Assessment of Options for Replacement of Bełchatów Lignite Power Plant

Documentation

12.07.2019

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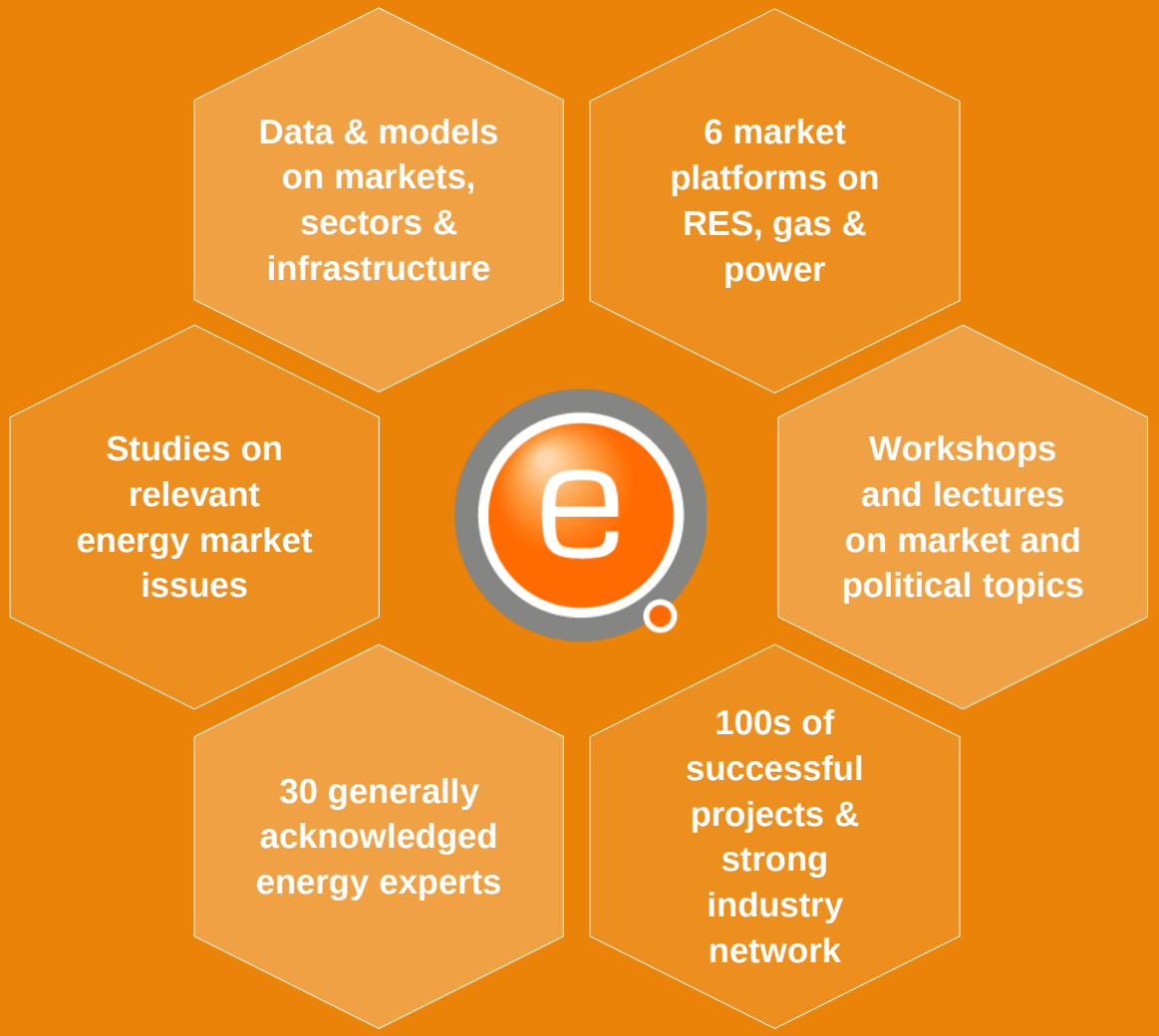
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Content

Executive Summary

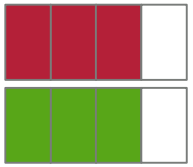
Executive Summary

Aligning the power system with RES	• It is of increasing significance to align system design with technological “mega trends”. While conventional generation technologies suffer increasing costs, RES becomes more and more competitive. This manifests in different ways, foremost: RES rely less and less on subsidies.
A coal phase-out cuts emissions	• The Coal Exit scenario brings down CO_2-emissions by 38 % and other emissions by 42 – 64 % vs. Reference. The global climate and the health of the Polish population will benefit. • An earlier phase-out of Bełchatów plays an important part, contributing approx. 5 % of this reduction.
A coal phase-out reduces costs	• A scenario with less coal and more RES is more cost efficient than the reference. Savings of 64 bn. € equal 9.5 % of overall system costs and thus represent a significant potential to contribute to the cost efficiency of the Polish economy. • Bełchatów plays an important part, contributing 4 bn. € to this reduction.
Substituting coal with RES is technically feasible	• Security of Supply is assured in the Coal Exit scenario given natural gas (and storage) can be utilized as back-up. • High shares of RES can be integrated in the system with little curtailment. The system should be designed to supply a high level of flexibility.
RES enable Polish import independency	• RES allow for a reduction of import dependency in the power sector, effectively cutting power imports. • Switching from coal to gas leads to more gas demand, but demand levels are in line with the Polish strategy of diversifying source countries (LNG, Baltic pipe).
RES provide employment opportunities	• Direct employment is higher by 45 % in Coal Exit vs. Reference while total employment is also continuously and significantly higher. Even though this is an estimate, it clearly indicates significant employment opportunities for the Polish workforce by expanding renewables and phasing out coal.
Phasing out coal has multiple benefits	• A consistent Coal Exit strategy by 2035 allows less CO_2, less negative health effects, less power imports and lower system costs while providing employment opportunities. • Phasing out coal therefore provides for a diverse set of benefits.
Further ambitions beyond coal exit necessary.	• CO_2-emissions from the power sector decline sharply at first but stabilize at a certain level. This demonstrates the need for further ambitions beyond a coal exit and the need for Deep-Decarbonization technologies to cut emissions further (RES & storage or CO_2-neutral or renewable gas).

Scoping of Replacement Options

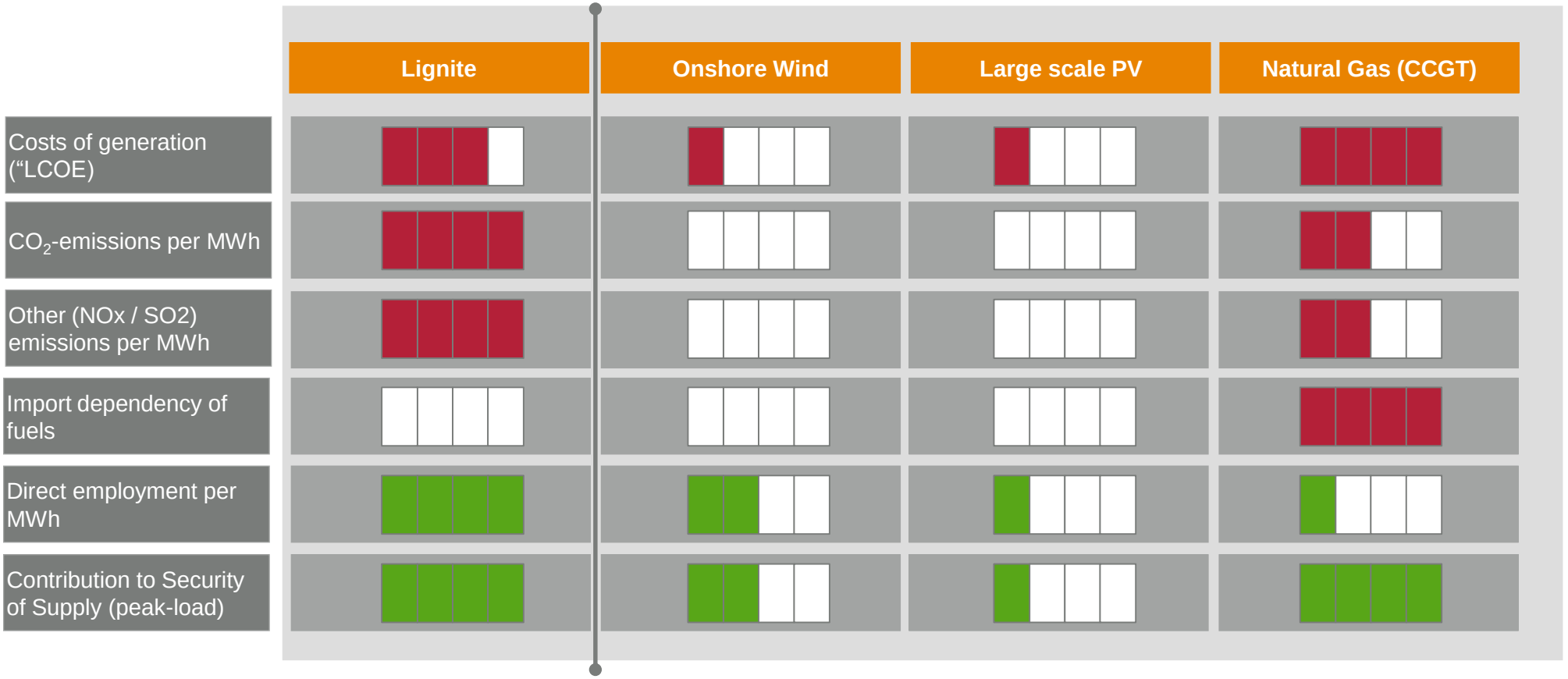
Overview of Replacement Options

The matrix shows a qualitative ranking of replacement options vs. lignite



„More bars = bad“

„More bars = good“



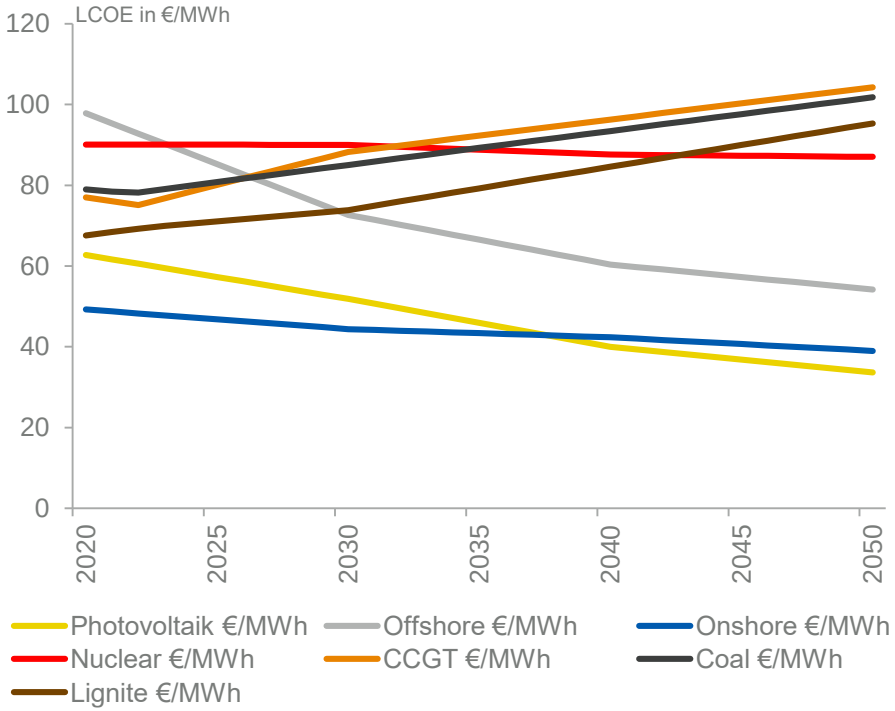
- Different technologies have different strengths & weaknesses
- A mix of technologies is best suited to replace lignite
- enervis’ power market model will optimize the combination of replacement technologies.

Security of Supply: One bar was added for PV because of its contribution to summer peak demand.

Cost Development of Technologies

Forecasted cost developments make RES more and more competitive and therefore an energy-economically attractive option, whereas other generation technologies become less attractive (coal, gas)

LCOE



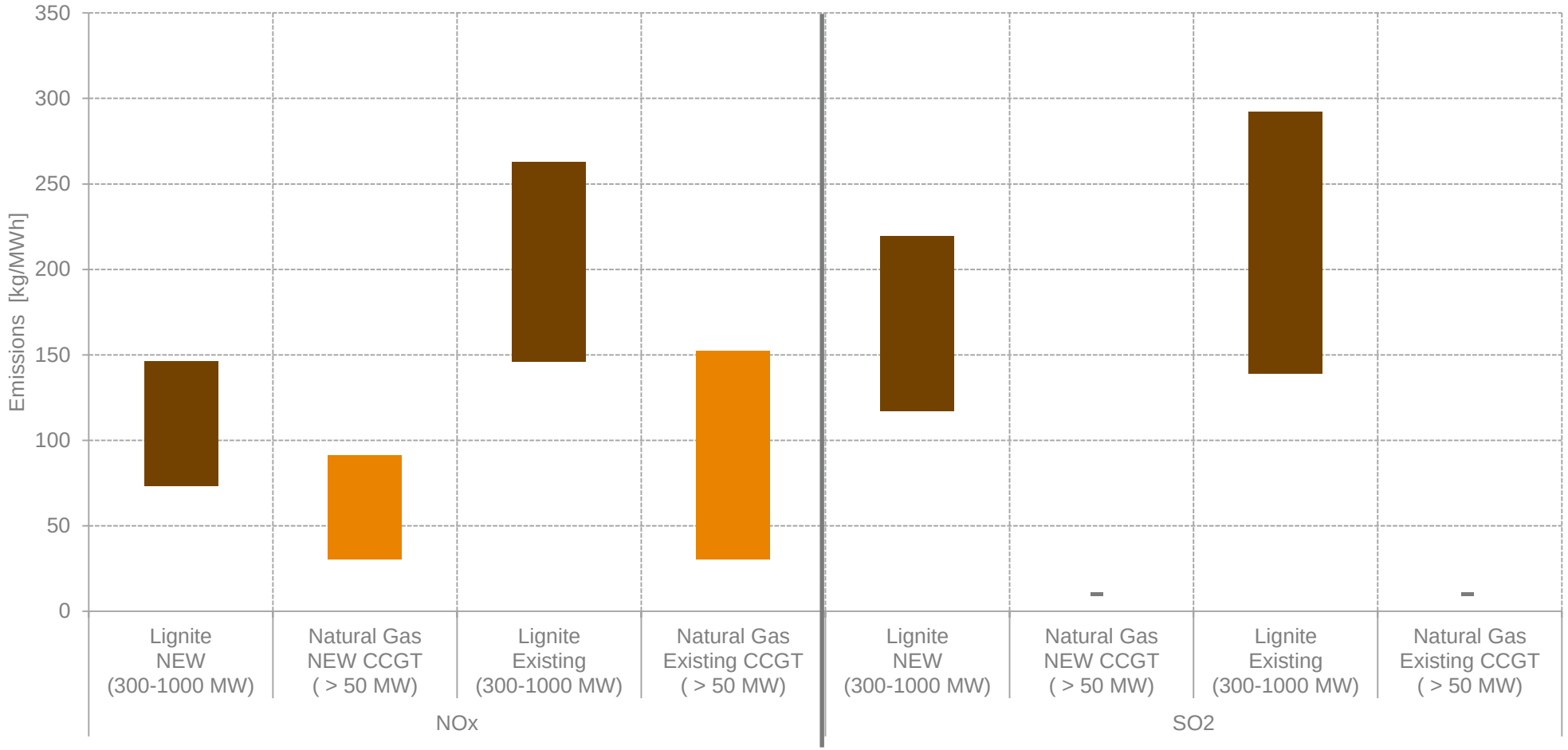
This is based on a compilation of different sources including ASSET (2018), Fraunhofer ISE (2018), BWE / INES (2018), Agora Energiewende 2017. Coal costs include add. costs vs. market prices (e.g. transport costs).

Comments

- **Graph shows the development of average costs of new units of different technologies.**
- **Three trends are clear:**
  - Renewables still see further cost reductions, highest for offshore
  - Conventional technologies see rising costs given rising CO_2- and fuel prices.
  - Nuclear is forecasted to have stable prices (here based on ASSET project funded by EU-Commission)
- **This was calculated with normalized full load hours (4000 for CCGT and 5000 for Coal), not taking into account potential strong reduction in utilization of conventional technologies.**

Emissions of Lignite & Natural Gas

Gas-based generation has significantly lower emissions compared to lignite while wind / PV cause no emissions at all (not included)

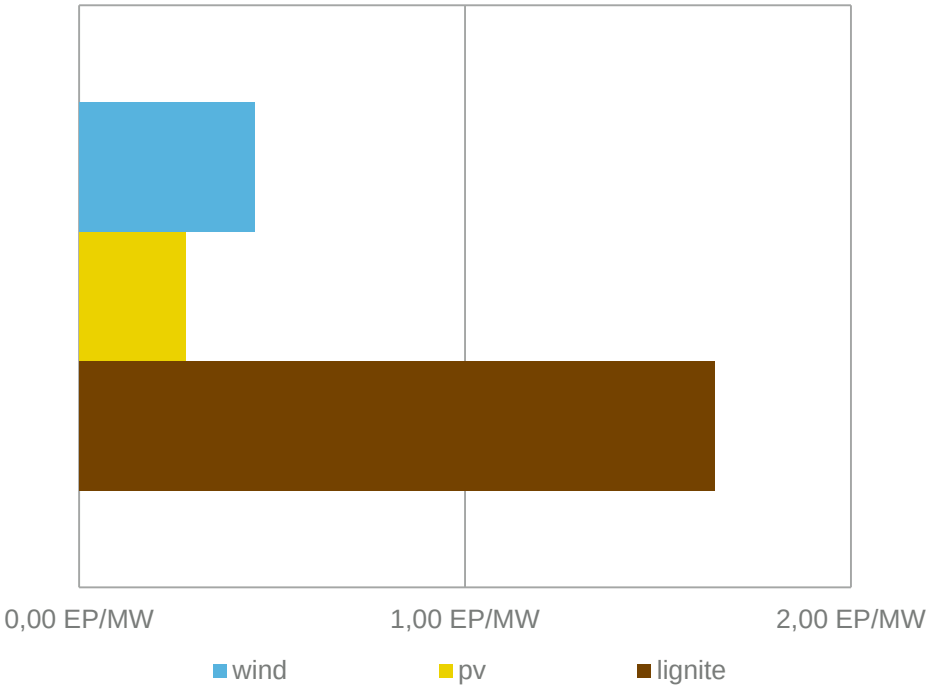


Emission standards according to BAT-AELs.

Assumptions for direct employment per MW

Lignite has high direct employment vs. renewable options…

Direct Employment



Sources: WISE (2019) numbers for PV and wind onshore averaged over lifetime of units for the period of 2021 – 2030. For lignite, 2018 numbers of operators were taken.

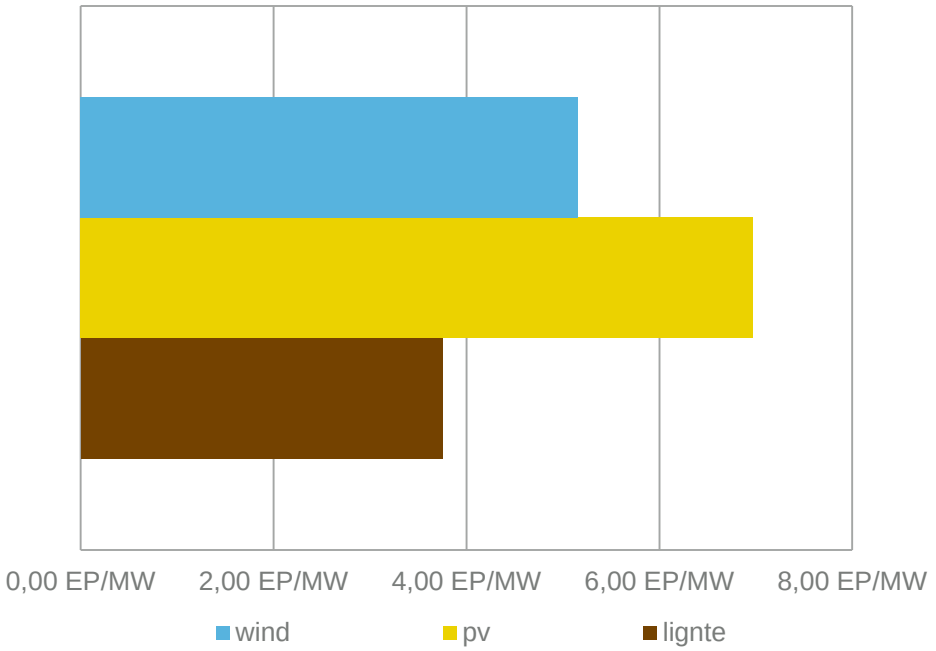
Comments

- For interpretation of employment effects, it needs to be taken into consideration, that each MW of lignite needs to be substituted by more than 1 MW (e.g. three MW) of renewables due to lower utilization of RES.
- Assumptions for RES are based on employment effects for construction and operation of units. For RES employment effects have been averaged over the lifetime of plants (e.g. 20 years).

Average total employment of technologies

…while RES provides valuable indirect employment opportunities.

Total Employment



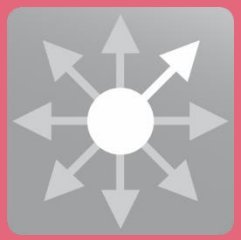
Sources for RES: Fragkos et al (2018): Employment creation in EU related to renewables expansion. For lignite: DEBRIV, EEFA, Öko-Institut.

Comments

- Total employment includes indirect employment effects beyond operation and construction (e.g. manufacturing).
- For RES employment, average European numbers were taken, since data for RES-industries in Poland has shown strong annual fluctuations (see Observ'ER 2017 & 2018)
- For lignite total employment was estimated based on direct employment and indirect employment multiples (approx. 2.5)

Interim Summary

COST DEVELOPMENTS



- It is of increasing significance to align the Polish system with technological “mega trends”. Here, renewables (RES) see further cost reductions, highest for offshore wind, while conventional technologies see rising costs given CO_2- and fuel price increases.

EMISSIONS & EMPLOYMENT

- Gas-based generation has significantly lower (NOx, SO2) emissions compared to lignite while wind / PV cause no emissions at all.
- Whereas lignite provides more direct employment per MW, RES provide valuable indirect employment opportunities.

SCOPING OF TECHNOLOGIES

- Different technologies have different strengths & weaknesses.
- A mix of technologies (RES & gas) is best suited to replace lignite.
- enervis’ power market model will optimize the combination of replacement technologies.

Power Market Scenarios & Core Assumptions

Scenario and Model Overview

enervis Fundamental Power Market Model eMP

enervis can derive the deployment of and investment in power plants based on a techno-economic modelling approach. Interactions between regions are captured via interconnection capacities.

INPUT
(initial analyses and databases)

Policy / framework

Weather data

Load development

Interconnections

Commodities
fuels, CO_2, transport costs, exchange rates

European generation capacities

MARKET MODEL
(fundamental simulation)

fundamental energy market model: eMP

- European scope – regional resolution
- hourly and power plant level resolution
- energy market design
- individual analysis: regions, technologies
- individual set of assumptions
- embedded in enervis modelling landscape

RESULTS
(selection)

market prices

- wholesale: spot, intraday
- balancing energy: primary, secondary reserve, tertiary control
- market design
- CO_2 certificate prices
- income of interconnectors

standard evaluation

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

individual evaluations (examples)

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

Scenario Framework & Storylines

Two scenarios for the Polish power sector 2020-2050 are modelled / “Reference” is based on current national energy policy and functions as a baseline for the system level assessment / “Coal Exit” assumes a coal phase out by the mid 2030ies and relies more on renewables

	Reference Scenario	Coal Exit Scenario
Storylines	• **Adoption of current national energy policies**	• **Significant alignments of national energy policy with European and global climate targets**
	• Ongoing **commitment to coal-fired generation** • Low ambition and support for expansion of renewables, particularly onshore wind • Commissioning of domestic nuclear units is not considered economically feasible and not assumed in the scenario	• Ambitious phase-out trajectory for entire national coal and lignite fired fleet with zero coal capacity **by 2035** end • **System-level** decline of coal capacities is replaced with cost-efficient mix of renewables (wind onshore and solar photovoltaics) and gas-based capacities • **Plant-level** decline of lignite generation from Bełchatów lignite power plant is replaced with additional wind onshore and PV capacities
	• Power sector remains **carbon-heavy** and **renewable expansion limited**	• Coal generation is offset by increasingly **market-based expansion of renewables** with gas capacities providing SoS

Overview of Core Scenario Assumptions

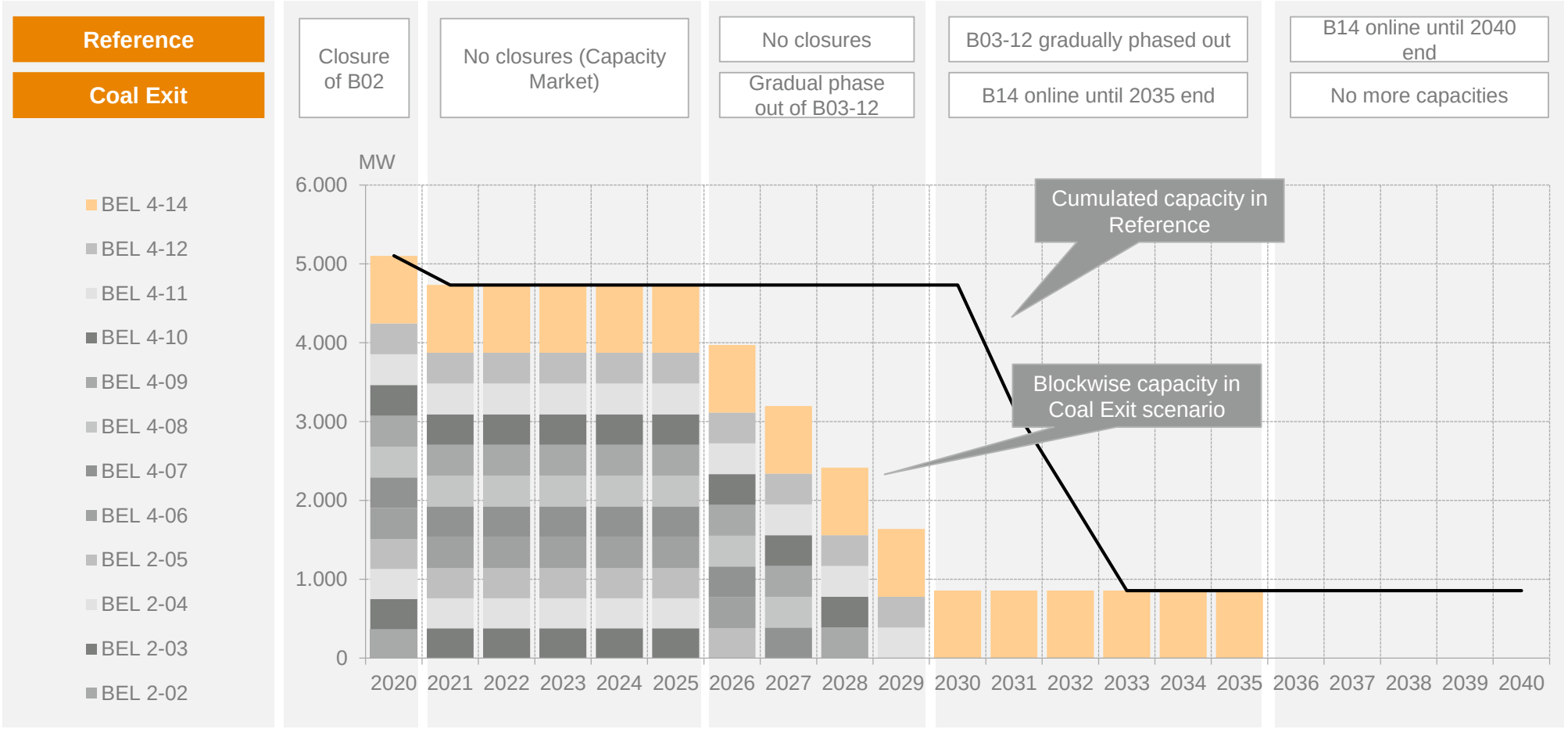
Two scenarios for the Polish power sector 2020-2050 are modelled / “Reference” is based on current national energy policy and functions as a baseline for the system level assessment / “Coal Exit” assumes a coal phase out by the mid 2030ies and relies more on renewables

	Reference Scenario	Coal Exit Scenario
Fuel and CO_2 Prices	**Until 2022**: futures quotes Q1 2019 **Long-term**: IEA WEO 2018 “New policies Scenario”	
Nuclear Capacities	No future commissioning of nuclear capacities in Poland	
Bełchatów Lignite Power Plant	Trajectory according to plant lifetime and projections based on PEP 2040	Stepwise closure of Bełchatów blocks B02-12 before **2030**, B14 by **2035**
Other Coal Capacities		National coal phase-out in Poland by **2035**
Gas Capacities	Deployment according to economic feasibility within the scenario	
Renewable Energy Capacities	Mid-term trajectory for wind onshore, offshore and PV based on PEP 2040 and current projections	Replacement of Bełchatów generation by mix of wind onshore and PV Additional deployment of wind onshore and PV capacities according to economic feasibility (LCOE)
Power Demand	Increase in demand according to PEP 2040 projections (avg. 1.7% p.a. 2018-2040) due to E-mobility & GDP growth. Total 230 TWh in 2040.	

Trajectory for Bełchatów Lignite Power Plant Capacity

Trajectory for Bełchatów Power Plant Capacity*

Phase I blocks B02-B12 of Bełchatów site (commissioning 1983 to 1988) to be retired first and before 2030 in Coal Exit Scenario / Phase II blocks B14 (commissioning 2011) phased out in 2035



Sources: PSE, PGE announcements. B01 was decommissioned in June 2019.

* as of January 1st.

Fuel and CO_2-Price Assumptions

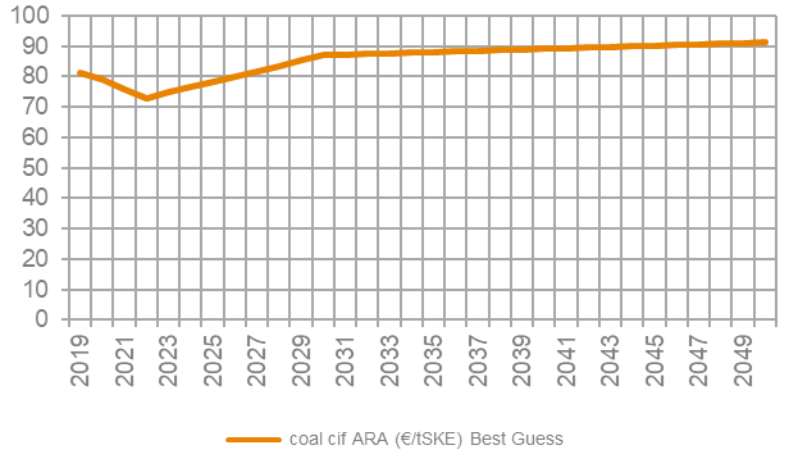
Fuel price development

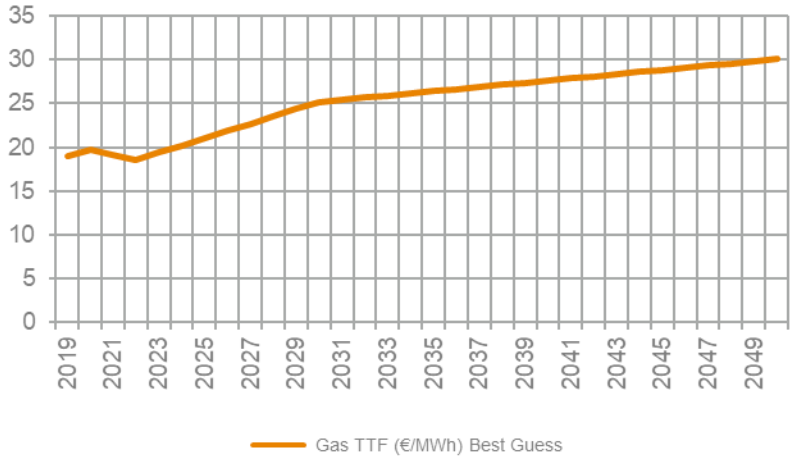
Short-term: futures quotes Q1 2019 / Long-term: price development according to long-term study World Energy Outlook 2018 New Policies Scenario

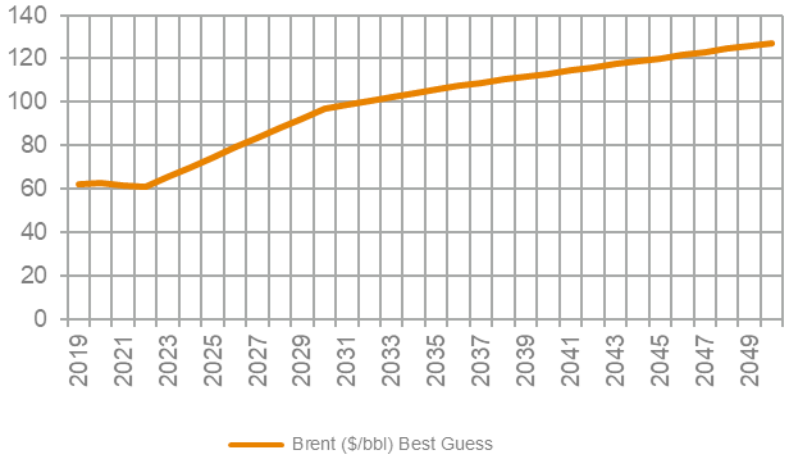
	Brent Oil	Gas	Coal	CO_2
2019 - 2022	Average future quotes Q1 2019 for front years			
2023 - 2030	Interpolation between futures quotes 2022 and projections for 2030 of the World Energy Outlook 2018			
2031 - 2040	Projections „New Policies Scenario“- World Energy Outlook 2018			
after 2040	Extrapolation of price development 2039/40			

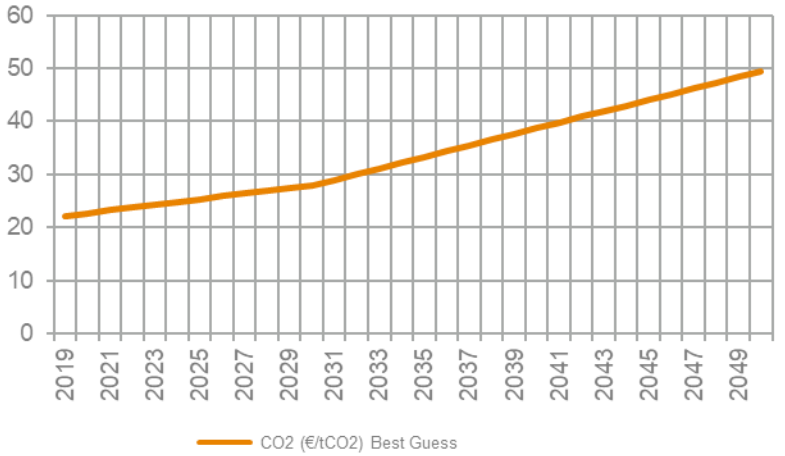
Fuel and CO_2 price assumptions*

Short-term: future quotes Q1 2019 / Long-term: price development according to long-term study World Energy Outlook 2018 “New Policies Scenario”







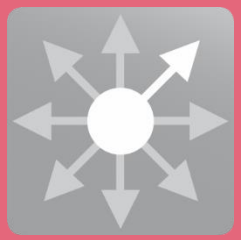


* Real 2019 excl. country-specific transport and structuring costs.

Interim Summary

Interim Summary

SCENARIOS



- Two scenarios were modelled, a “Reference” scenario functions as a baseline for the sake of comparison, while a “Coal Exit” scenario describes a more sustainable development with less coal and more renewables.

REFERENCE

- ”Reference” is mainly based on current Polish energy policy, with the exception, that nuclear energy was excluded from the scenario.
- This is based on a general assessment of the likelihood of deployment of nuclear plants.

COAL EXIT

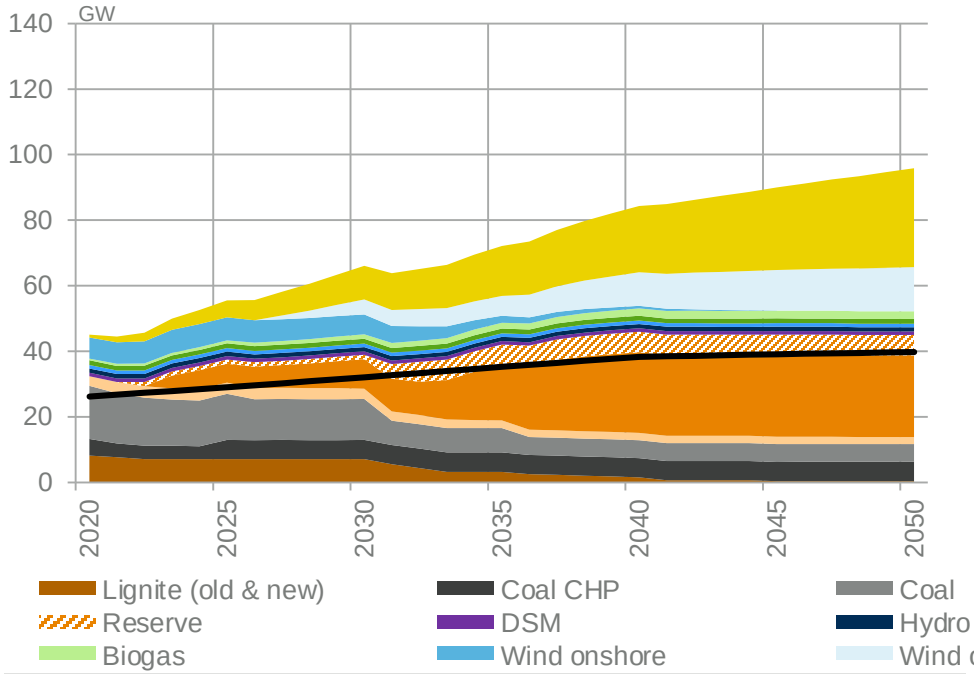
- Coal Exit assumes a national coal phase out by the end of 2035. Most Bełchatów units are phased out by 2030.
- Generation of coal is substituted by RES, while gas provides Security of Supply.
- An additional Sensitivity allows for a deeper analysis of the effects of Bełchatów.

Capacity and Generation

Capacity Structure

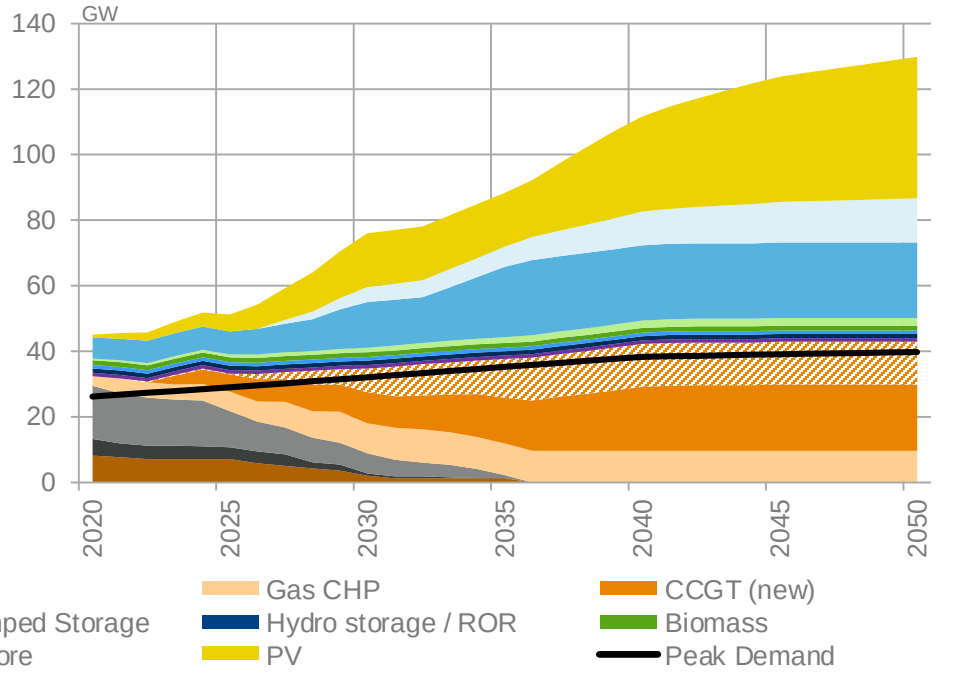
Decline in coal capacities is replaced by mix of renewables and gas-fired capacities

Reference



- Graph shows the development of power generation capacities in Poland from 2020-2050 including backup capacities (Gas GT)
- In the Reference, lack of political backing for wind onshore and lack of ambition in PV expansion results in a low renewable deployment
- Capacity demand is provided with CCGT and OCGT

Coal Exit

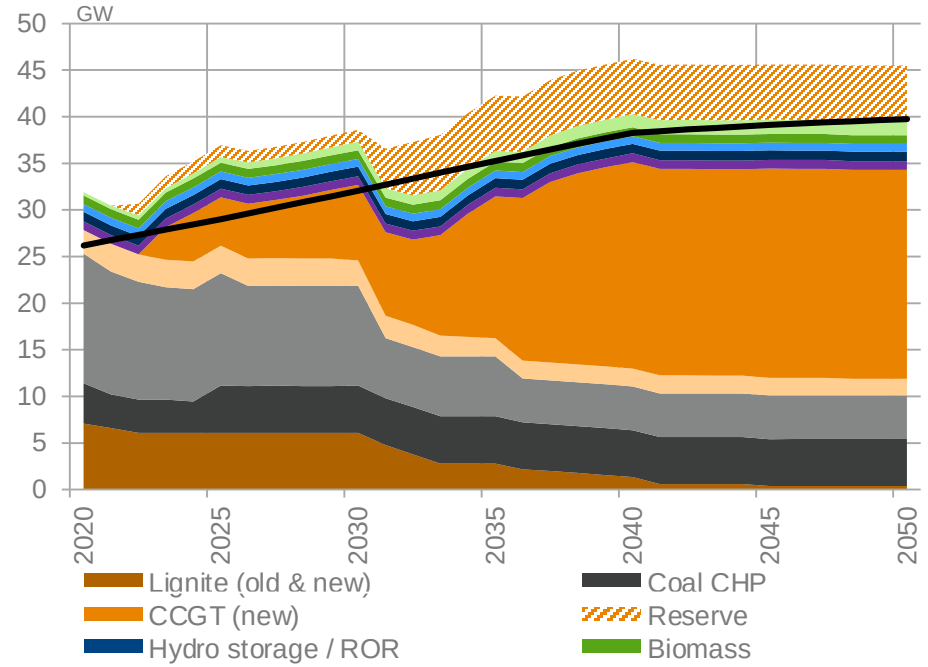


- Graph shows the development of power generation capacities in Poland from 2020-2050 including backup capacities (OCGT)
- Onshore wind and photovoltaics, mostly market driven, offset the decline of coal capacities from the mid 2020ies
- Cogeneration from coal-based assets is replaced by CHP gas

Focus on Security of Supply

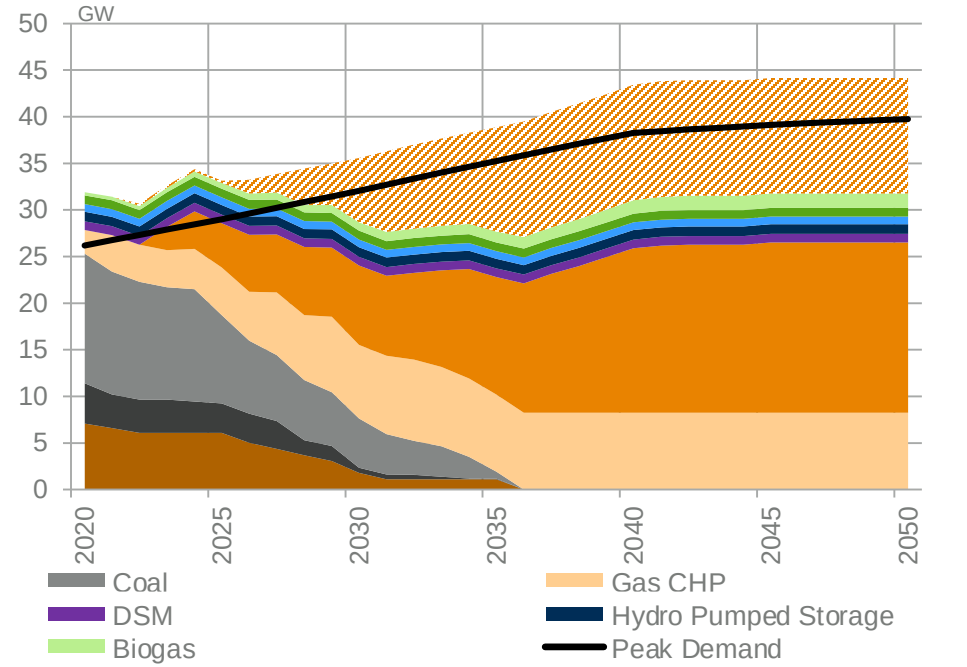
A more gas-heavy capacity mix in Reference results in less need for backup capacity compared to the needs of a more volatile system profile in Coal Exit / Level of reserves beyond peak load were modelled based on the assumption, that spare capacity needs to be deployed within Poland

Reference



- Graph shows the capacity development of dispatchable technologies only versus residual peak load (capacity was derated to asses SoS effect)
- As extension of (dispatchable) capacities incentiviced by wholesale power prices is not sufficient, a capacity reserve is required from the early 2020ies that increases to roughly 6 GW in the long run

Coal Exit

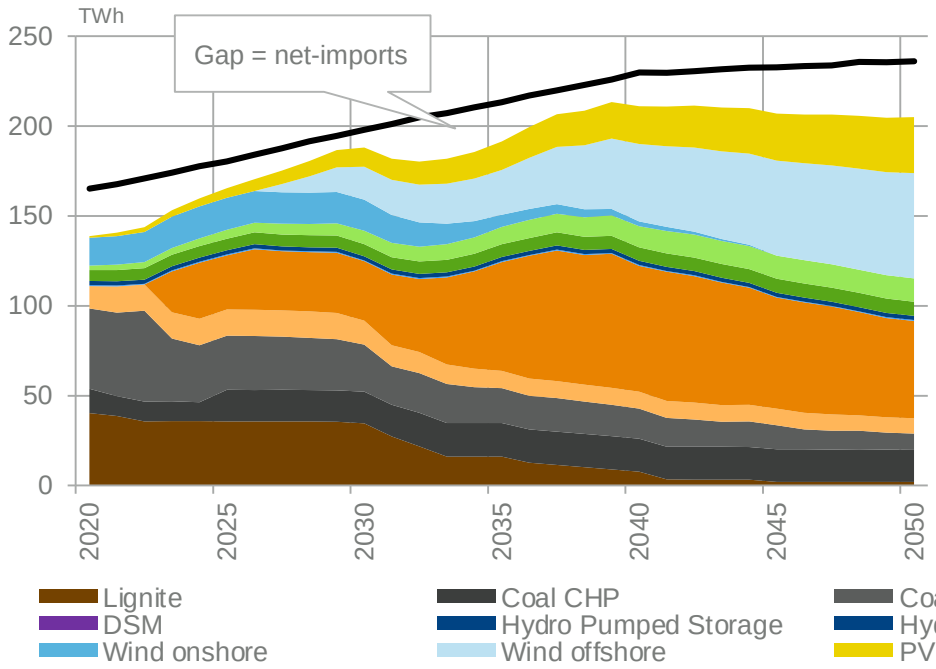


- Graph shows the capacity development of only the dispatchable generation technologies versus residual peak load (capacity was derated to asses SoS effect)
- With more renewable capacities at the expense of gas-based in the market, there is a higher need of backup capacities in the Coal Exit scenario

Generation and Demand

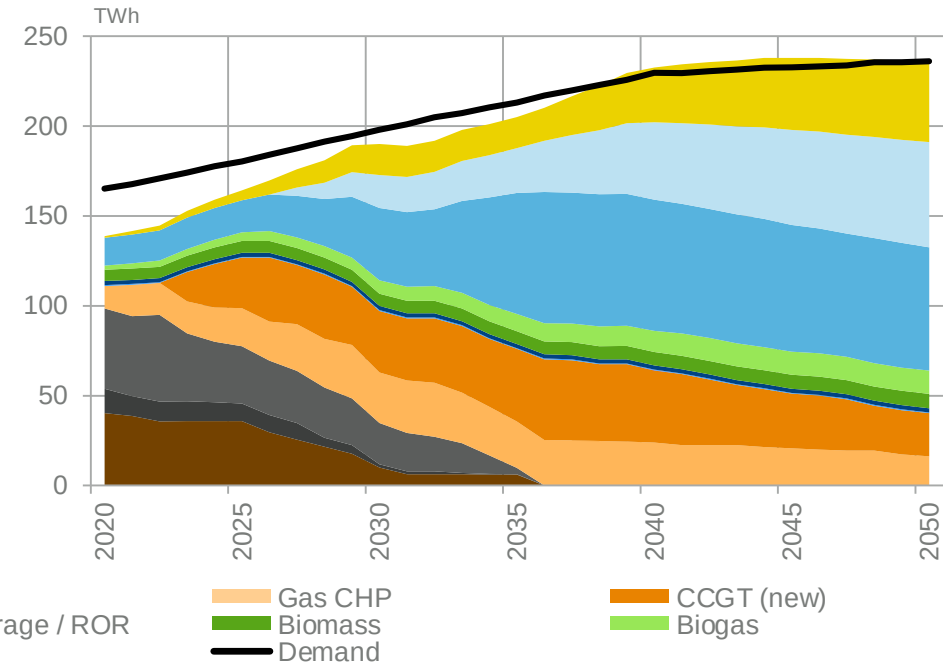
Phasing out coal while fostering renewables allows for an overall balanced mix and a neutral import / export balance

Reference



- Graph shows the development of demand and power generation per technology from 2020-2050
- Without nuclear and not enough renewables the system relies strongly on gas and imports

Coal Exit

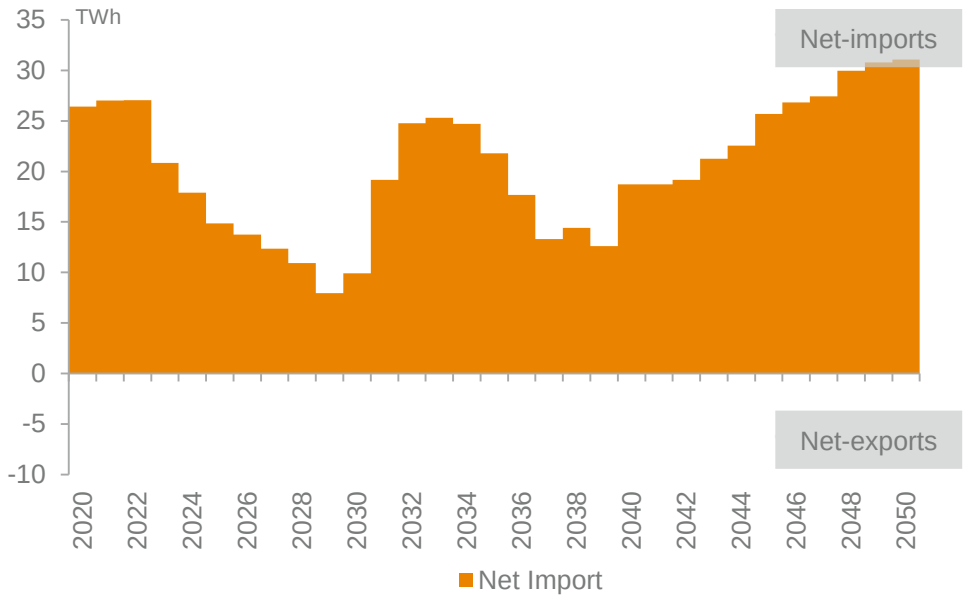


- Graph shows the development of demand and power generation per technology from 2020-2050
- While coal declines, renewables and gas dominate the outcome long-term
- Overall generation aligns well will demand, allowing for a balanced import / export situation

Import / Export Balance

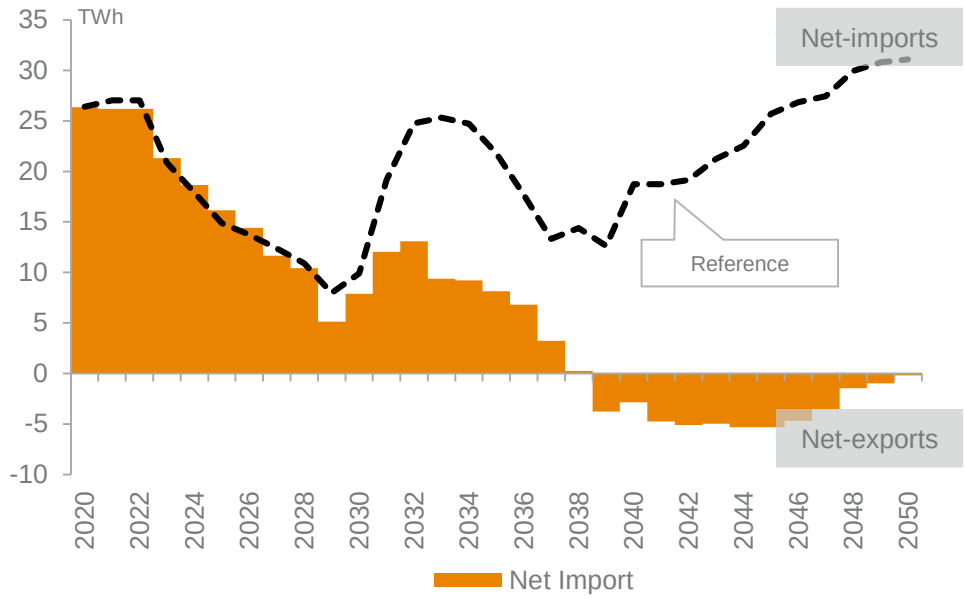
Poland stays net-importer of electricity in Reference while the trade balance evens out in the long run in Coal Exit

Reference



- Graph shows the annual net-balance of electricity traded with neighboring regions
- Due to relatively expensive generation mix compared to neighboring regions which see increasing share of renewables, Poland remains net-importer of electricity in Reference

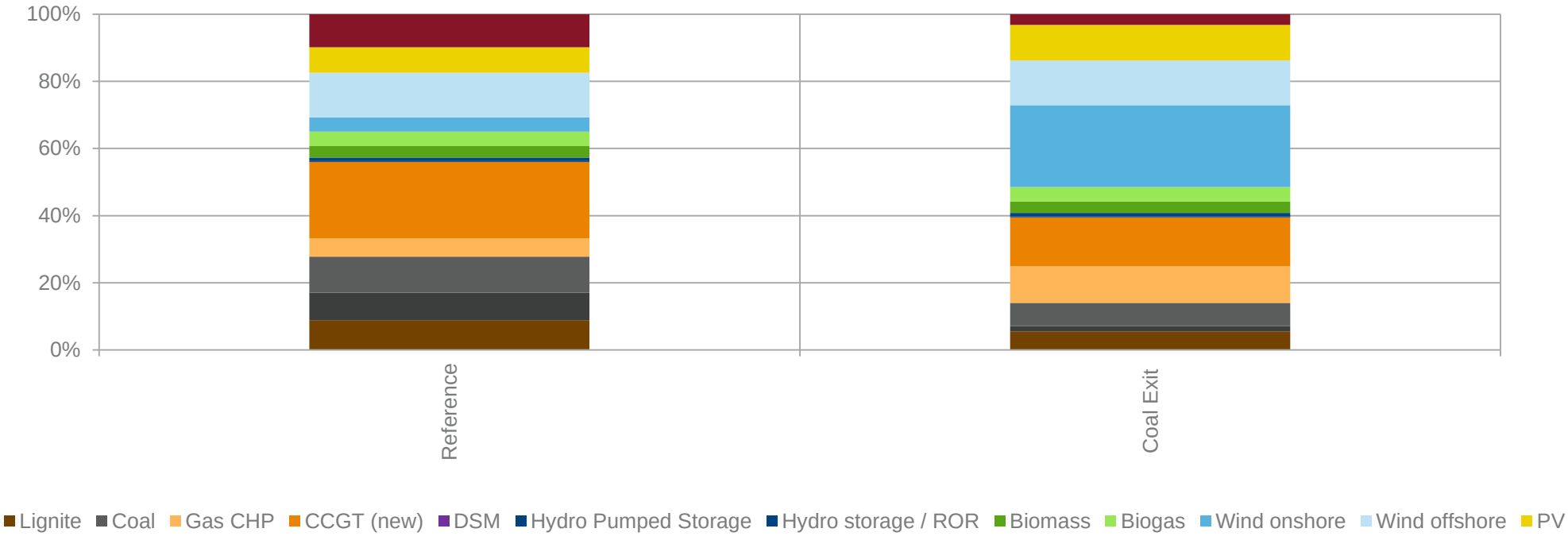
Coal Exit



- Graph shows the annual net-balance of electricity traded with neighboring regions
- As Coal Exit scenario deploys significantly more domestic renewables, the export balance is about even in the long run after a decade of net-exports

Generation structure*

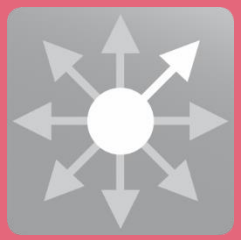
The graph shows shares of different technologies in overall wholesale power generation 2020-2050 (sum of generation of all years) / The total share of fossil-based generation is close to 60% in Reference, half of it stemming from coal / The fossil share is reduced to around 40% with a Coal Exit strategy with an even stronger reduction in the coal-based share



* Here, reserve capacities by definition are not taking part in the wholesale market and hence not dispatched by the model.

Interim Summary

GENERATION MIX



- In the Reference, lack of political backing for wind onshore and lack of ambition in PV expansion results in a low renewable deployment.
- In the Coal Exit scenario onshore wind and photovoltaics, mostly market driven, offset the decline of coal capacities from the mid 2020ies.

SECURITY OF SUPPLY

- SoS is assured in all scenarios, given a certain reserve is installed.
- High shares of RES can be integrated in the system with little curtailment and SoS issues if natural gas (and potentially storage) can be utilized as backup.

IMPORTS

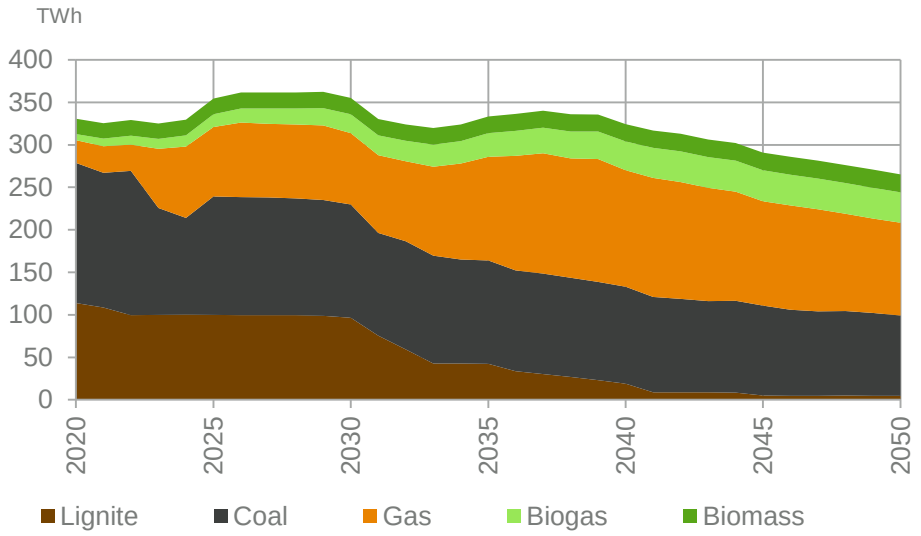
- RES allow for a reduction of import dependency in the power sector, while conventional generation cannot meet the growing Polish power demand.

Fuel Demand & Emissions

Development of Fuel Demand*

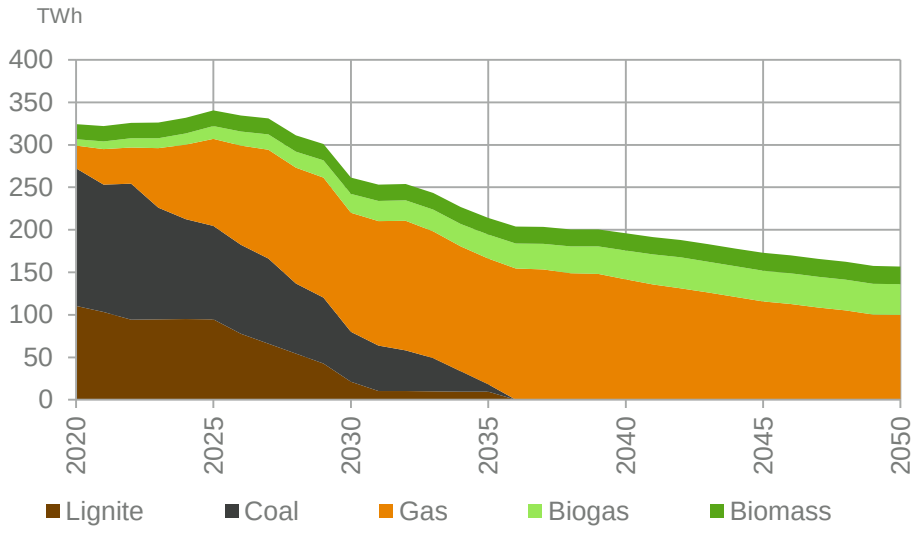
Both scenarios see an increase in gas demand, stronger even in Reference due to the lack of RES expansion

Reference



- Long-term fuel demand consists of hard coal and gas. Hard-coal is assumed to be imported long-term by many studies (see Wise / enervis 2017)

Coal Exit



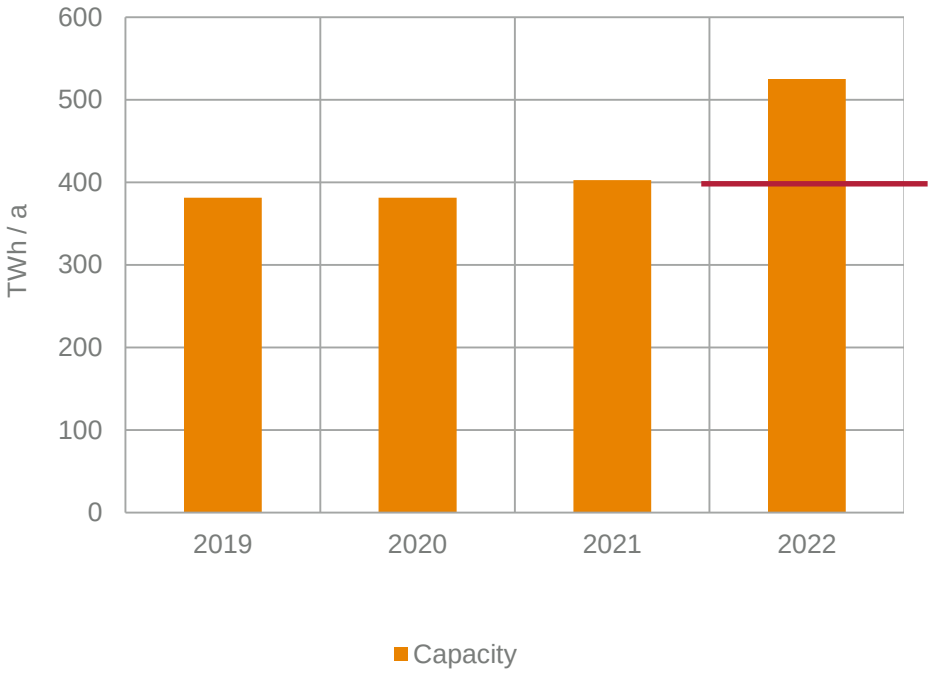
- Even though gas demand increases further RES & storage or CO_2-neutral gas could cut natural gas demand further
- Gas demand is in cogeneration by a significant degree

* In this analysis, fuel demand of the power sector is included, while heating and other sectors are not covered.

Gas Import Capacity Poland

Gas demand of both scenarios can be met by additional gas import capacity from the north / LNG

Import Capacity Poland



Source: Compilation based on GAZ system (2018): GASI NTERCONNECTION POLAND – LITHUANIA (GIPL) STATUS AND POTENTIAL IMPACT ON THE BALTIC STATES MARKET.

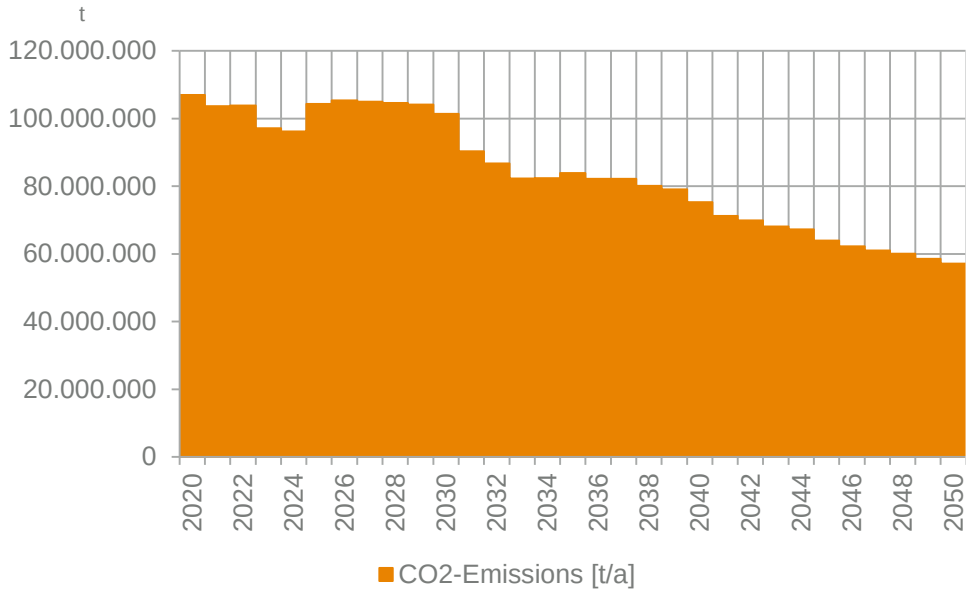
Comments

- **PL has a lot of import capacity (here excl. Belarus, rough estimate)**
  - Full capacity of *Swinoujscie LNG terminal (7,5 BCM) is expected for 2022*
  - *Baltic Pipe (10 BCM)* which are expected for 2022
- **We assume, that the additional capacity provided by these two projects here (122 TWh Ho / a) from 2022 on is the max to be absorbed by gas-based power generation.**
- **All other capacities are assumed to go to the heating sector.**

Development of CO_2-Emissions

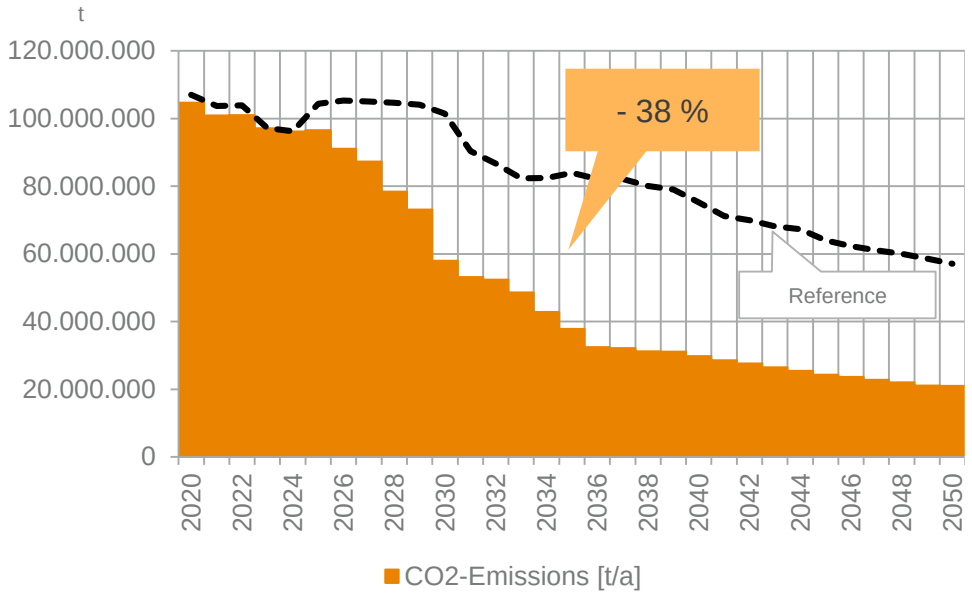
While CO_2-emissions already decline in the Reference due to age-based phase out of the most CO_2-intensive plants, in Coal Exit the reduction is both earlier and significantly higher

Reference



- Graph shows the development of fossil CO_2-emissions from the power sector
- Yearly CO_2-emissions almost halve in Reference by 2050 due to technical retirements of coal-based assets

Coal Exit



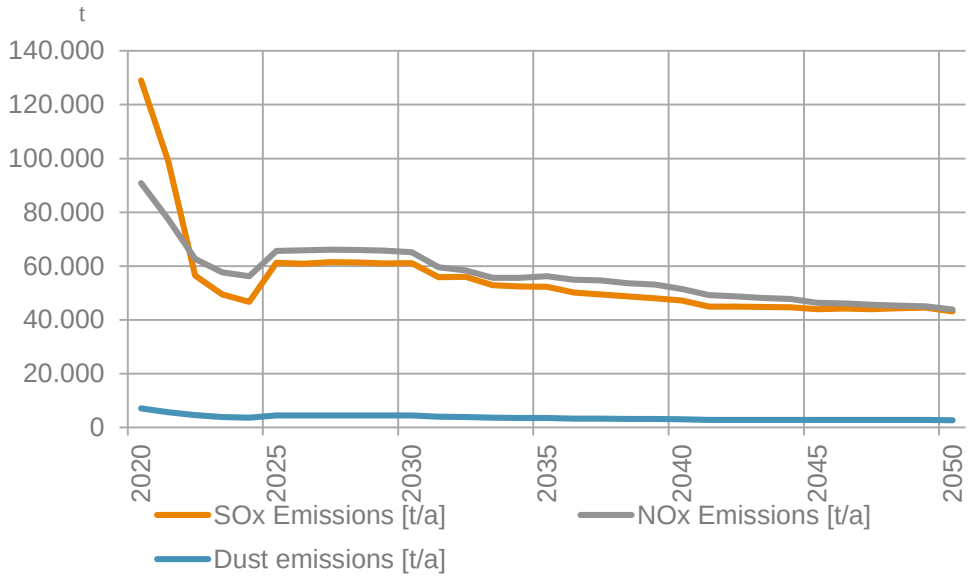
- Graph shows the development of fossil CO_2-emissions from the power sector. CO_2-emissions decline sharply in the period from mid 2020 to mid 2035 due to closure of all coal and lignite plants
- A certain emissions persists due to remaining gas-generation. This demonstrates a need for Deep-Decarbonization technologies* to cut emissions further (RES & storage or CO2-neutral or renewable gas)

* Deep-Decarbonization Technologies are technologies to cut emissions at relatively high but stable (not exponentially increasing) CO2-abatement costs. They are therefore suitable to reduce “the last” remaining emissions of sectors (e.g. moving from -80 % to -95 % vs. 1990).

Development of Other Emissions

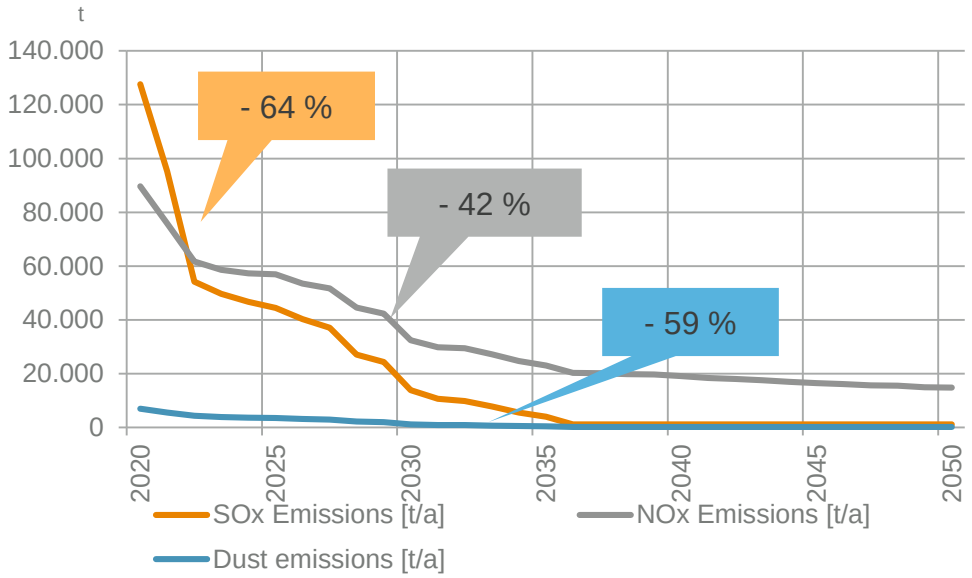
SOx and dust emissions are reduced to close to zero in the Coal Exit pathway while NOx remains stable on a low level after initial sharp decline due to a sustained share of gas generation

Reference



- Graph shows the development of other emissions from power plants which can be related to health costs
- After a decline due to retrofitting measures and planned closures of coal-fired capacities, the level of SOx, NOx and dust emissions stagnates in the Reference

Coal Exit

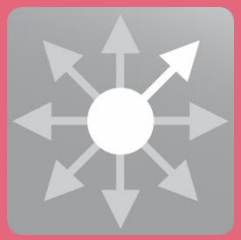


- Graph shows the development of other emissions from power plants which can be related to health costs
- The emission of SOx and dust can be terminated by the Coal Exit while the remaining share of gas results in continued emission of NOx well below the level of Reference

Sources: Estimates are based on BREF limits for plants.

Interim Summary

FUEL DEMAND



- Though gas demand increases, demand of both scenarios can be met by additional gas import capacity (LNG,..).
- Reference relies on hard coal and gas. Coal is assumed to be imported long-term by many studies.
- In Coal Exit, gas demand is in cogeneration by a significant degree.

CO2-EMISSIONS

- A Coal Exit leads to a sharp decline of CO_2-emissions in the period from mid 2020 to mid 2035 due to closure of all coal and lignite plants in that period.
- Overall CO_2 emissions decline by almost 1 bn. t 2020-2050.

OTHER EMISSIONS

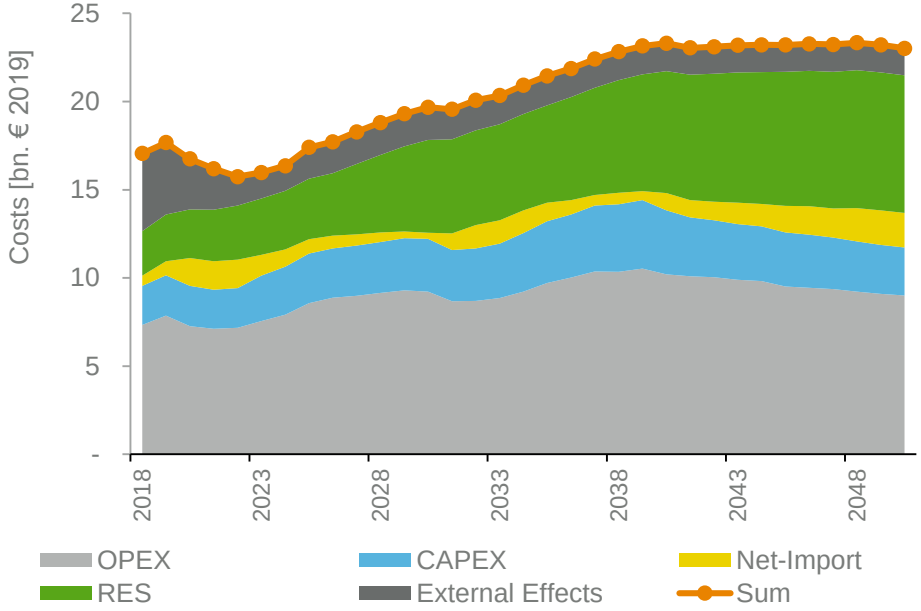
- The emission of SOx and dust can be terminated by the Coal Exit while the remaining share of gas results in continued emission of NOx well below the level of Reference.
- This translates to health benefits for the Polish population and a prolonged lifetime.

Total Costs of Power Generation

Development of Costs of Power Generation

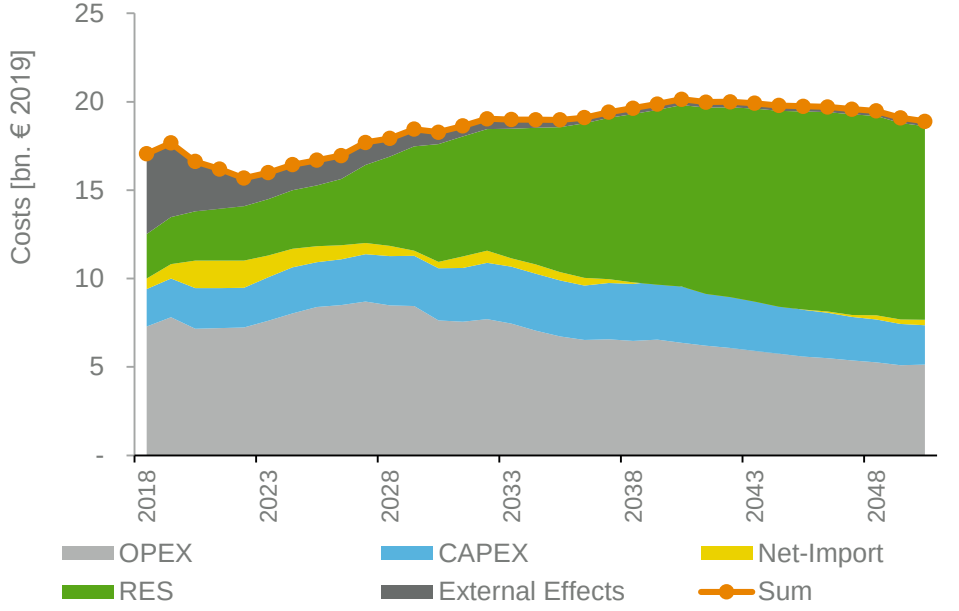
A consistent Coal Exit strategy stabilizes system costs and thus leads to relevant cost decreases vs. the increasing costs of the Reference scenario.

Reference



- Graph shows costs of powers generation (excl. grid costs)
- Initial cost decrease caused by strong reduction in external effects (health), then costs start to increase, driven mostly by renewable-related cost effects

Coal Exit



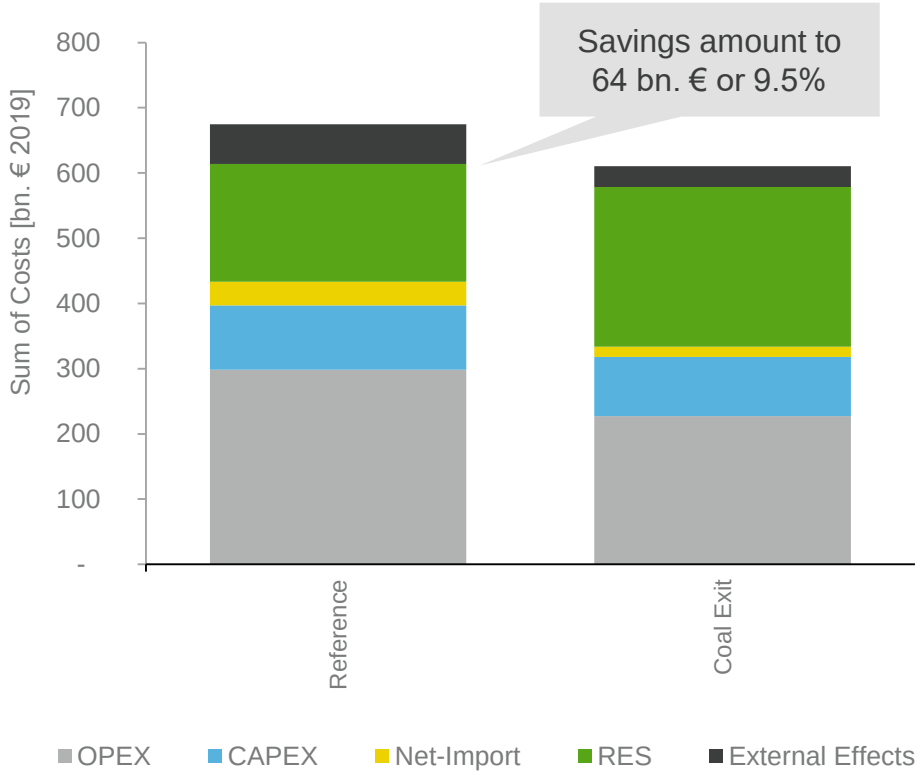
- Coal Exit scenario sees stable costs and thus allows a savings vs. Reference
- Though costs for RES are higher, savings occur in OPEX, imports and external effects

* OPEX (“Operational expenditure”) and CAPEX (“capital expenditure”) represent costs of non-renewable generation technologies, while “RES” include OPEX and CAPEX of Renewables.

Sum of Costs of scenarios

Coal Exit scenario has significantly lower total costs of power generation / Difference equals 9.5 % of overall system costs and thus represents relevant savings

Sum of Costs



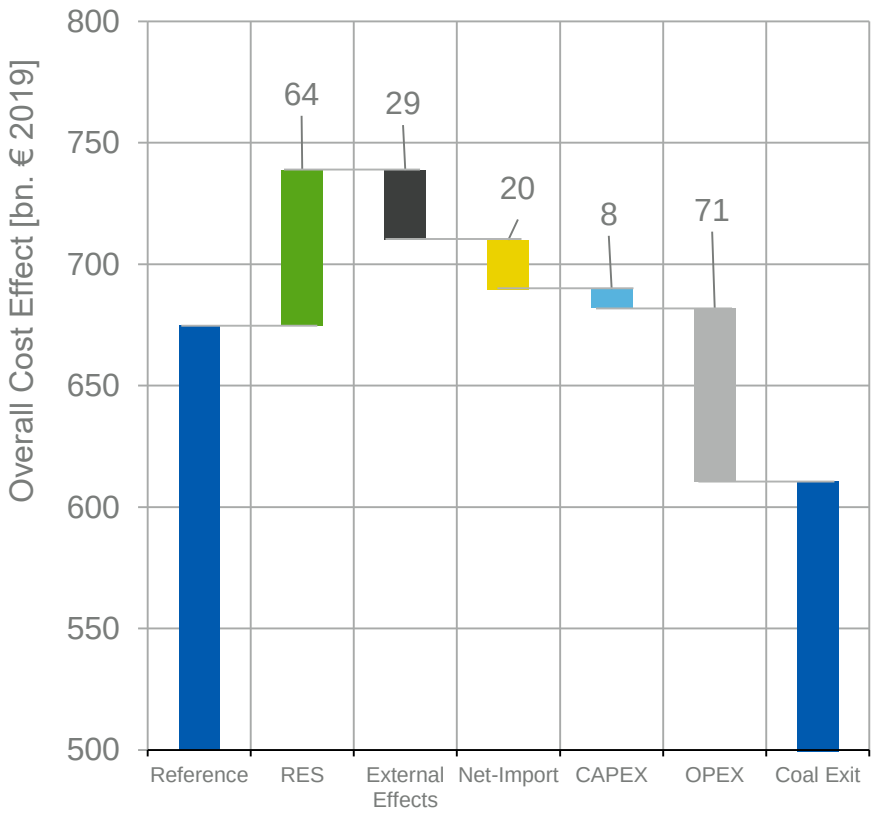
Comments

- **The graph shows overall costs of the scenarios. The bars represent sums of different cost component over 2020-2050.**
  - Coal Exit scenario has lower total costs of power generation.
  - Savings amount to 64 bn. €
  - This equals to 9.5% of overall system costs and thus represents relevant savings
- **A consistent Coal Exit strategy therefore contributes to cost efficiency of the Polish economy**

Focus on Cost Effects

Though Coal Exit scenario has more costs for RES, these prove to be a „good investment“, cutting costs for OPEX, CAPEX and imports / on top of that, less external effects basically imply better health for the Polish population.

Sum of Costs

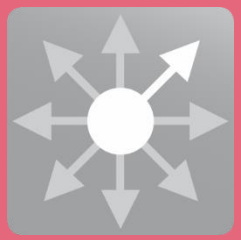


Comments

- **Comparing costs allows for observing the following effects:**
  - RES costs are higher in Coal Exit scenarios vs. Reference.
  - Since Reference relies stronger on gas (less RES) this causes additional OPEX and some CAPEX
  - Coal-Exit (more precisely more RES deployed in that scenario) also reduces import costs, contributing to import independency of the Polish power market
  - Due to lower levels of coal generation, levels of external effects are lower in Coal Exit scenarios. External effects are mainly reductions in life expectancy caused by different emissions (dust, SOx, NOx) monetarized at a certain value (taken from CE DELFT 2018: “Environmental Prices Handbook EU28“). Less external effects thus basically imply better health for the Polish population.

Interim Summary

SCENARIOS



- In the Reference scenario, costs start to increase from 2022 onwards.
- A consistent Coal Exit strategy stabilizes system costs vs. the increasing costs of the Reference scenario.

OVERALL SAVINGS

- Coal Exit scenario has significantly lower total costs of power generation.
- Savings equal 9.5 % of overall system costs and thus represent a significant potential to contribute to cost efficiency of the Polish economy.

EFFECTS

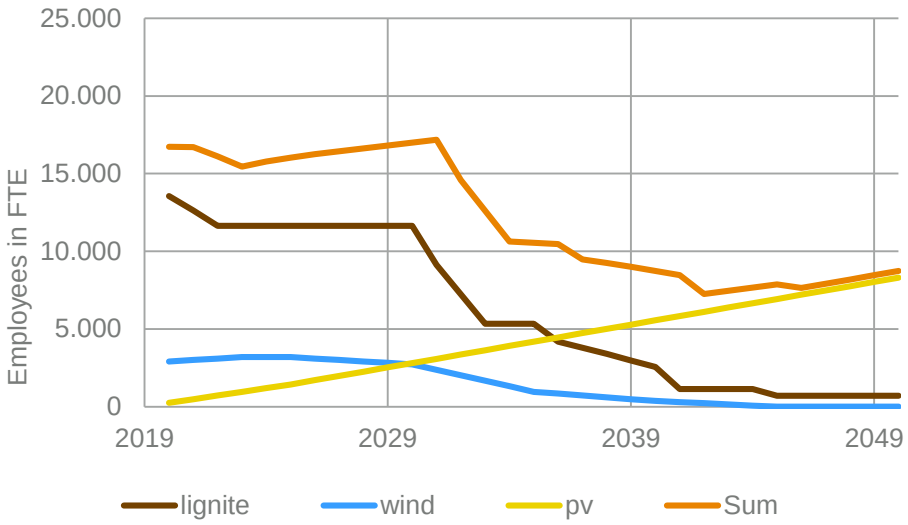
- Coal Exit scenarios has higher costs for RES, these prove to be an „good investment“, cutting costs for OPEX, CAPEX and imports.
- On top of that, less external effects thus basically imply better health for the Polish population.

Employment Effects

Development of Direct Employment

Direct employment for lignite drops while all scenarios see growing direct employment in wind & PV / Employment effects from construction were averaged out over the lifetime of units (this levels out employment effects of construction over time)

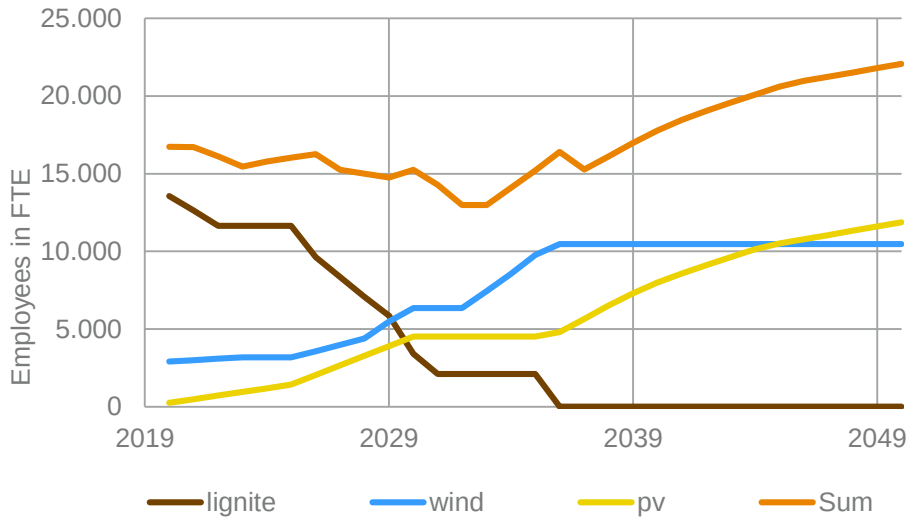
Reference



- Graph shows employment for construction and operation
- Reference sustains some minor employment in lignite until 2050 while wind-onshore phases out and PV gains significance

Sources: Own calculation based on different sources.

Coal Exit



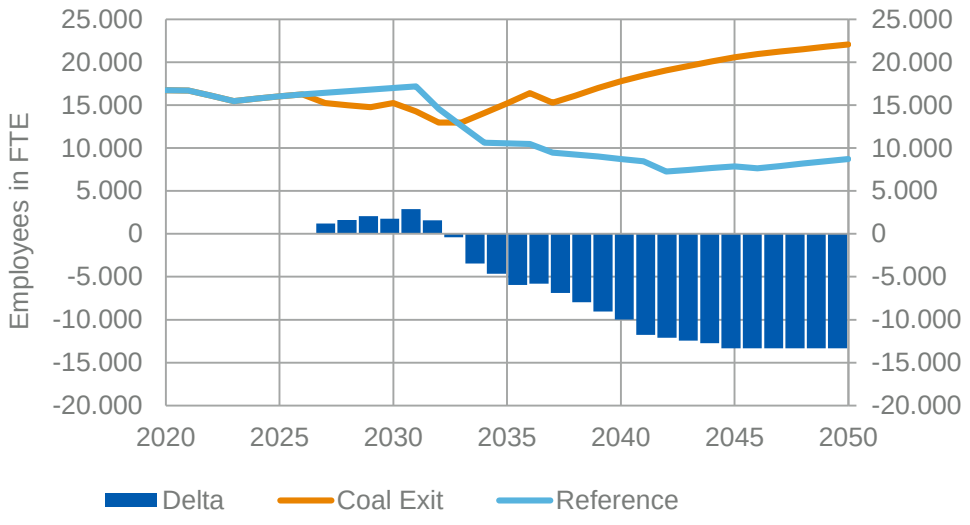
- Graph shows employment for construction and operation
- Coal exit phases out employment in lignite until 2035 while wind-onshore gains significance (until maximal extension of capacities is reached)
- PV is a major contributor to direct employment

Sources: Own calculation based on different sources.

Comparison of Direct Employment

Overall level of direct employment in operations & construction in lignite, wind and PV is significantly higher in the Coal Exit scenario

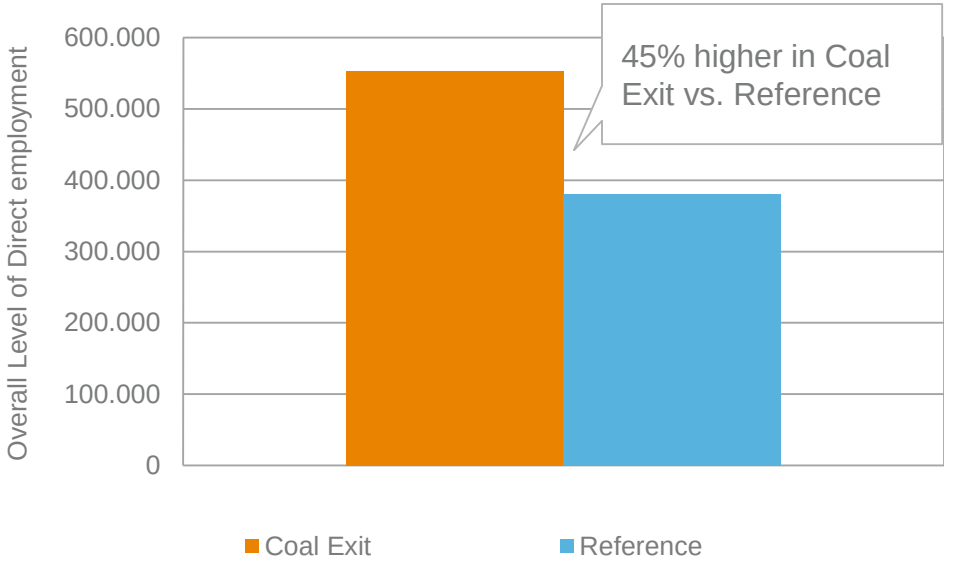
Development



- For a short period, 2026 until 2031, direct employment is higher in Reference, then Coal-Exit scenario dominates until 2050

Sources: Own calculation based on different sources.

Overall Level



- Overall level of direct employment measured in FTE-years until 2050 is higher in the Coal Exit scenario
- Employment is higher by 45% in Coal Exit vs. Reference

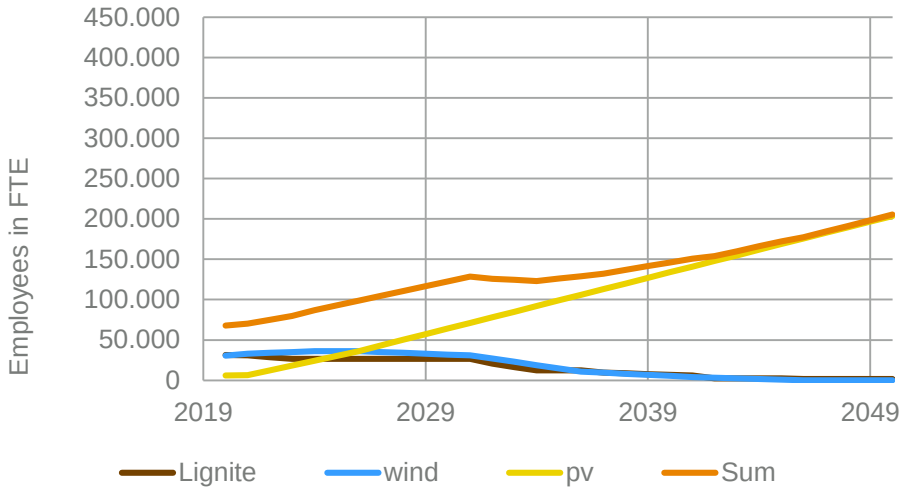
Sources: Own calculation based on different sources.

Development of Total Employment

Estimated total employment for lignite drops while all scenarios see growing employment in wind & especially PV

Estimate

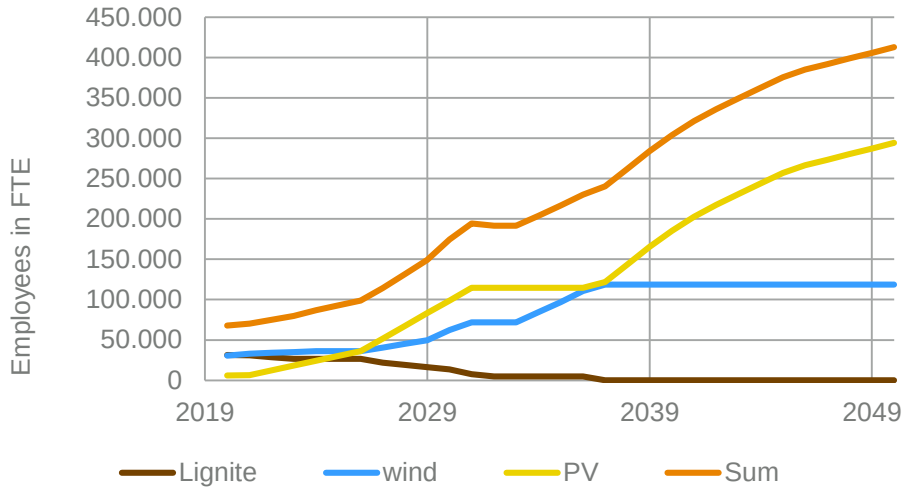
Reference



- Graph shows an estimate of total employment
- Reference sustains some very minor employment in lignite until 2050 while wind-onshore phases out and PV gains significance and dominates the other two technologies

Sources: Own calculation based on different sources.

Coal Exit



- Coal Exit phases employment in lignite until 2035 while wind-onshore gains significance until maximal extension of capacities is reached
- PV is a major contributor to total employment

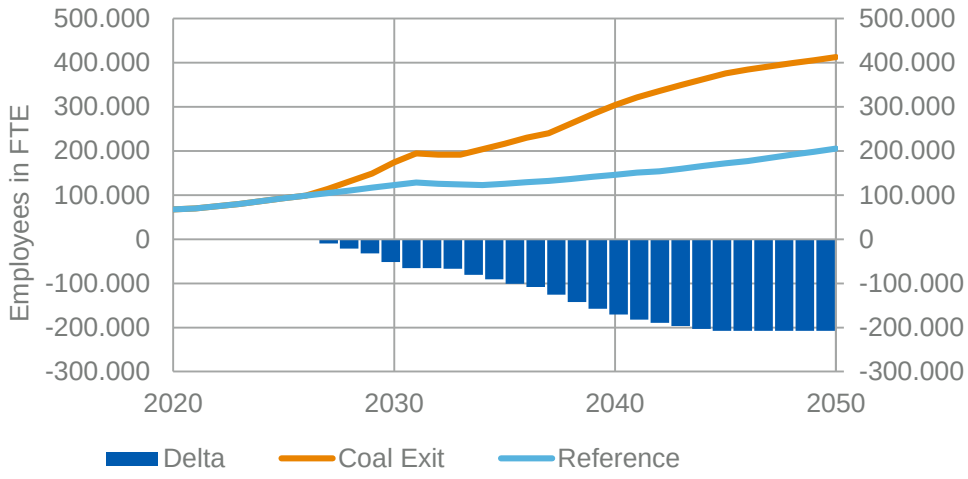
Sources: Own calculation based on different sources.

Comparison of Total Employment

Estimate

Overall level of total employment in lignite, wind and PV is continuously and significantly higher in Coal Exit scenario / Even though this is a rough estimate, this clearly indicated relevant employment opportunities for the Polish workforce provided by the Coal Exit scenario

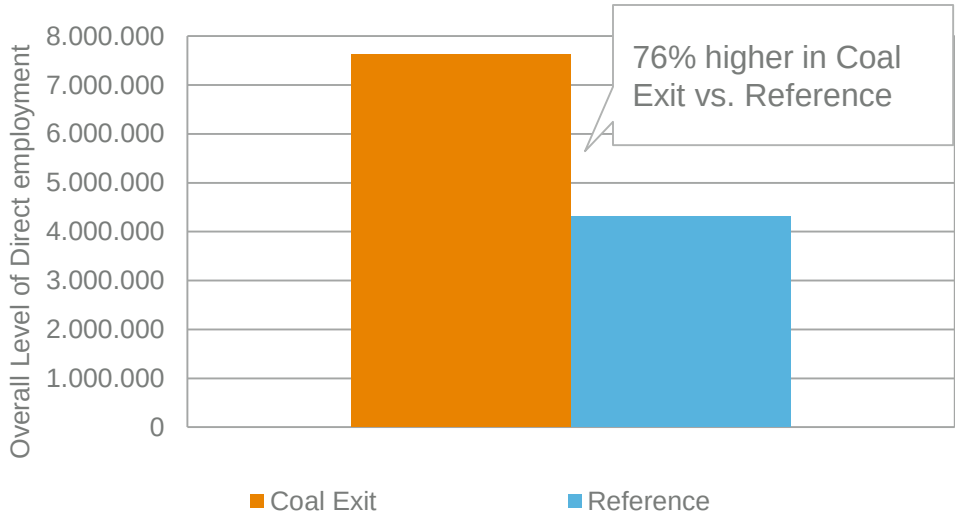
Development



- Total employment is continuously higher in Coal Exit scenario

Sources: Own calculation based on different sources.

Overall Level

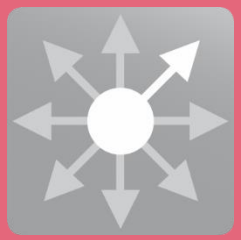


- Overall level of direct employment measured in FTE-years until 2050 is higher in Coal Exit scenario
- Employment is higher in Coal Exit vs. Reference by 76%

Sources: Own calculation based on different sources.

Interim Summary

METHOD



- Using forecasted capacities from the power market model and assumptions regarding the level of employment per technology, an assessment of employment potential for each scenario was prepared.
- PV, wind onshore and lignite were analyzed (excl. hard-coal).

DIRECT EMPLOYMENT

- Overall direct employment for operation and construction is higher in Reference in a short period 2026-2031, then Coal Exit scenario dominates until 2050.
- Direct employment is higher in Coal Exit vs. Reference by 45 %, indicating employment opportunities.

TOTAL EMPLOYMENT

- Total employment (incl. manufacturing etc.) is continuously and significantly higher in Coal Exit vs. Reference.
- Even though this is an estimate, this clearly indicates significant employment opportunities for the Polish workforce by expanding renewables.

Analysis of Bełchatów Effect

Sub-scenario for Analysis of Bełchatów Effect

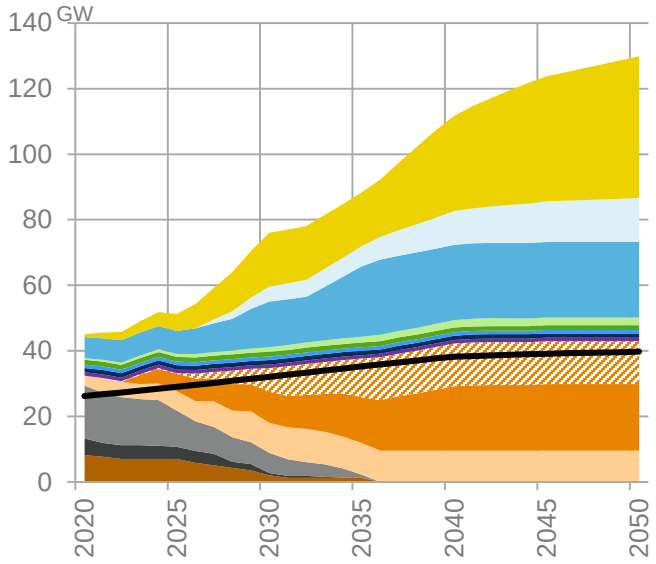
A second version of the Coal Exit scenario was modelled to analytically capture the effect of Bełchatów within the Coal Exit pathway by means of a Sensitivity analysis / Hence, all parameters are kept equal as in the Coal Exit scenario except for the trajectory of Bełchatów capacities

	Reference	Coal Exit Scenario	
		Sensitivity	Coal Exit Scenario
Fuel and CO_2 Prices	**Until 2022**: futu s quotes Q1 2019 **Long-term**: IEA WEO 20 8 "New policies Scenario"		
Nuclear Capacities	No future commissioning o nuclear capacities in Poland		
Bełchatów Lignite Power Plant	Closure according to projections based on PEP 2040	Bełchatów trajectory as in Reference, no phase out	Closure of Bełchatów B02-12 by 2030, B14 by 2035
Other Coal Capacities		Coal phase-out in Poland by 2035	
Gas Capacities	Deployment according to econ mic feasibility within the scenario		
Deployment of Renewable Energy Sources	Mid-term trajectory for Wind Onshore, Offshore and PV based on PEP 2040 and current projections	As in Reference	Replacement of Bełchatów generation by mix of wind onshore and PV
		Additional deployment of wind onshore and PV capacities according to economic feasibility (based on LCOE)	
Electricity Demand	Increase in demand according to PEP 2040 projections (vg. 1.7% p.a. 2018-2040) due to E-mobility & GDP growth. Total 230 Wh in 2040.		

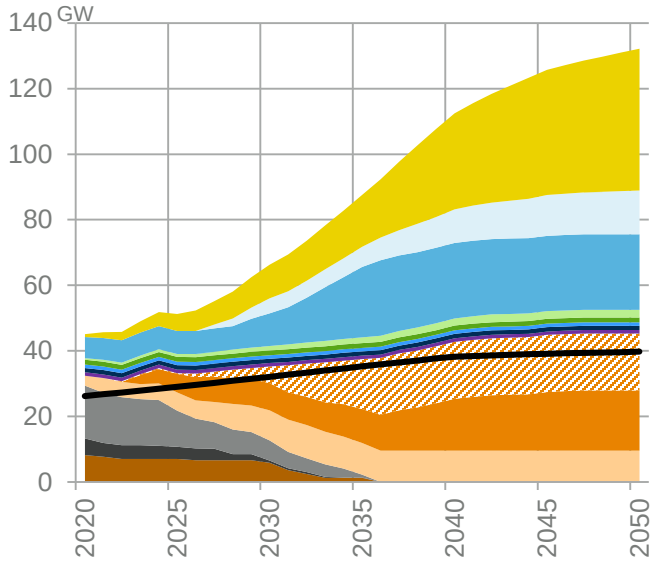
Focus on Capacity Structure Differences of Bełchatów

In earlier years, Bełchatów phase-out results in higher PV and wind onshore capacities and slightly higher backup which inverses in the long run due to an additional market-based gas investment cycle

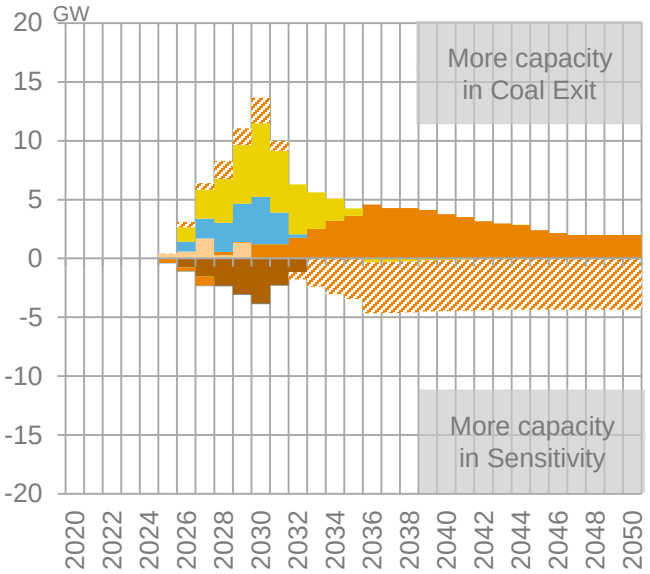
Coal Exit



Coal Exit Sensitivity



Delta



- Graph shows the development of generation capacities in the original Coal Exit pathway from 2020-2050 as previously presented

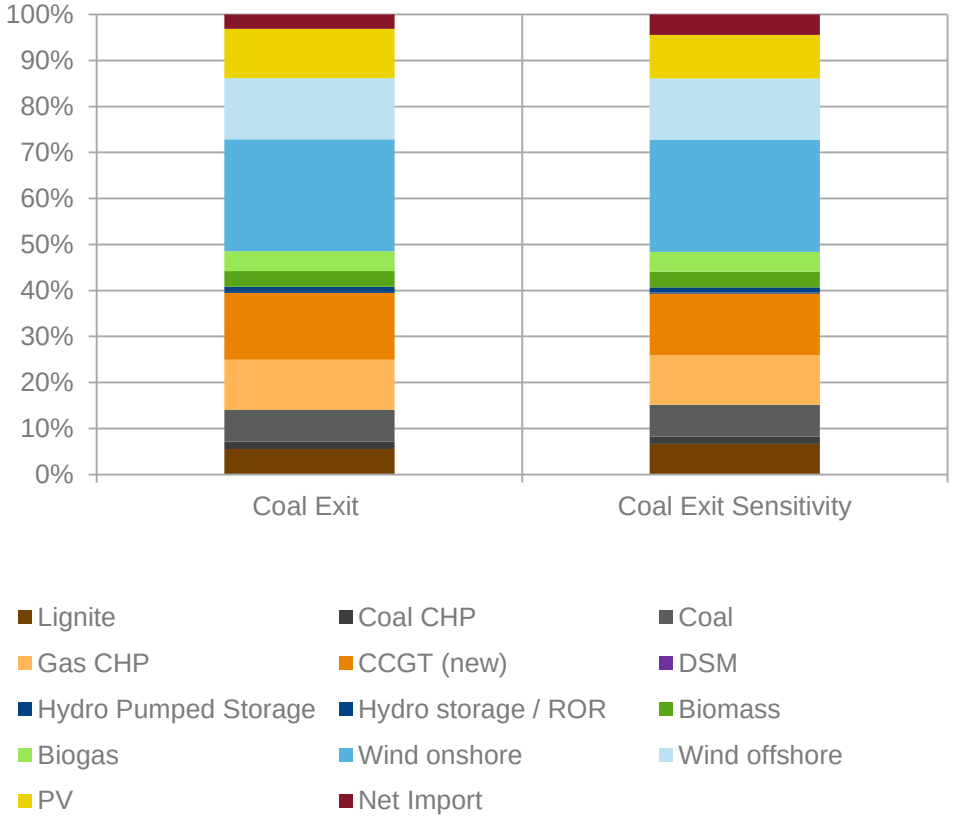
- Graph shows the development of generation capacities in the Coal Exit Sensitivity
- By design, lignite capacities and renewable capacities are offset versus the original

- Phasing out Bełchatów reduces lignite in between 2026 and 2032 (below x-axis) & is offset by RES (above x-axis). This is complemented by investment in gas which reduces the need for backup capacities

Focus on Generation Structure Effect of Bełchatów

Sensitivity analysis focusing on Bełchatów shows that phasing out the plants is offset by net imports, gas and renewables.

Sum of Generation



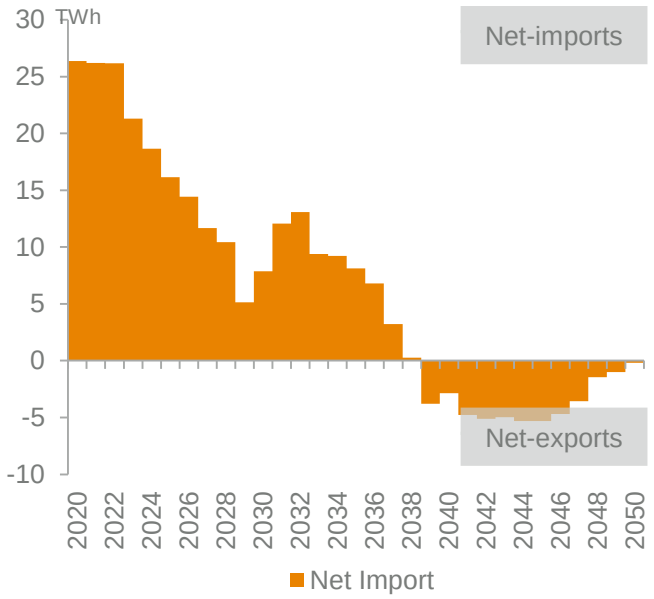
Comments

- The graph shows shares of different technologies in overall power generation 2020-2050 (sum of generation of all years)
- Sensitivity analysis focusing on Bełchatów shows that phasing out the blocks is offset by net imports, gas and renewables.

Focus on Import / Export Balance Differences

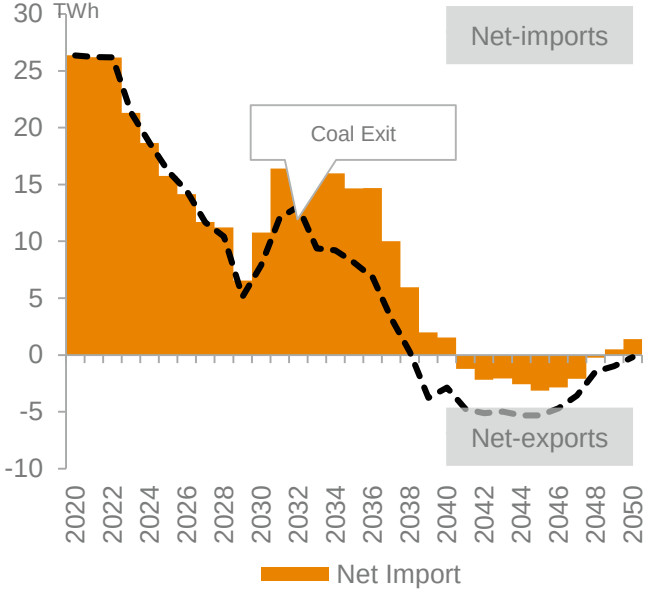
The replacement of Bełchatów generation shifts renewable installations forward and hence contributes to balancing Poland's net-imports

Coal Exit



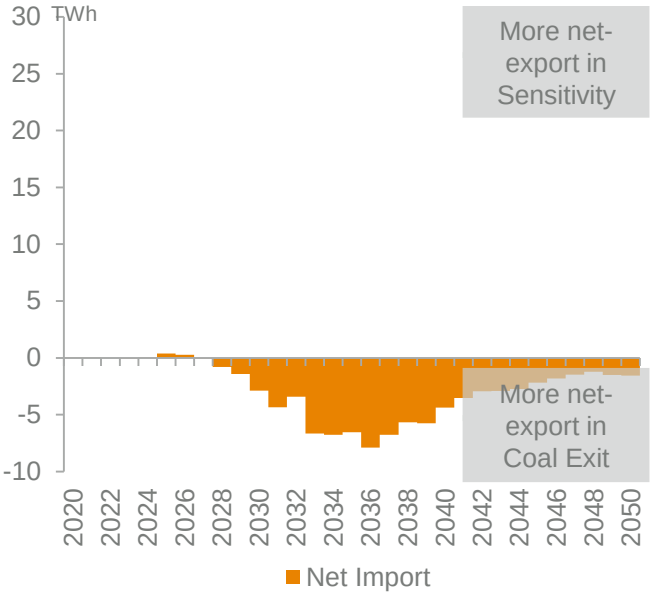
- The export balance almost steadily balances with increased penetration of renewables and their generation

Coal Exit Sensitivity



- Replacement of Bełchatów shifts RES deployment ahead in time versus market-based installations in Poland and other European regions
- This leads to a faster decrease of net-exports

Delta

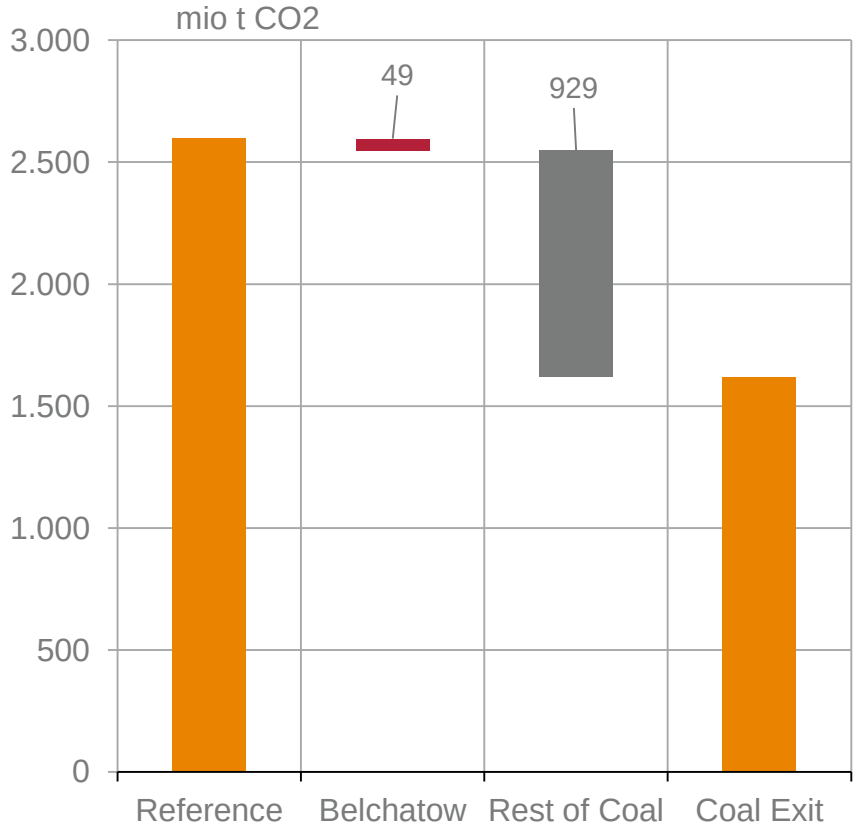


- The effect on the import / export balance is evened out over time as the share of renewables syncs again

Focus on CO_2-Emission Effect of Bełchatów (I)

Phasing out Bełchatów earlier is responsible for 50 mio t savings of the overall 1 bn. t reduction of the Coal Exit scenario

Sum of CO_2-Emissions



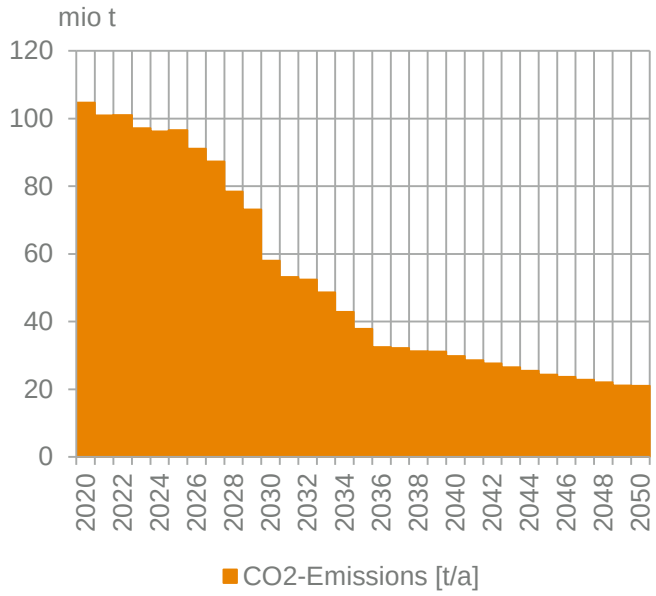
Comments

- The graph shows overall CO_2-emissions from the power sector in the scenarios
- Sensitivity analysis focusing on shows that phasing out the Bełchatów plants contributes to overall savings in CO_2 of the Coal Exit scenario.
- The effect seems relatively small because of the temporal limitation and a slight increase in emissions from gas-based generation (see next slide)

Focus on CO_2-Emission Effect of Bełchatów (II)

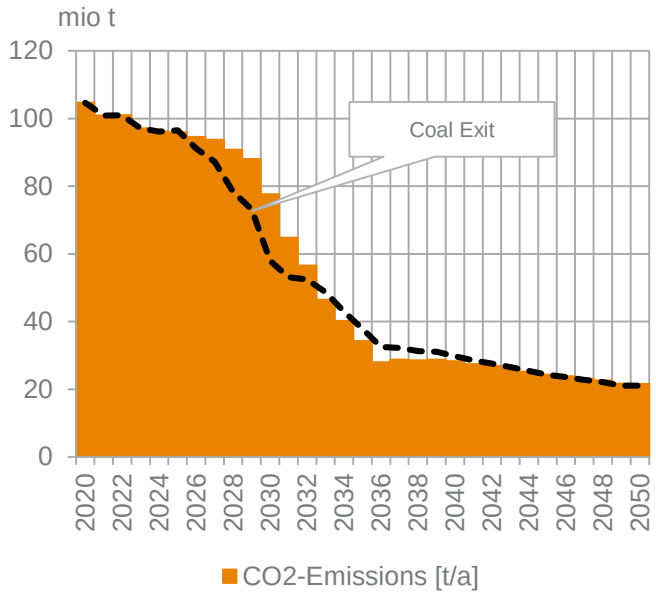
The CO_2-savings effect of Bełchatów alone accounts for 20% of reduction in the decade after 2025, but is slightly reduced over the long term by slightly increased gas based generation

Coal Exit



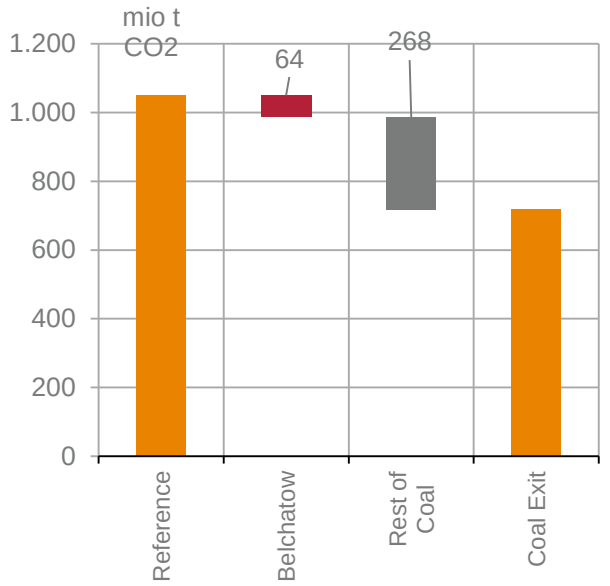
- Phasing out the coal and lignite fleet in the Coal Exit pathway leads to sharp decline in emissions between 2025 and 2035

Coal Exit Sensitivity



- The effect of earlier Bełchatów retirement is significant in the respective period (2025-2035)
- Especially the phase out of the older blocks shows notable system-level effect (2025-2030)

Cumulated Effect 2025-2035

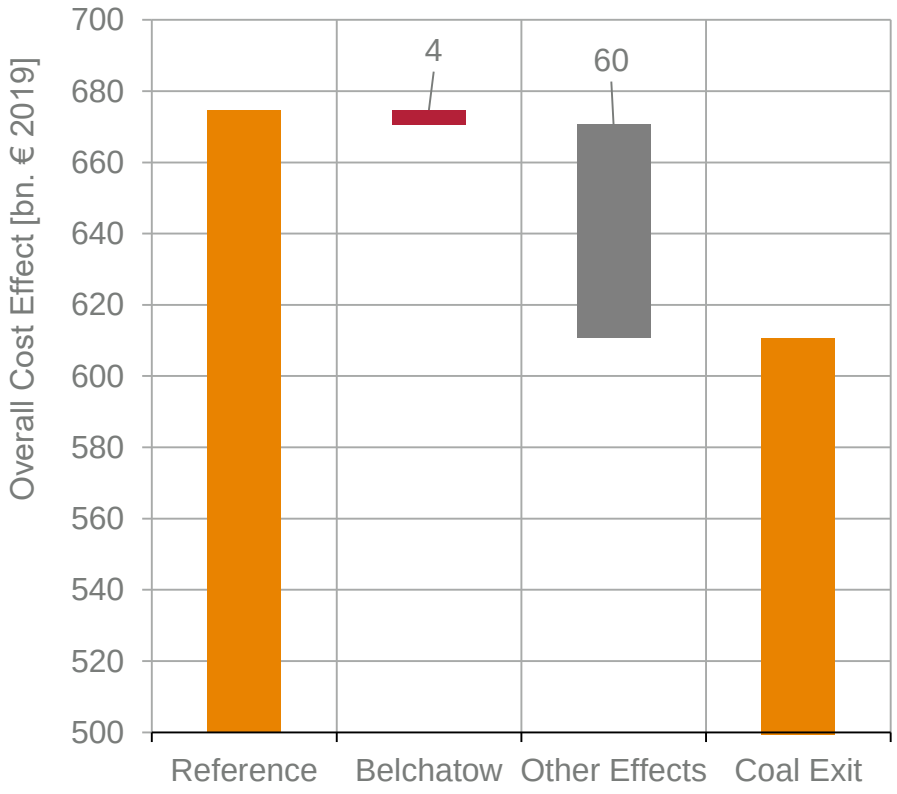


- Out of roughly 3.3 mio t CO_2-savings in the decade after 2025 in the Coal Exit strategy, Bełchatów accounts for almost 20%
- Later on, emissions savings are partly and temporarily offset by slight increase in gas generation

Focus on Cost Effect of Bełchatów

Phasing out Bełchatów earlier is responsible for 4 bn. € savings of the overall 64 bn. € savings of the Coal Exit strategy

Sum of Costs

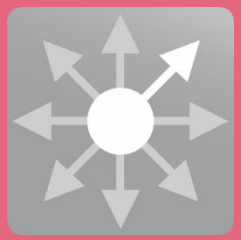


Comments

- **The graph shows overall costs of the scenarios. The bars represent sums of cost component over 2020-2050.**
- **Additional Sensitivity analysis focusing on Bełchatów shows that phasing out the plants earlier contributes to the overall savings of the Coal Exit scenario.**

Interim Summary

SENSITIVITY



- A second version of the Coal Exit scenario was modelled to analytically capture the effect of Bełchatów within the Coal Exit pathway by means of a Sensitivity analysis.
- All parameters were kept equal as in the Coal Exit scenario except for the phase out of Bełchatów and substitution via RES.

CO_2 / IMPORTS

- Sensitivity analysis shows that phasing out Bełchatów contributes to the overall savings in CO_2 of the Coal Exit scenario.
- The replacement of Bełchatów generation shifts renewable deployment forward and hence contributes to balancing Polands net-imports.

COST EFFECTS

- Additional Sensitivity analysis focusing on Bełchatów shows that phasing out the plants earlier contributes to overall savings of the Coal Exit scenario.
- Bełchatów is responsible for 4 bn. € savings of the overall 64 bn. savings of the Coal Exit scenario.

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