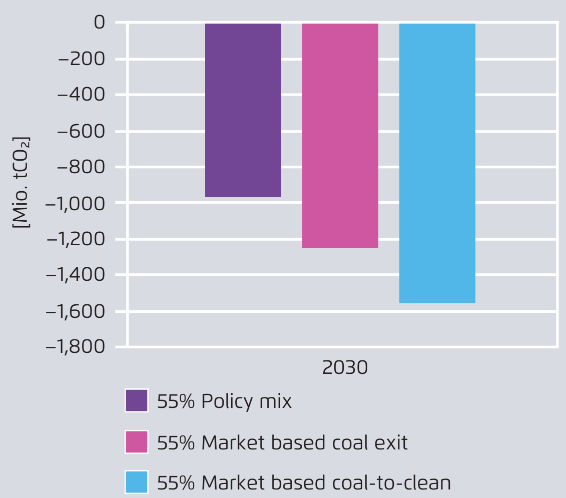
Differences between the cumulated CO_2 emissions in the 55% scenarios and the 40% scenario (2020 to 2030) Figure 10



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one annual emission volume represent a significant reduction in emissions.

In total, the 55% PM scenario results in a CO_2 reduction of 1 billion tonnes by 2030; the 55% MCE scenario results in an additional fifth of this reduction; and the 55% MCTC scenario increases reduction by 61 percent vs. the policy mix phase-out.

In the first years, the differences to the 40% PM scenario as well as between the 55 percent scenarios are caused by the impact of the respective CO_2 price trajectories on fossil dispatch, particularly on coal units. After 2023, there is the additional effect of coal capacity reduction, which happens at a higher rate in the 55% PM than in 40% PM, and at a slightly higher rate in the two market-based 55 percent scenarios (55% MCE and 55% MCTC) than in the 55% PM. Because the avoided coal generation is offset by CO_2-neutral renewables in all 55 percent scenarios, CO_2 emissions from gas-fired capacities play only a minor role in the scenario differences.

3.3 Cost implications and distribution

3.3.1 Investment volumes

Transforming the power systems to reach the 55 percent GHG reduction target requires additional investment in the power generation capacities of the EU for all 55 percent scenarios.[24]

Figure 11 shows the yearly investment volume differences for the 55% PM scenario compared with the baseline by technology (left axis). The figure also presents the cumulated investment through 2030 (right axis).

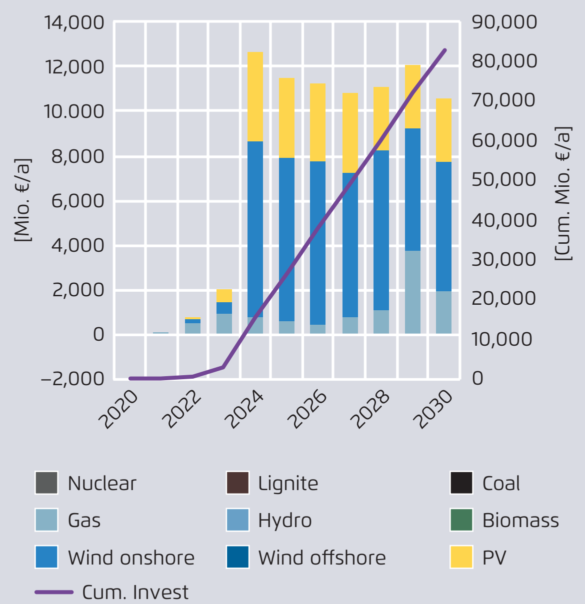
Additional investments compared over the 40 percent scenario are mainly channeled towards onshore wind and PV assets and, to a lesser extent, to gas-based capacities. They cumulate to 83 billion euros (55% PM), 96 billion euros (55% MCE) and 131 billion euros (55% MCTC) by 2030.[25]

Additional investment volumes represent financing needs but can also be read as an important indicator of economic stimulus and employment opportunity. Both can be valuable for the green recovery.

3.3.2 Incremental generation costs

The "incremental generation costs" ("IGC") is an indicator of the overall economic efficiency of a scenario, independent of distributional effects

Investment volume differences by technology between the 55% Policy Mix and the 40% Policy Mix scenario in the EU — Figure 11



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24 Please note that all numbers here exclude grid-related investments. We focus on investment costs related to power generating units.

25 Incremental differences between the 55% scenarios are mostly driven by the aforementioned structural changes in the capacities – specifically, differences in the expansion of onshore wind assets.

between consumers and generators and defined relative to another scenario.[26]

The cost components considered within this analysis are:

- → Import costs: costs for (net-)power import from surrounding market zones is assessed based on wholesale import prices.
- → External effects: these (mostly) account for the negative health effects caused by pollutants emitted from coal-based power generation. These effects were evaluated in monetary terms.
- → CO_2: all costs caused by the procurement of CO_2 certificates within the ETS. These costs also represent additional income for, say, governmental institutions.
- → OPEX: operational costs of conventional power generation. This includes fuel costs, though in this case excludes carbon costs, which were addressed separately.
- → CAPEX:.investment and capital costs. Within CAPEX we only include conventional power generation, since renewable generation is addressed separately.
- → RES: All costs relevant for investment in and the operation of renewable energy sources (OPEX and CAPEX of RES).

Figure 12 shows the additional incremental generation costs cumulated over time for the 55 percent scenarios compared to the 40 percent scenario, broken down into the aforementioned cost components (stacked bars) as well as in total (line).

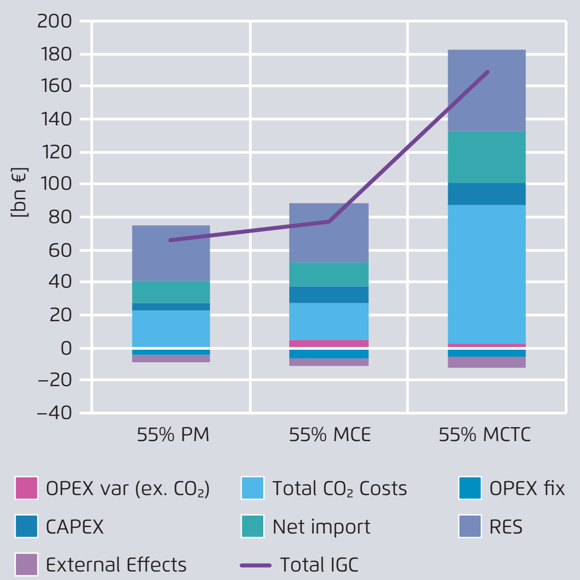
26 Incremental generation costs account for costs that change between scenarios, whereas the scenario costs (e.g., capital stock) do not influence the relative "merit" and are thus not necessarily included. Lower costs imply that power is generated more cost efficiently, which can either reduce end-consumer costs or increase the rents ("profits") of power producers by the same amount (or do both in part). Since producer rents and consumer prices are, from an economic point of view, distributional in nature, economic efficiency is often assessed based on generation costs.

Cumulative incremental generation costs are positive in all 55 percent scenarios, which indicates there are additional system costs in comparison to the baseline 40 percent scenario. Within the 55 percent scenarios, IGC is lower in the policy mix scenario relative to both ETS-driven scenarios.

The 55% PM scenario leads to an additional cumulative IGC of 66 billion euros from 2020 to 2030. The main drivers for this difference are the higher CO_2 costs in the medium term, long-term RES and import costs. These components dominate diverse savings in OPEX and the external effects by the end of the decade.

While RES costs indicate investment needs largely fundable under EU schemes (see Part I), revenues from auctioned CO_2 certificates can also be seen as a source of income and can thus provide significant additional financing. See as an example the recent statistics for

Cumulated incremental generation costs (IGC) of 55% scenarios compared with the 40% PM scenario in the EU (2020 to 2030), the breakdown of cost components (stacked bars) and total ICG (line) — Figure 12



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Germany, which auctioned 2.4 billion euros worth of certificates in the first half of the current year.[27] The differences in import costs stem more from the hourly pattern of import needs than from an increase in total imported volumes (see Figure 8: Power generation in the EU through 2030). Accordingly, there are fewer total imports but at hours with higher residual loads and thus higher prices.

For the 55% MCE scenario, the additional IGC amounts to 78 billion euros in the same time period. The market-based coal-to-clean scenario (55% MCTC) induces significantly higher costs (169 billion EUR). However, CO_2 costs (23 billion euros or 30% of total IGC in 55% MCE and 85 billion euros or 50 percent of total IGC in 55% MCTC) are by far the dominant driver of these differences. A second driver is higher import costs, which rise because imports to the EU are becoming cheaper relative to generation inside of the EU.

27 https://www.faz.net/aktuell/wirtschaft/klima-energie-und-umwelt/CO₂-zertifikate-bringen-rekordeinnahmen-strompreis-steigt-17465425.html

Economic principles indicate that, if markets function perfectly and ETS volumes are not counted as costs, the specific CO_2 abatement costs of a market-based approach should be lowest. The scenario comparison here only illustrates that a sensible mix of policies can lead to lower absolute costs, especially when additional ETS volumes are considered a cost. This illustrates that targeted policies can limit the overall distributed financial volume and that the ETS mechanism causes rather extensive distributional effects.

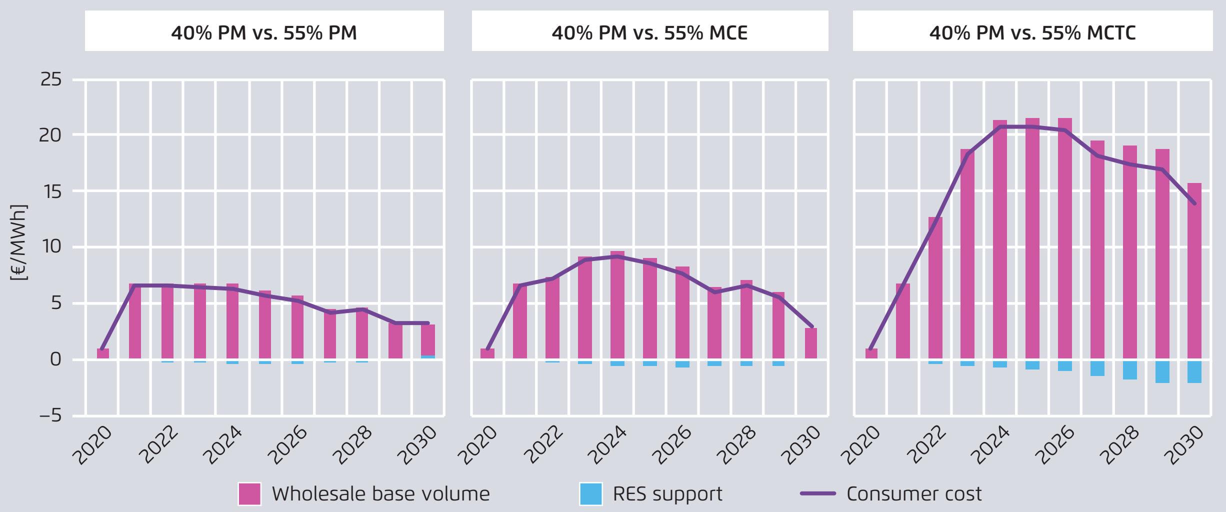
3.3.3 Consumer costs

The additional costs to consumers are an indicator of the distributional effects for power consumers within the considered scenarios.

The development of this indicator is illustrated in Figure 13, which shows the consumer cost differences between the 55 percent scenarios and 40% PM baseline scenario over time.

The total consumer cost difference between the 55% PM scenario and the 40% PM scenario (violet line) per year results from the difference of the

Consumer cost differences — Figure 13



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wholesale base volume cost (magenta bars) and the RES support (blue bars). In the first half of the decade, costs to consumers increase by 6 to 7 EUR/MWh. Additional consumer costs in the 55 percent scenario are hedged starting in 2025 by the increased availability of carbon-free renewable generation, reducing additional consumer costs to about 3 EUR/MWh in 2030.

By comparison, both ETS-driven scenarios (55% MCE and 55% MCTC) lead to higher additional consumer costs due to the impact of the assumed carbon prices on fossil generation costs. Modeling results indicate that a market-based coal-exit scenario reaches a maximum cost increase of 10 EUR/MWh by the middle of the decade, while costs are likely to decrease again to levels approaching those of the policy mix scenario (3 EUR/MWh) as RES shares increase and mitigate the impact of carbon and fuel costs. At the same time, increasing wholesale prices decreases RES support needs.

In view of the above-mentioned findings, consumer cost differences in the 55% MCTC scenario could reach a maximum of 22 EUR/MWh by the middle of the decade and remain at high levels (14 EUR/MWh) through 2030. This indicates that a completely market-based approach with relatively high CO_2 prices would pose challenges from a distributional point of view.

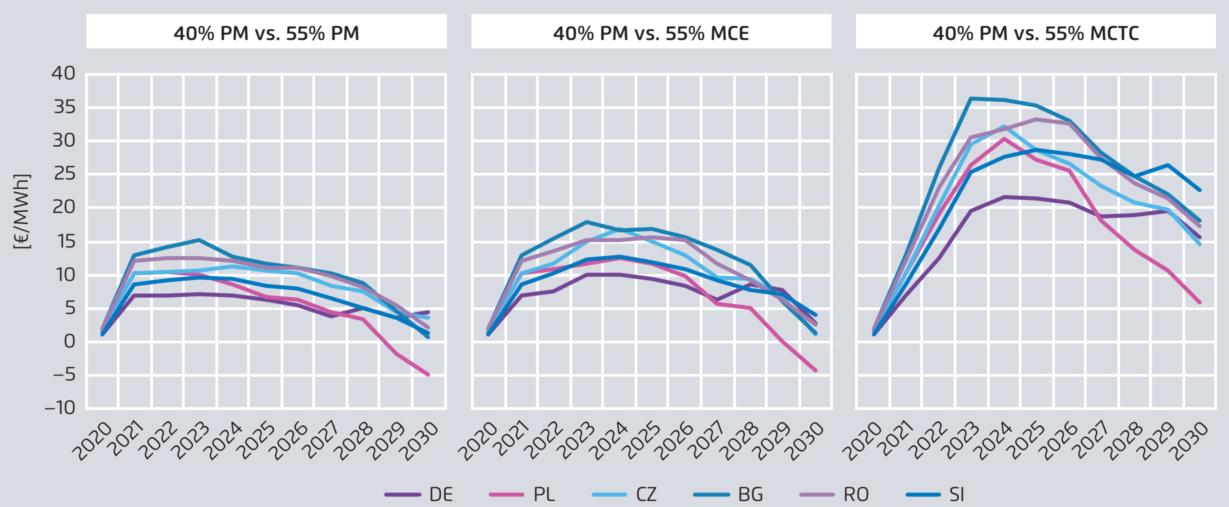
At the same time, revenues from auctioned CO_2 certificates imply a source of income that could be used to reduce costs to consumers via various channels. This effect is not modelled here, however.

3.3.4 Wholesale price effects

The wholesale electricity price is another indicator of costs to consumers in different scenarios. The relevance of this indicator is greatest for industrial consumers, which in many countries pay power prices relatively close to the wholesale level.

Figure 14 shows the difference between wholesale base price levels in each of the 55% PM scenarios compared with the 40% PM scenario for the "Coal-6" markets over time.

Wholesale base prices differences in the Coal-6 countries — Figure 14



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A strong initial impact (until 2023) on wholesale prices can be observed, which is mainly driven by the assumed CO_2 price increase combined with a relatively static capacity mix during this timeframe. The price thus decreases until 2030 as the generation mix becomes less carbon intensive. The difference levels out below 5 EUR/MWh in the 55% PM and 55% MCE scenarios. In the case of Poland, prices even decrease relative to the 40% PM scenario. In the 55% MCTC scenario with a significantly stronger ETS price, the price differences range between 5 and 20 EUR/MWh in 2030. Note that the 55% PM scenario has the lowest overall impact on price levels, mainly due to the lower assumed CO_2 prices. Overall, the price effect is within the expected range as other studies have shown.

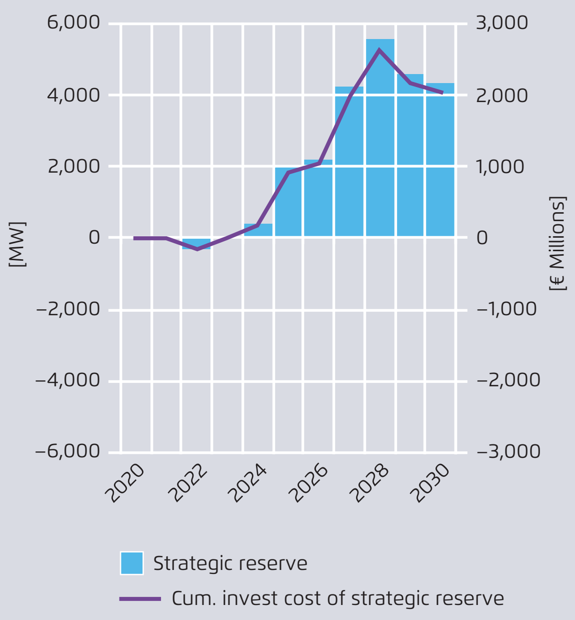
3.3.5 Safeguarding security of supply through strategic reserves

To further assess the security of supply effects of energy policy scenarios, the potential strategic reserve capacity needs were examined for the focus countries. A "Capacity Balancing Approach" was applied to calculate strategic reserve demand at the national level. This represents a case in which policy makers wish to ensure that national peak loads are met mostly by domestic generation capacities. The calculations assume a limited contribution import capacity. If necessary, additional new gas units will be deployed to cover the demand for strategic reserve capacities.

Applying a capacity balancing approach based on the assumption that policy makers want to ensure that peak load is mainly met by domestic generation capacities leads to the deployment of additional gas capacities beyond those the power market model would deploy based on market signals. Figure 15 shows the required yearly additional strategic reserve capacity (MW) and the cumulated investment costs for the "Coal-6" countries. Here, the difference between the 55% PM scenario and the 40% PM scenario is shown. Capacity demand increases until the late 20s and then levels off. Reserve capacities peak at approximatively 5 GW.[28] This illustrates that overall additional capacity for reserve purposes is rather limited relative to the size of the underlying system. The 2030 breakdown of additional strategic reserve capacities among the "Coal-6" countries in the 55 percent policy mix scenario is: 600 MW for Bulgaria, 100 MW for the Czech Republic, 3.4 GW for Germany, and 300 MW for Romania. For Poland and Slovenia, the 55 policy mix scenario does not require additional strategic reserve capacities beyond those which can be contracted from existing capacities to serve peak load on a national basis.

28 We assume that hard-coal units can contribute to a strategic reserve for up to ten years after their respective market exit. Under this assumption, there would be no net demand for additional reserves.

Differences in strategic reserve capacities (55% PM vs. 40% PM scenario) on Coal-6 level — Figure 15



enervis (2021)

4 Summary of scenario analysis

The path to reaching the 2030 target is clear: A phase-out of the remaining 38 GW coal capacities in EU countries can be met with 100 GW of additional wind and PV. Additional costs to the consumer versus the baseline remain limited – averaging 5 EUR/MWh.

Modelling indicates that a full coal exit by 2030 is possible with an additional market-based deployment of gas of around 15 GW and overall investment volumes of 82 billion EUR. Additional strategic reserves of 4 GW would be necessary to cover national peak loads or secure non-standard weather years. This would require building on average two additional gas-based power plants per year between 2024 and 2030 in the EU, which is feasible but given the timeline would need a fast decision on governance and incentive structures.

There are three core policy approaches available to incentivize necessary developments: increased ambition in ETS-carbon pricing, national policies to govern and accelerate the coal phase-out and policy-based support for renewable expansion. The greater the EU ambition is with regard to ETS pricing, the fewer national policies for subsidizing RES expansion and coal decommissioning will be necessary. The current ambition to reform the ETS (~54 EUR/t CO_2 in 2030) already significantly reduces the need for additional national incentives, but not entirely.

The modelling indicates that sustained prices above 65 EUR/t CO_2 alongside the necessary RE expansion could lead to a full and market-driven coal phase-out. National regulations should be adapted to provide security of supply and to avoid the overcompensation of coal plant closures.

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Agora Energiewende develops scientifically sound, politically feasible ways to ensure the success of the energy transition – in Germany, Europe and the rest of the world. The organization works independently of economic and partisan interests. Its only commitment is to climate action.

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