ENERDAY, April 9, 2021

The impact of carbon prices on power sector emissions:

Insights from a model-comparison experiment

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Introduction

Research context: “Model comparison for impact analysis of policy instruments” (MODEX-POLINS)

Funder

- German Fedaral Ministry for Economic Affairs and Energy (BMWi)

Project partners

- Universität Duisburg-Essen (Lead)
- ewi Energy Research & Scenarios gGmbH
- Fraunhofer-Institut für Energiewirtschaft und Energiesystemtechnik IEE
- Hertie School
- Öko-Institut e.V.

Existing literature on the EU ETS

The EU ETS

- Oldest and largest international emission trading scheme in operation to date
- Covers 40% of EU carbon emissions
- Power sector is the largest contributing sector

Existing literature: different models & different assumptions

- *Many* model-based studies on the EU ETS itself, or on complementing national climate policy such as renewable energy support and coal phase out
- These studies yield wide range of model results for similar scenarios: e.g. carbon prices of 87 €/t (Bruninx et al. 2020) vs. 25 €/t (Pietzcker et al. 2021) in 2030 under the 2018 ETS reform
- Parameter uncertainty is often addressed with sensitivity runs
- Model uncertainty, related to the abstraction from reality, remains unclear

Our contribution

Assessing model uncertainty

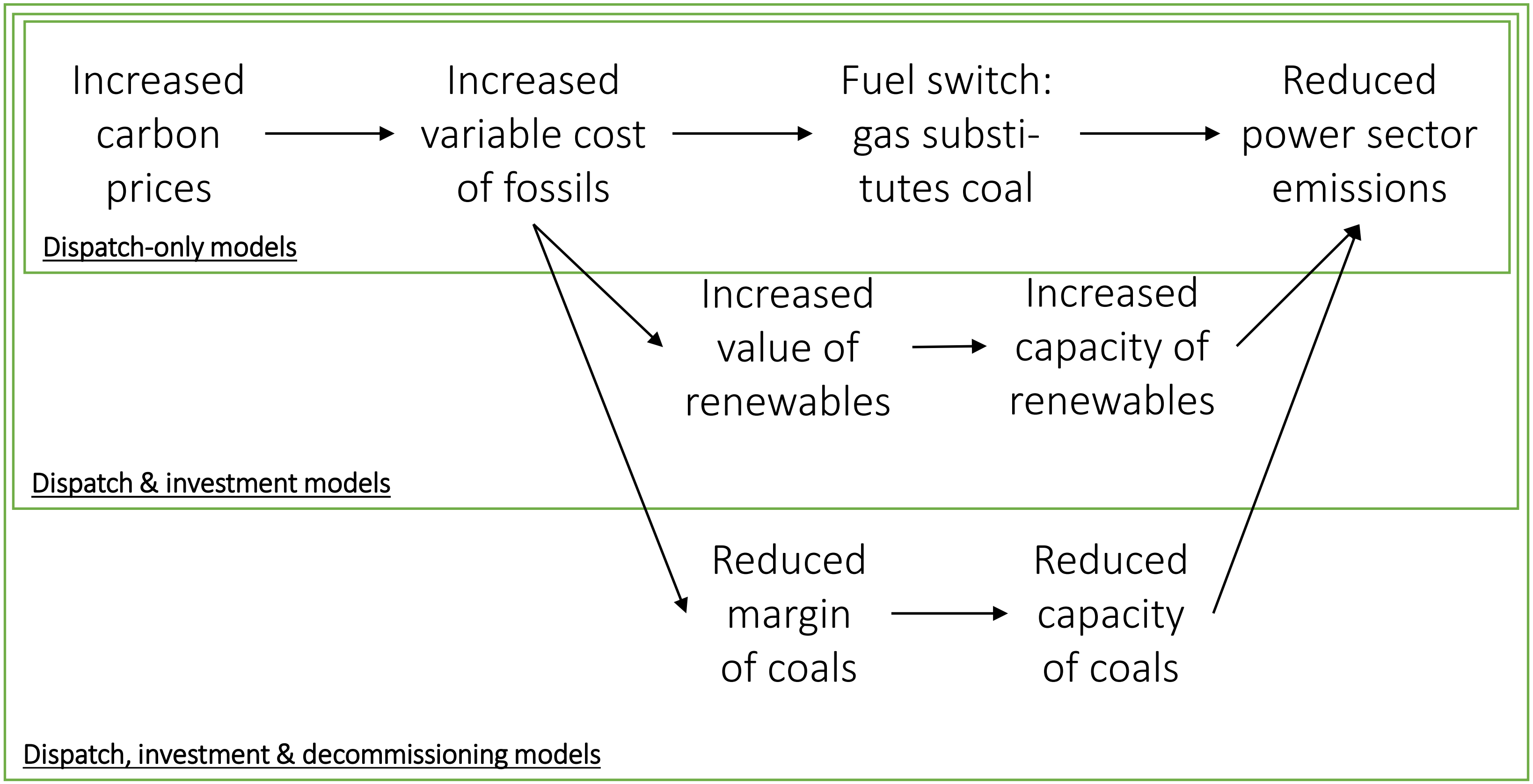
- Comparing results from multiple models within one study
- Using harmonized model inputs

Focus on the power sector

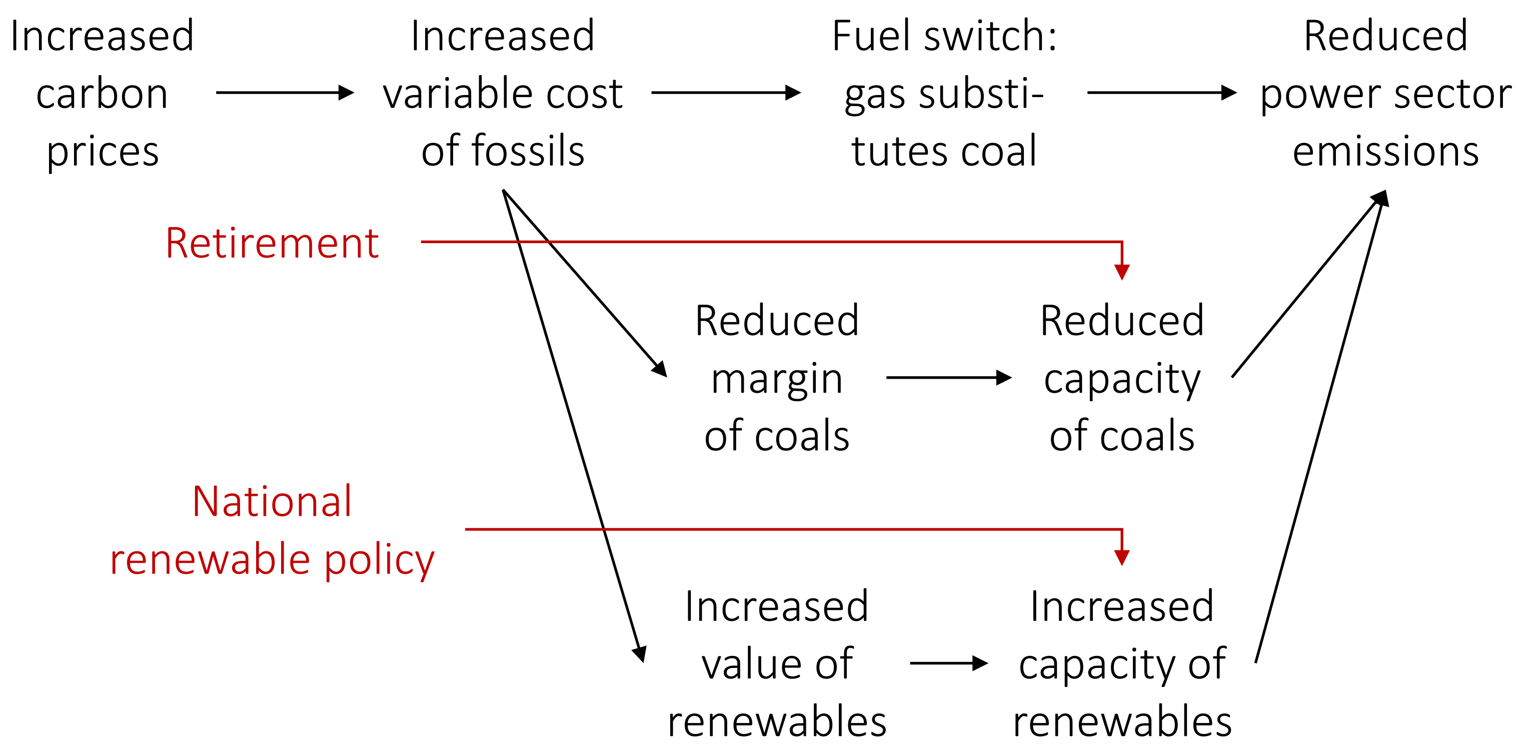
- ETS price as exogenous input → power sector emissions as endogenous result
- In reality, the ETS price will be endogenous to the cap

Theoretical framework

Causal paths from CO_2 prices to power sector emissions



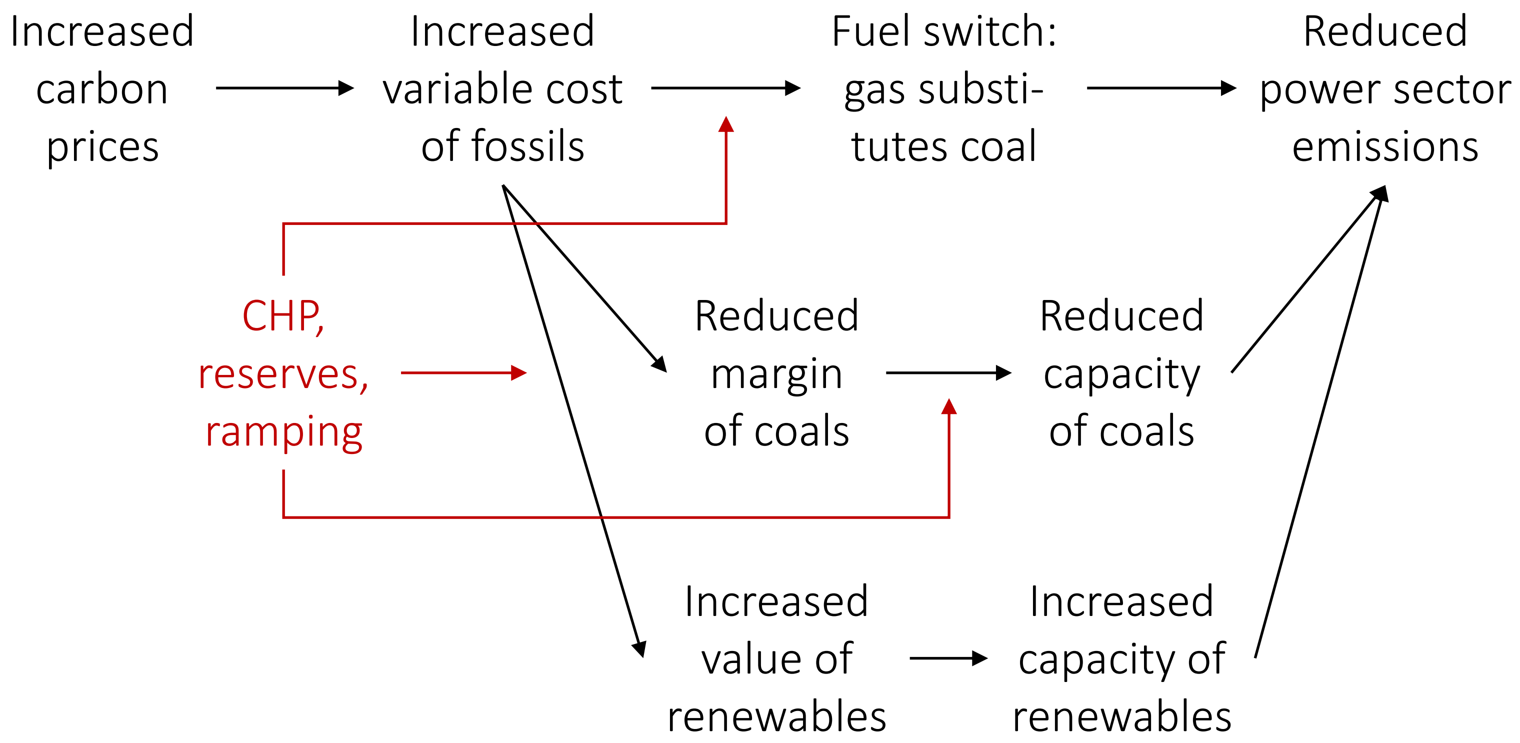
Exogenous factors



Even without increased CO_2 prices

- some renewable capacity will be added through national renewable policy
- some coal capacity will be retired

Moderators of the impact of CO_2 prices



Combined heat and power (CHP), reserve provision, and ramping constraints may

- impede/amplify fuel switch and coal capacity reduction
- depress the value of renewables

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Experimental setup

Models

Dispatch models

- Joint Market Model (JMM), University Duisburg-Essen
- Power Flex (PFL), Öko-Institut

➢ Fixed capacity according to MAF with optimized dispatch

Dispatch + investment model

- Scope (SCO), Fraunhofer IEE

➢ Then-existing capacity based on lifetime + endogenous investment

Dispatch + investment + decommissioning models

- EMMA (EMM), Hertie School
- Dimension (DIM), Energiewirtschaftliches Institut Köln

➢ Enogenous decommissioning of then-existing capacity

Geographical scope

26 Countries (26C)

- EU27 + CH + GB + NO – MT – CY – SV – HR
- The model scope is motivated by the continental electricity system
- For perspective: the (post-Brexit) ETS covers EU27 + NO + LI + IS

EMMA covers only 12 countries (12C)

- DE, PL, GB, CZ, NL, FR, AT, CH, BE, DK, NO, SE
- Historically, this accounts for approx. 2/3 of the 26C emissions
- Results are extrapolated with fuel-specific factors calibrated on 2016

Scenarios

Scenarios

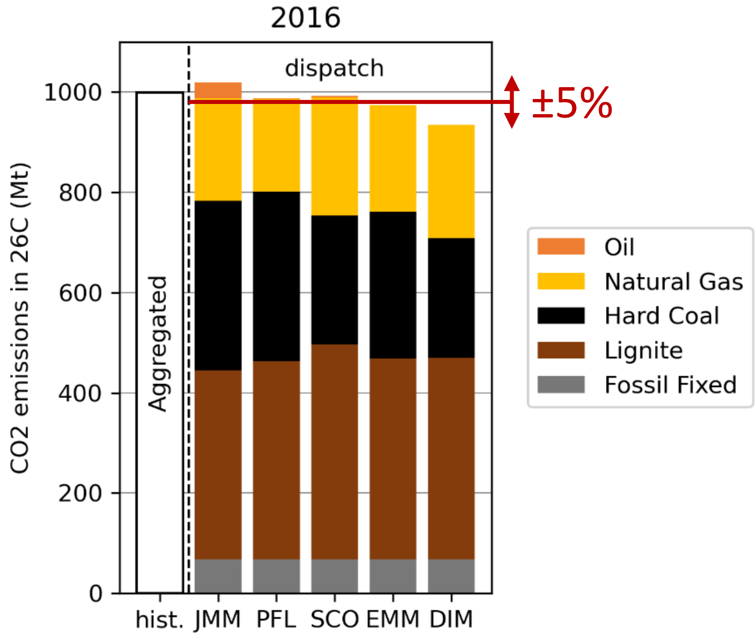
- 2016 for comparison
- 2030 with ETS prices of
  - 27 €/t CO_2 (pre 2018 reform, WEO)
  - 57 €/t CO_2 (post 2018 reform)
  - 87 €/t CO_2 (with further reform)

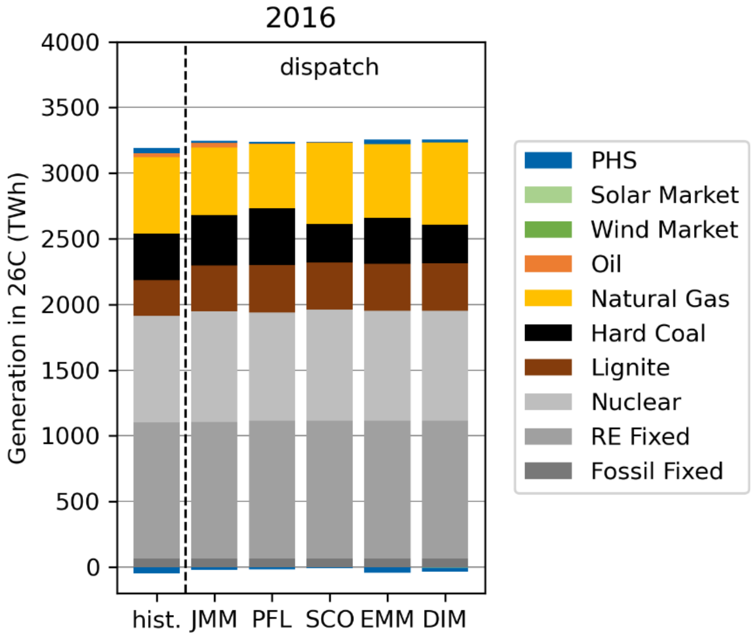
Other harmonized inputs

- Fixed renewables: bioenergy, hydro inflow (optimized dispatch), wind and solar (according to national targets)
- Fixed fossils: fossils other than lignite, hard coal, natural gas, and oil
- Nuclear: exogenous capacity (investment and decommissioning) as planned today
- Retirement of plants when reaching their lifetime

Results

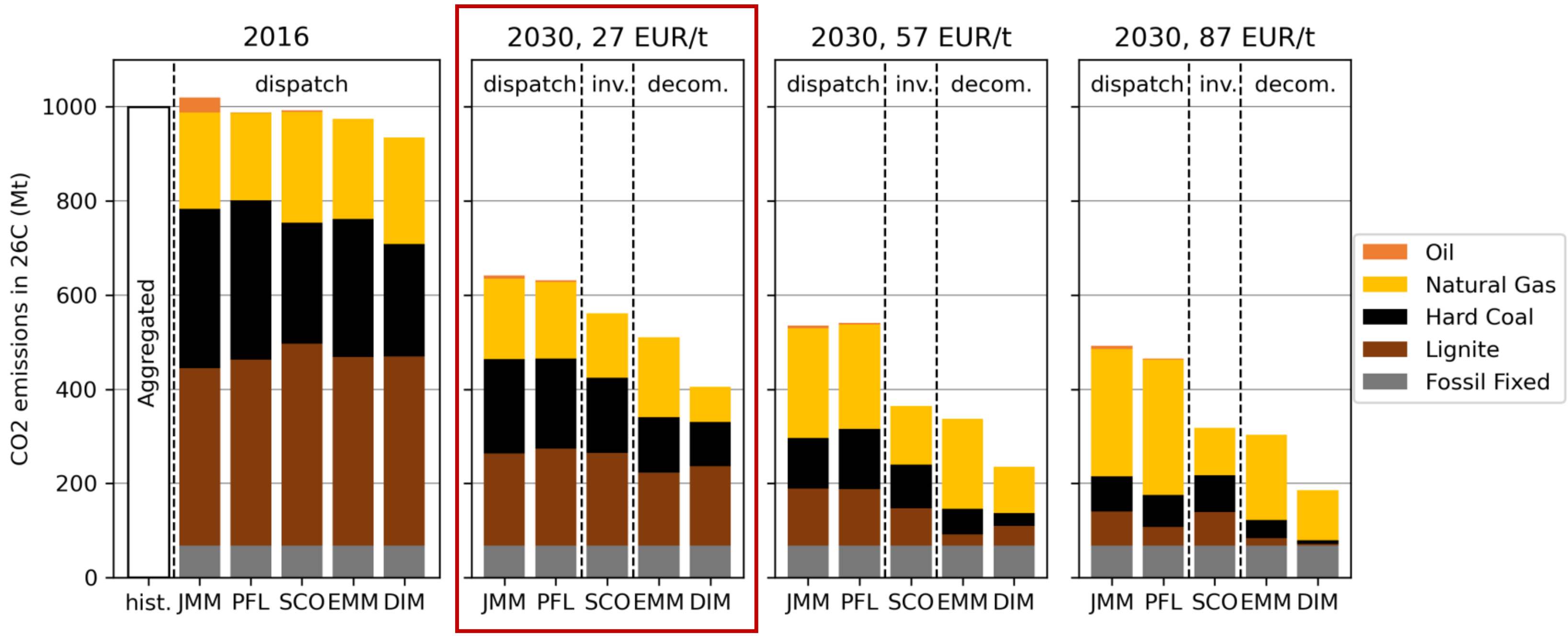
Historical emissions and generation





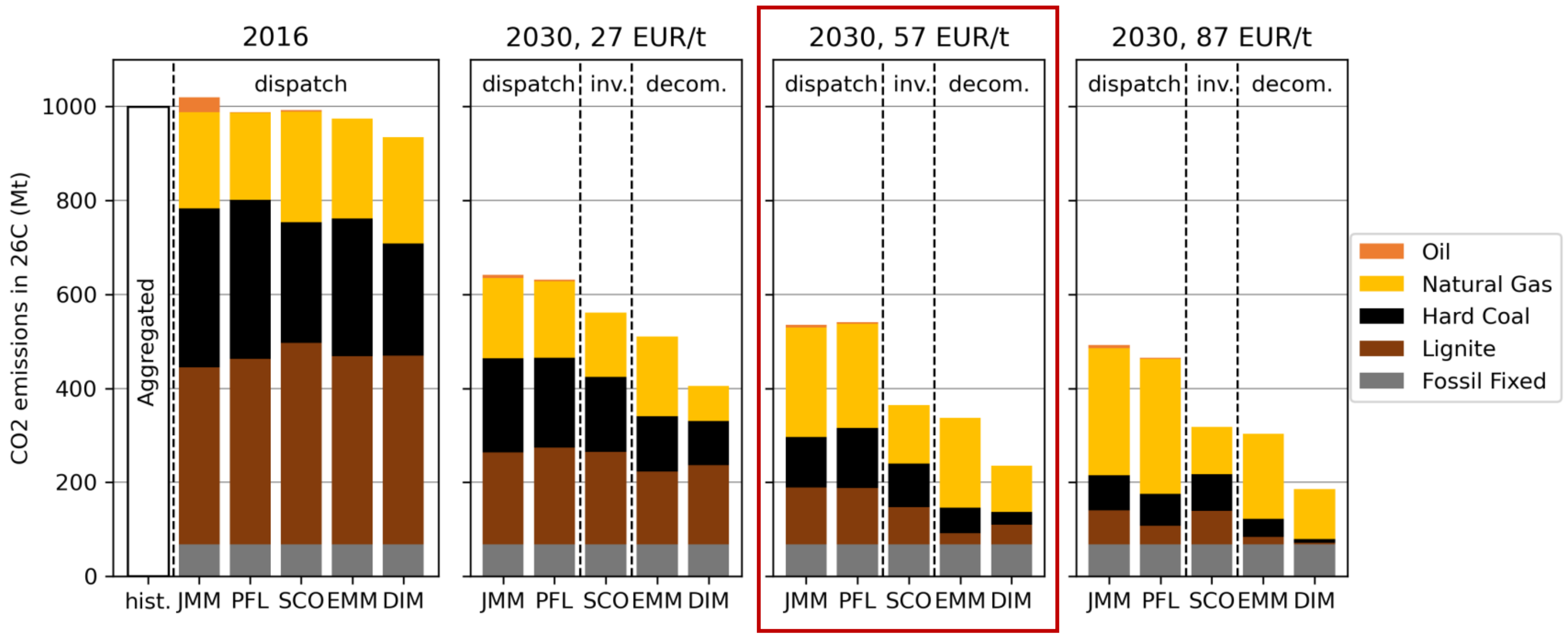
- Emissions: comparable on the aggregated level, with JMM 4% above and DIM 5% below average, substantial heterogeneity on the fuel-specific level
- Generation: similar to emissions, but not all variations in emissions can be explained by generation mix only (e.g. SCO vs. DIM)

Future emissions



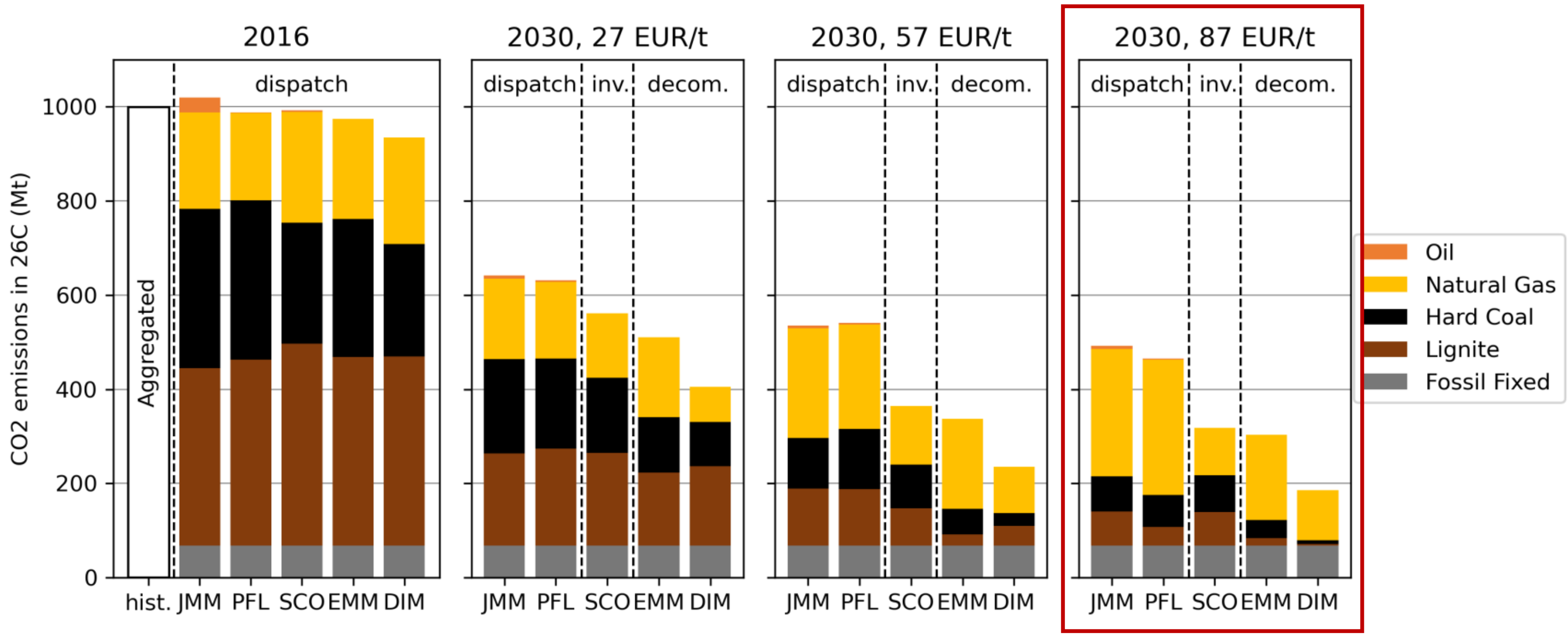
- At 27 €/t,
  - emissions are substantially reduced to 400-640 Mt (factor 1.6)
  - larger reductions in models with endogenous investment and decommissioning

Future emissions (cont‘d)



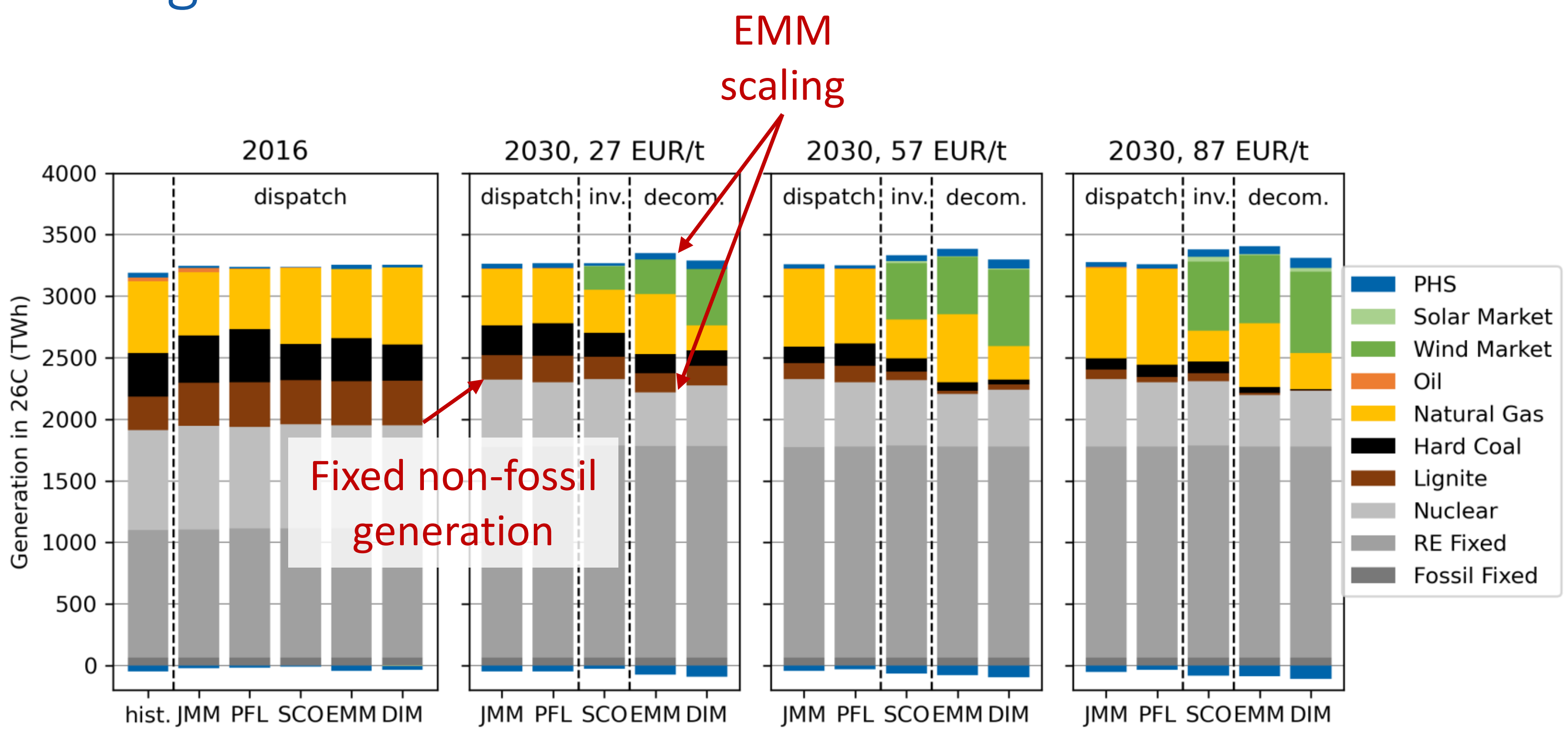
- At 57 €/t,
  - even larger variations in the results (240-540 Mt, factor 2.2)
  - ≈100 Mt further reduction in dispatch models → fuel switch
  - about twice as much reduction in investment models → capacity adjustments

Future emissions (cont‘d)



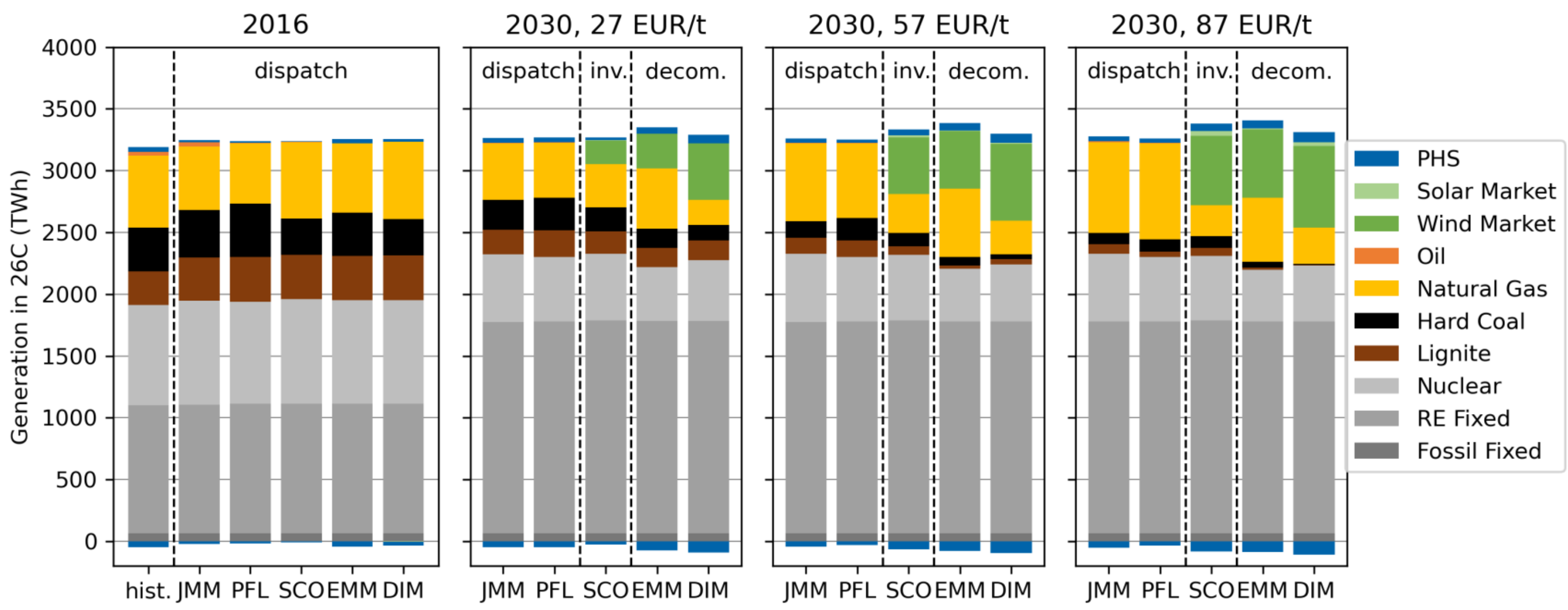
- At 87€/t,
  - somewhat smaller further reduction (to 190-490 MT, factor 2.5)
  - almost the same reduction across model types (50 Mt)
  - some heterogenous amounts of coal and lignite remains → CHP/decom

Future generation



- ¾ of electricity generation is quasi fixed → a substantial, price-inelastic part of the reduction is due to assumed national renewable targets
- EMM scaling yields less nuclear and larger overall generation → emissions will be somewhat higher

Future generation (cont'd)



- The main model differences are idiosyncratic to model types:
  - Fuel switch in the dispatch models
  - Endogenous wind investment in the investment models
  - Endogenous coal and lignite decommissioning in the decommissioning models

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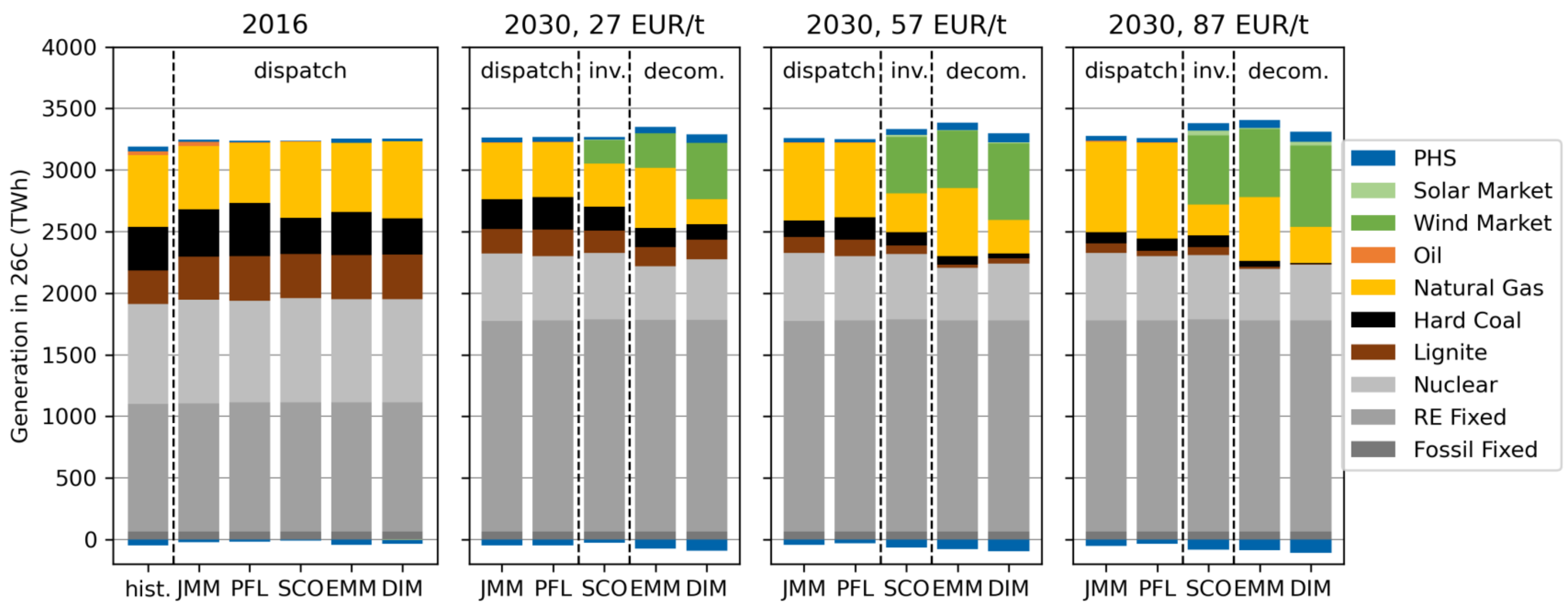
Future generation (cont'd)



- Some results cannot be explained by model types:
  - Larger wind investment in DIM → inter-temporal optimization, capacity values → confirmed in a case study
  - Different remaining coal production → CHP → subject of ongoing investigation

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Summary and conclusions

Summary and conclusions

Historical year 2016: similar results

Scenario year 2030: stark model differences

- Already at low carbon prices (400-650 Mt)
- Even more at higher carbon prices (250-550 Mt)
- The estimated impact of higher carbon prices depend on the model

Causes and conclusions

- Endogenous investment and decommissioning → dispatch models need consistent scenarios; investment models assume “perfect market delivery”
- Inter-yearly optimization → models without this feature need consistent inter-yearly scenarios; models with this feature assume inter-yearly “perfect market delivery” (non-myopic/hyperopic market players)
- CHP → although all models implement this feature, we find CHP to drive a large part of the model differences (and remaining carbon emissions)