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Integration of Electricity and Gas Market – Accounting for Interdependencies and Uncertainty

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Motivation

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Most quantitative models (and studies) of European energy markets focus on single energy sectors, such as electricity OR gas.

Nonetheless, gas- and electricity markets are linked:

- Gas prices have a significant impact on the competitiveness of gas-fired generation technologies
  - Short-term: full load hours
  - Long-term: cost levels drive investment substitution effects
- The competitiveness of gas-fired generation technologies as well as European policies (e.g. emission reduction targets and renewable energy deployment) affect the gas consumption by the electricity sector

Motivation - Energy sectors face significant challenges in treating uncertainties

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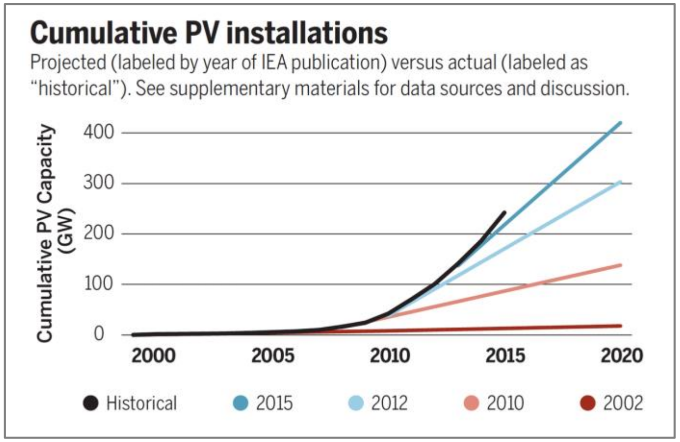
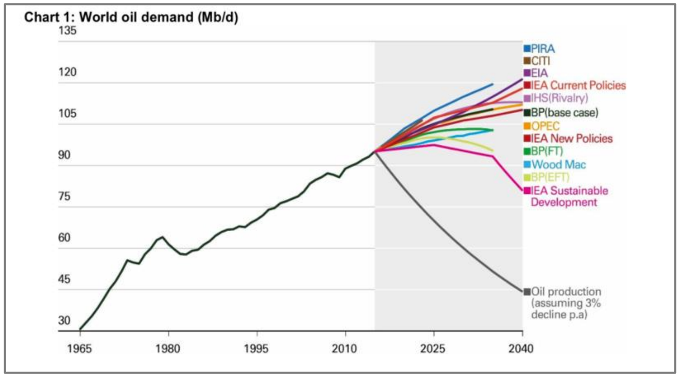
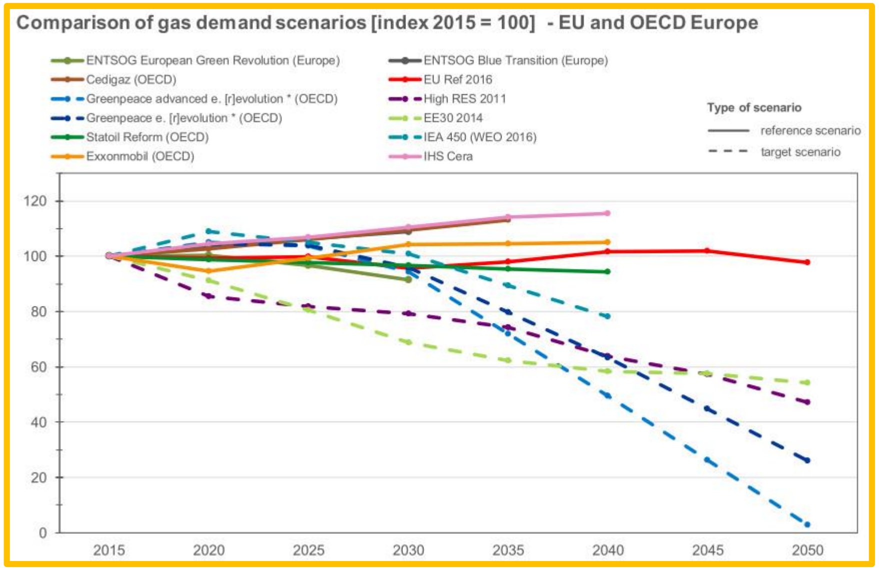


Source: Haegel et al. (2017)



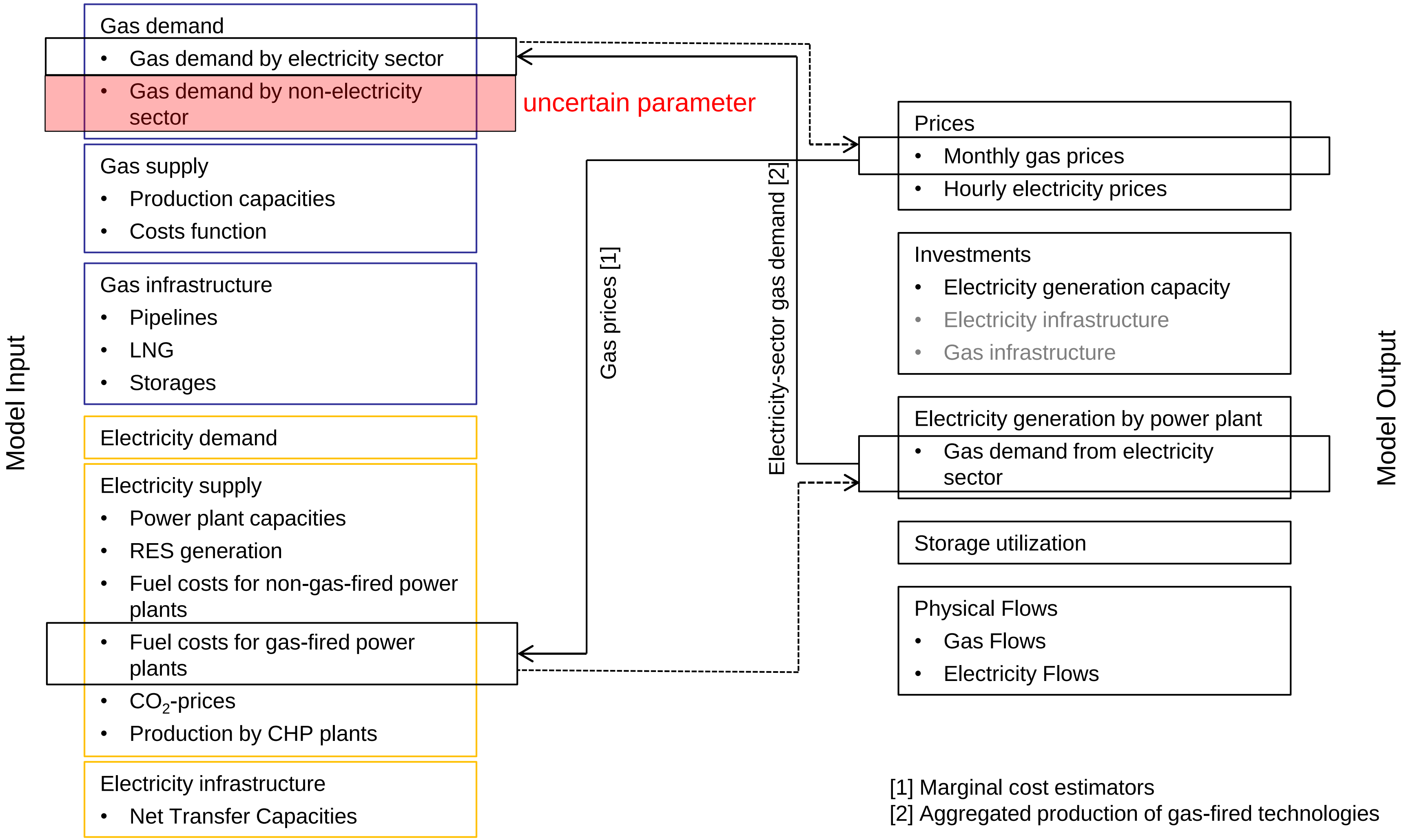
Source: Dale and Fattouh (2018), Peak Oil Demand and Long - Run Oil Prices



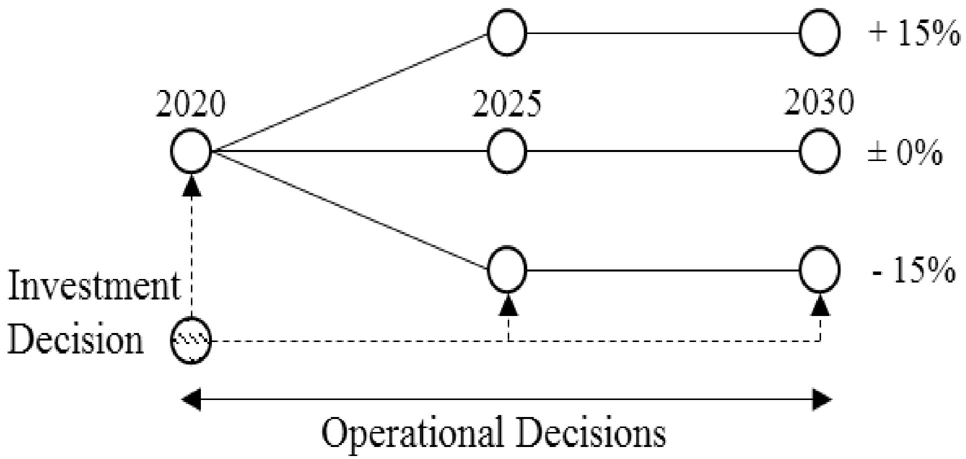
Source: **Prognos AG (2017)** based on (Cedigaz, 2015), (EC, 2016b), (E3M, 2014), (ENTSOG, 2015a), ENTSOG (2016c), (Greenpeace, 2015), (IEA, 2015), IEA (2016), (Statoil, 2016), (ExxonMobil, 2016), (IHS, 2016)

- Research focus: Evaluating the effects of uncertain gas demand on electricity generation investments

Methodology – Model integration



Methodology – Implementing uncertainty



- The model is formulated as a stochastic program with recourse.
- We account for uncertain gas demand by the non-electricity sector.

- The objective of our model is to minimize simultaneously the expected costs of our integrated model.
- We generate endogenous investment plans which has to hold for all possible scenario realizations

Results – Cumulative investments until 2030

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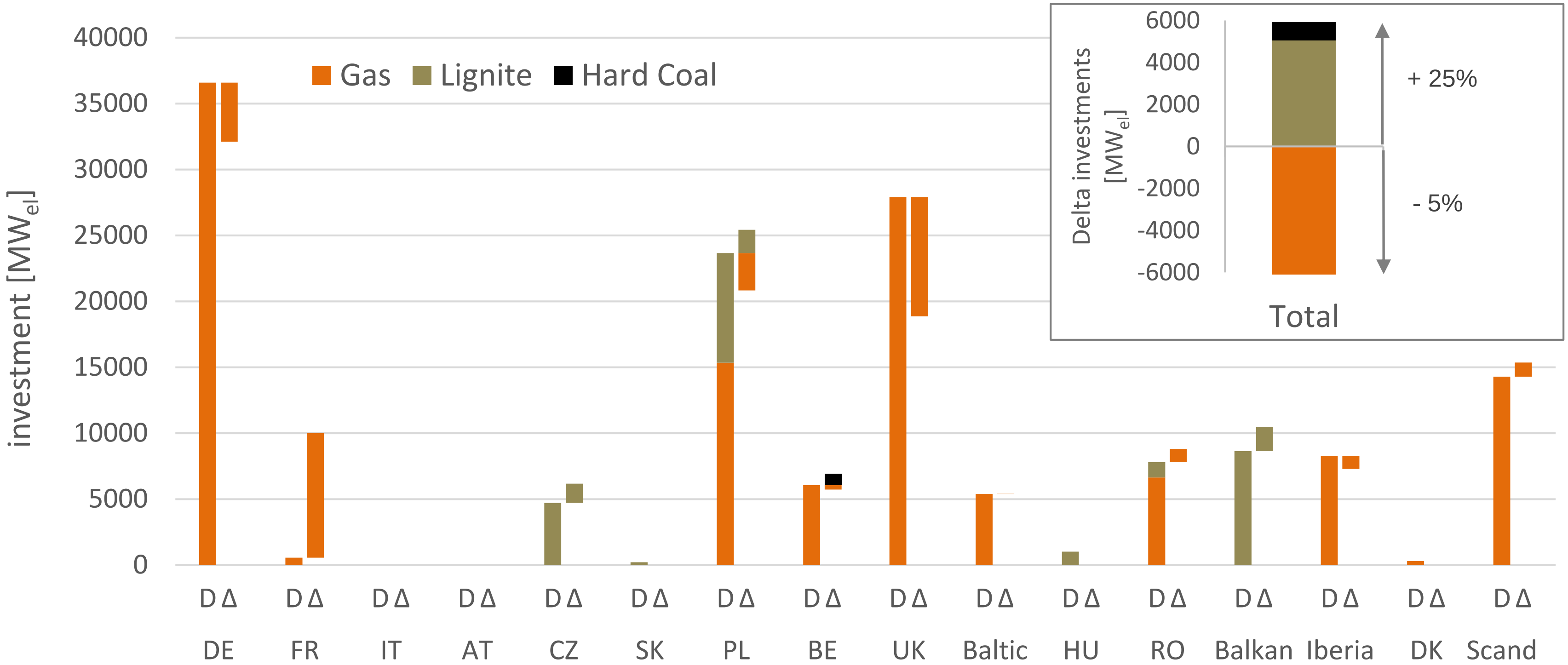
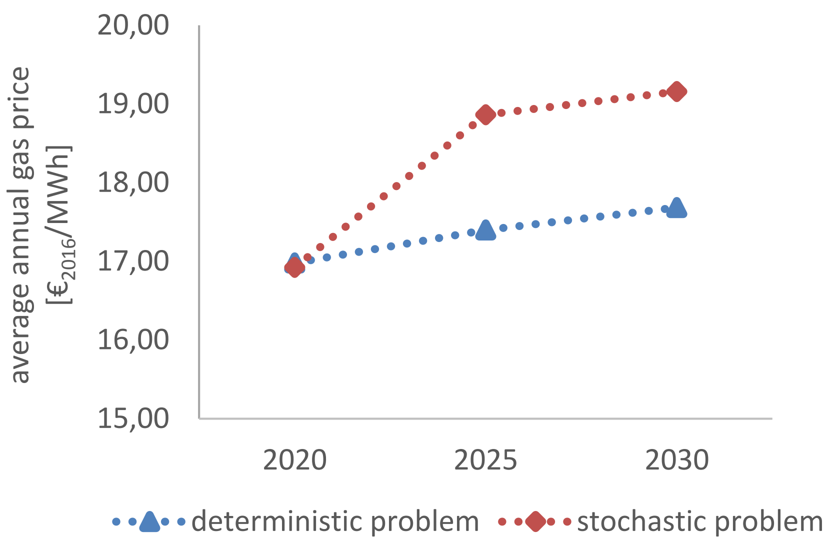


I. Majority of investments into gas-fired technologies

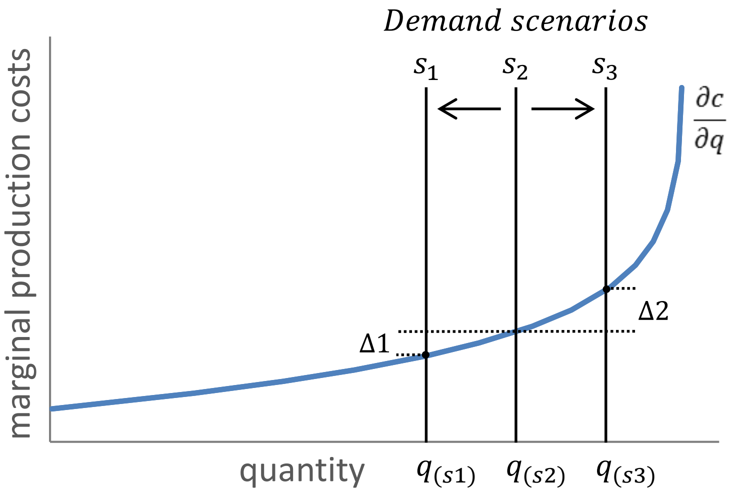
II. Overall, amount of investments into gas-fired technologies decrease in the stochastic solution

Results – Gas price differences as a driver for changes in optimal investment decisions

In the stochastic problem the average annual gas price in Europe increase about 1.47 €/MWh$_{th}$



This increase can be explained by the incremental slope of the logarithmic gas production cost functions.



$$\Delta 2 > \Delta 1, \qquad \forall\, x \in \frac{\partial c}{\partial q}$$

Results – cumulative investments until 2030

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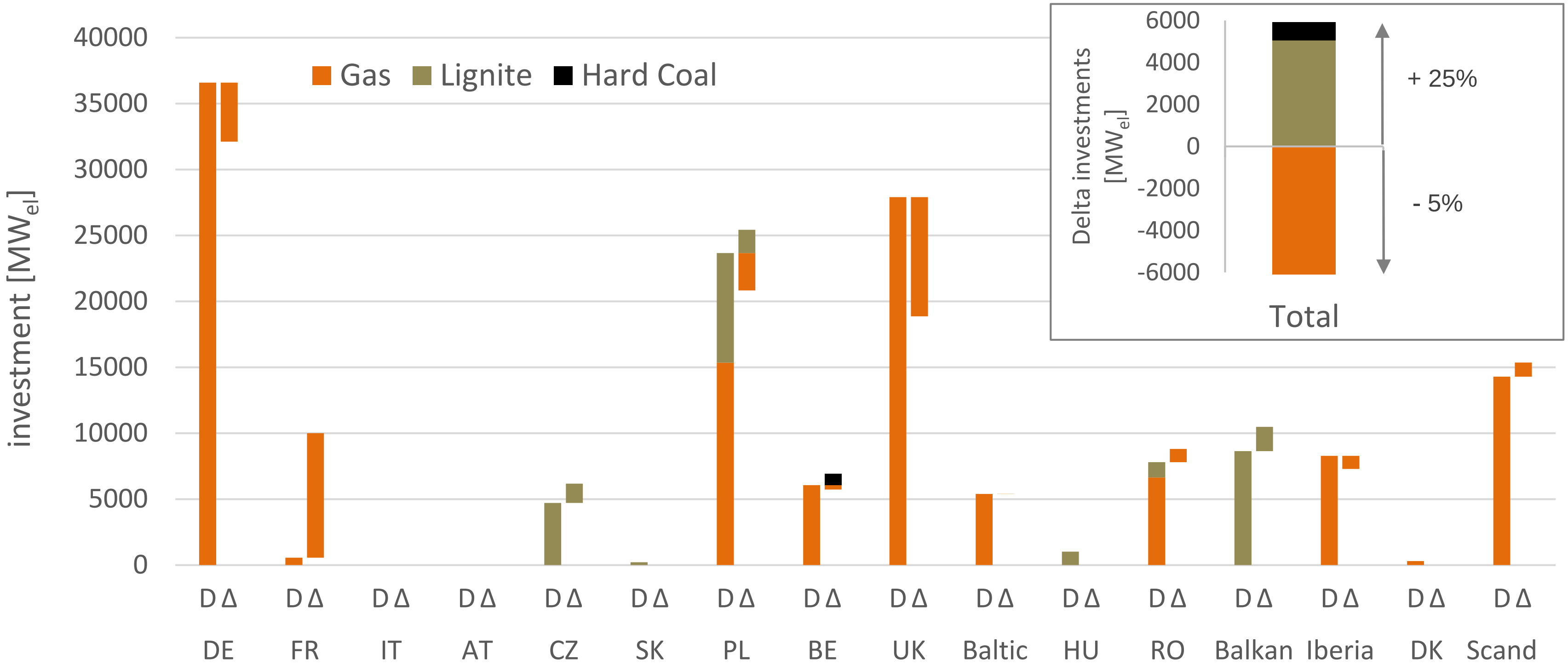

I. Majority of investments into gas-fired technologies

II. Overall, amount of investments into gas-fired technologies decrease in the stochastic solution

III. Overall, amount of investments into lignite and hard coal increase in the stochastic solution

IV. Reallocation of power generation investments

Results - Value of stochastic solution (VSS)

I. Define one scenario as the 'naïve' scenario that is assumed to occur in the future;

II. 'Naïve' scenario is solved with a probability of 1;

III. The vector of investment decisions is imposed into the stochastic model;

IV. The VSS is calculated as:

$$VSS = f_{\mathrm{inv}(determ)}^{stoch} - f^{stoch}$$

	Expected costs of ignoring uncertainty
VSS	€ 65 M
VSS (% of total costs)	0.026%

A. H. van der Weijde and B. F. Hobbs, "The economics of planning electricity transmission to accommodate renewables: Using two-stage optimisation to evaluate flexibility and the cost of disregarding uncertainty", 2012

Uncertainty: economic, technologic, and regulatory drivers

System: electricity market of GB

VSS (%) = 0.08%

M. Fodstad et. al., "Stochastic Modeling of Natural Gas Infrastructure Development in Europe under Demand Uncertainty", 2016

Uncertainty: gas demand

System: natural gas market for Europe (+ rest of the world on highly aggregated level)

VSS (%) < 0.01%

Conclusion

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- We create an integrated model considering both gas and electricity sector
- We implement gas demand from non-electricity sectors as an uncertain input parameter
- Compared to a deterministic system, we receive different investment decisions
  - Gas investments decrease and lignite and hard coal increase
  - We are able to observe reallocations of investments in gas-fired power plants
- We quantify and compare the VSS to other findings in literature

Thank you very much

Questions?

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