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Integrated Electricity and Gas Market Modelling – Effects of Gas Demand Uncertainty

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Motivation

- **Gas- and electricity markets are linked:**
  - Gas price patterns have a significant impact on the competitiveness of gas-fired power technologies
  - European policy focus on emission reduction and renewable energies in turn affects power sector demand development
  - Gas and coal cost levels drive investment substitution effects
- Nonetheless, most quantitative models (and studies) of European energy markets focus on single energy sectors, such as electricity <u>OR</u> gas.

Integration approaches

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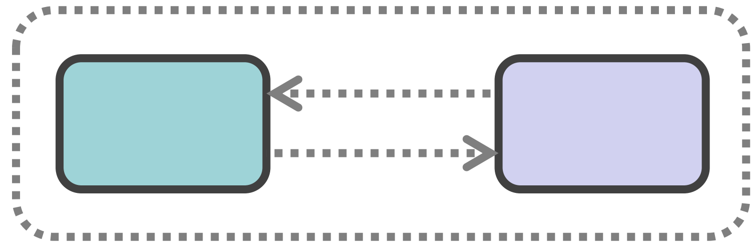
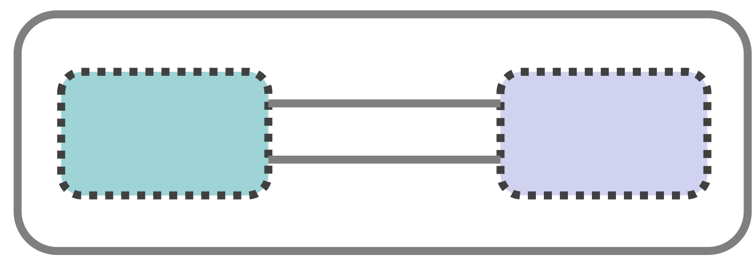
1) Separated models

2) “Soft-linked” models

3) “Hard-linked” models

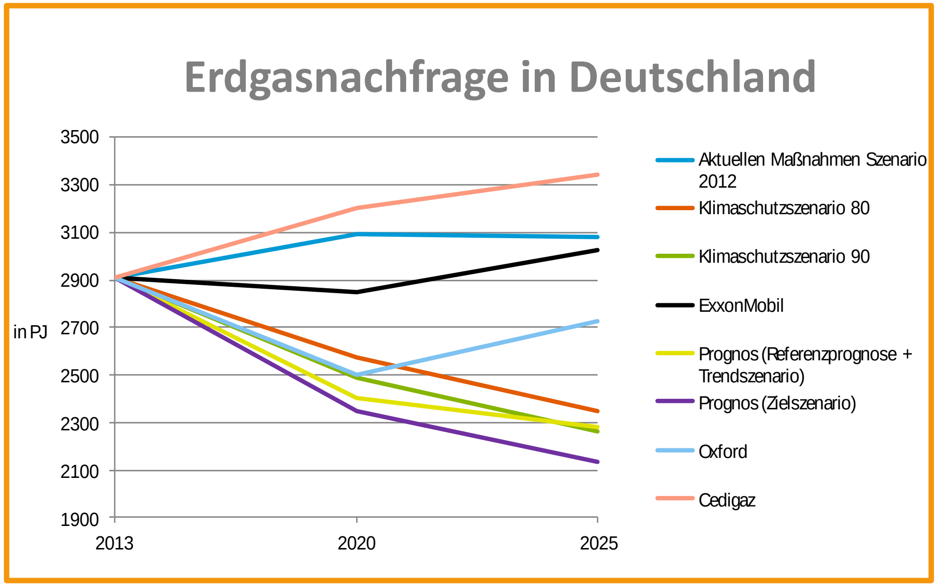


4) Integrated models

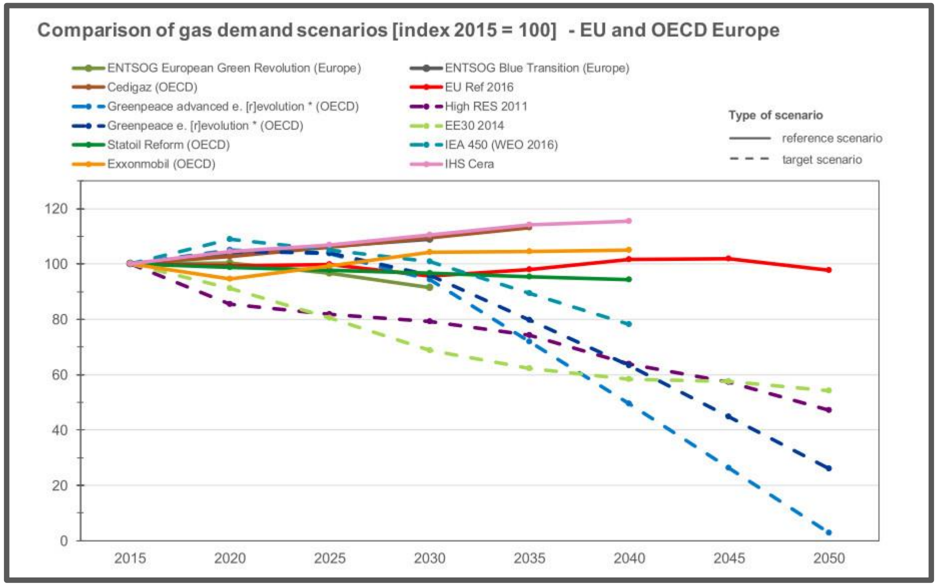


Uncertainty of gas demand

German / European gas demand uncertainty in 2 charts:



Source: Hans Von Soest, illustration from internal project with a gas trade utility, Jan 2016



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 general:

- Evaluate economic impacts of uncertainty drivers on the integrated energy system (including the feedback effects across the gas and electricity markets)

More specific focus for this presentation:

- Evaluate effects of uncertain gas demand on electricity generation investments

Model structure

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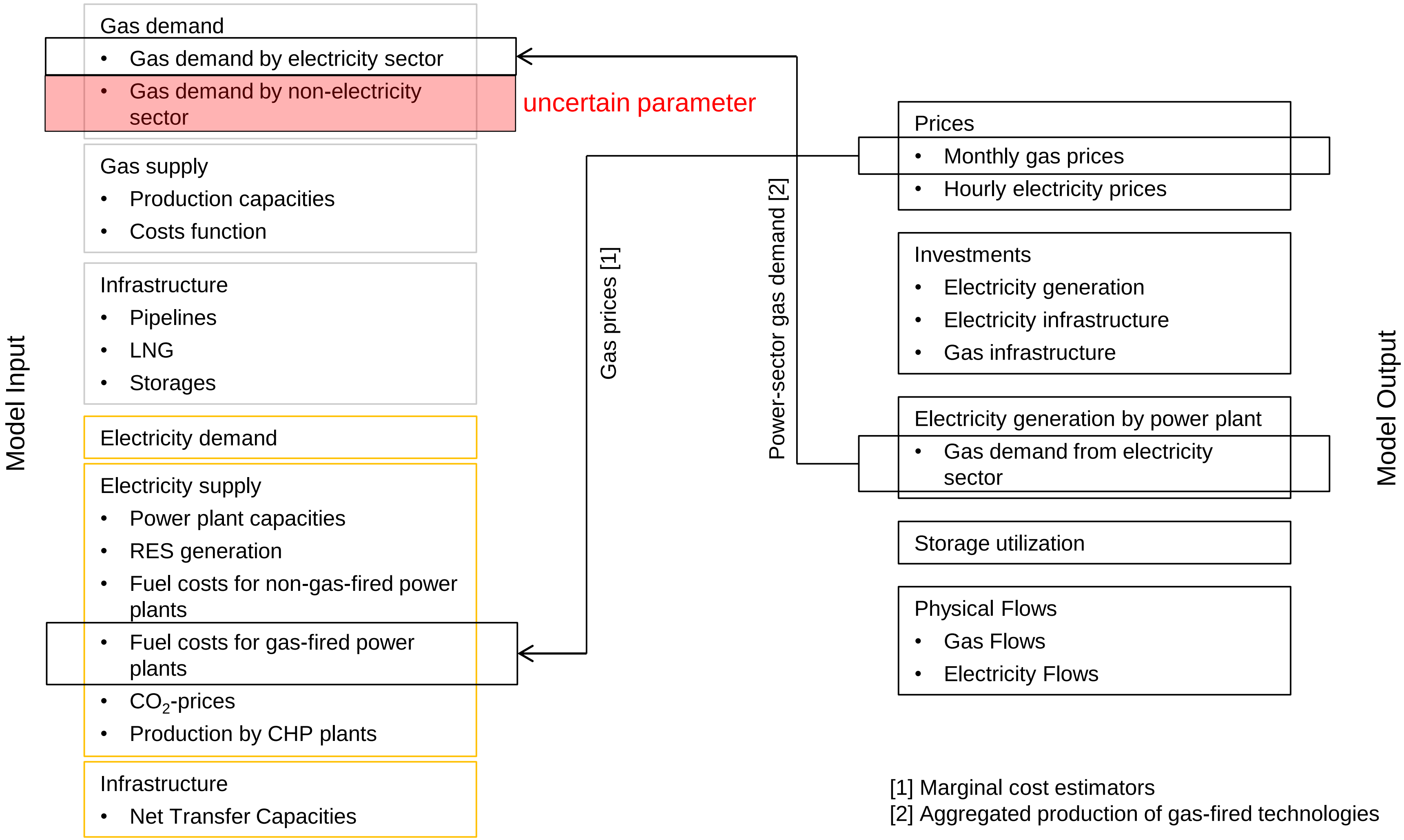
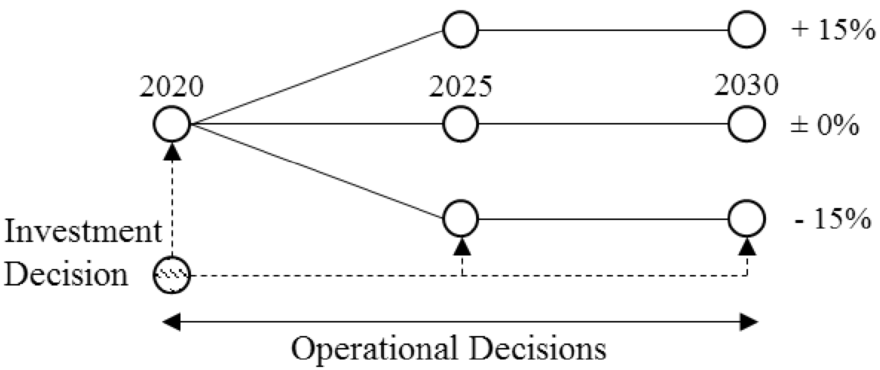


[1] Marginal cost estimators
[2] Aggregated production of gas-fired technologies

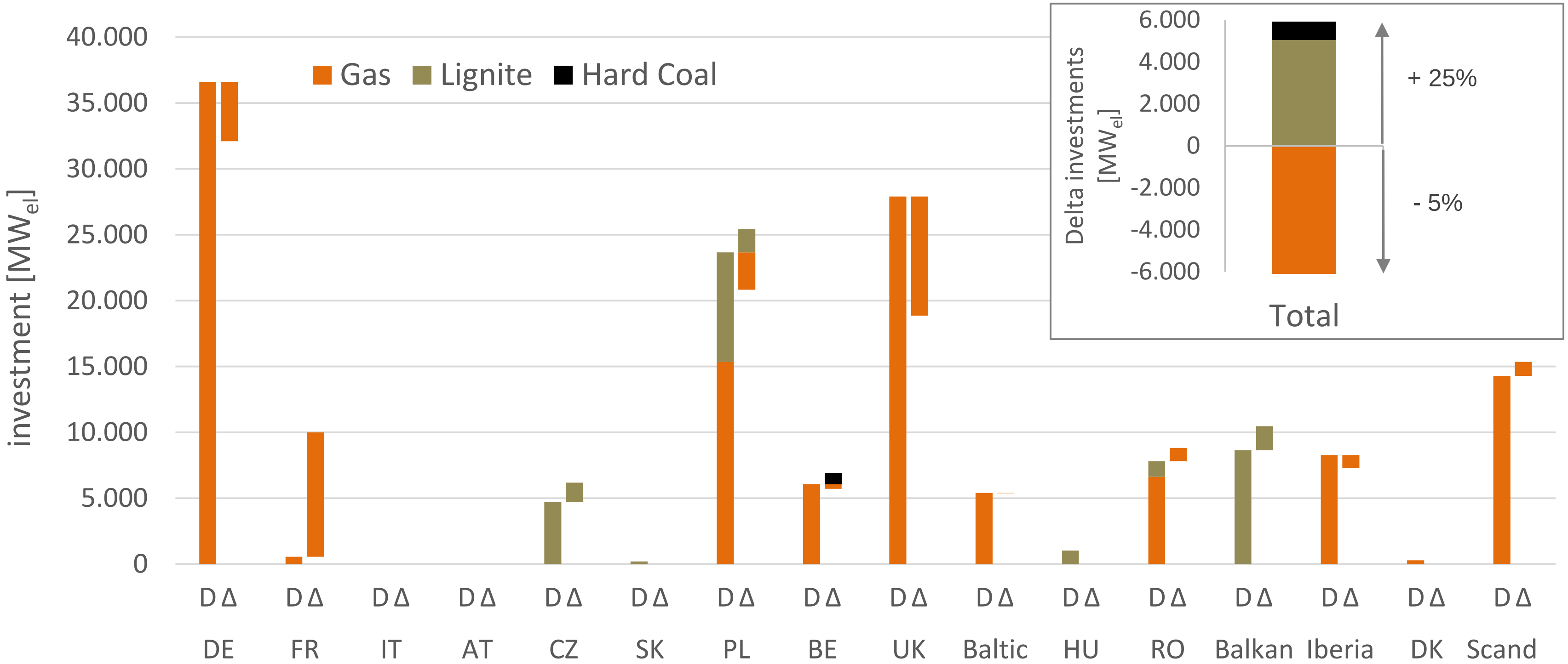


We represent uncertain gas demand from non-electricity sectors by a discrete realization probabilities (two-stage scenario tree)

The model simultaneously minimizes the total expected costs of both the electricity and gas sectors.

The ‘stochastic solution’ defines the optimal endogenous capacity extension plan (that has to hold for all scenarios), as well as scenario-dependent optimal dispatch decisions.

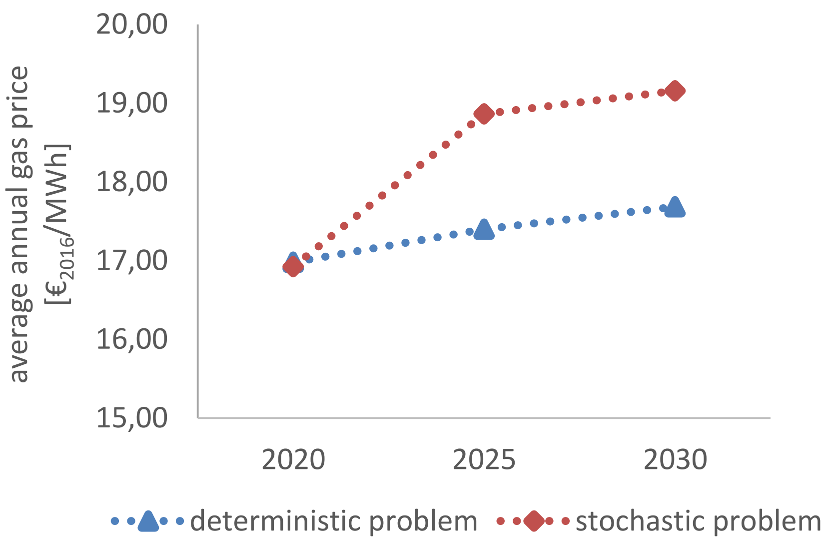
Cumulative investments in power generation capacities until 2030



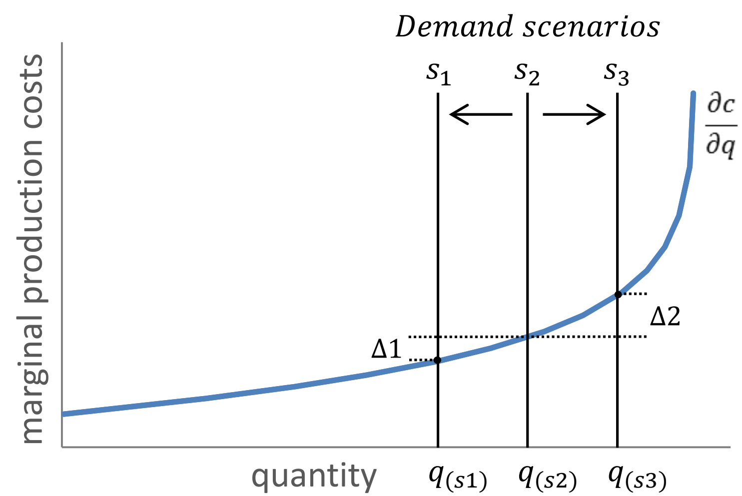
I. Majority of investments into gas-fired technologies

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

In the stochastic problem the average expected European annual gas price increases by 1.47 €/MWh in 2030



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



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

Cumulative investments in power generation capacities until 2030

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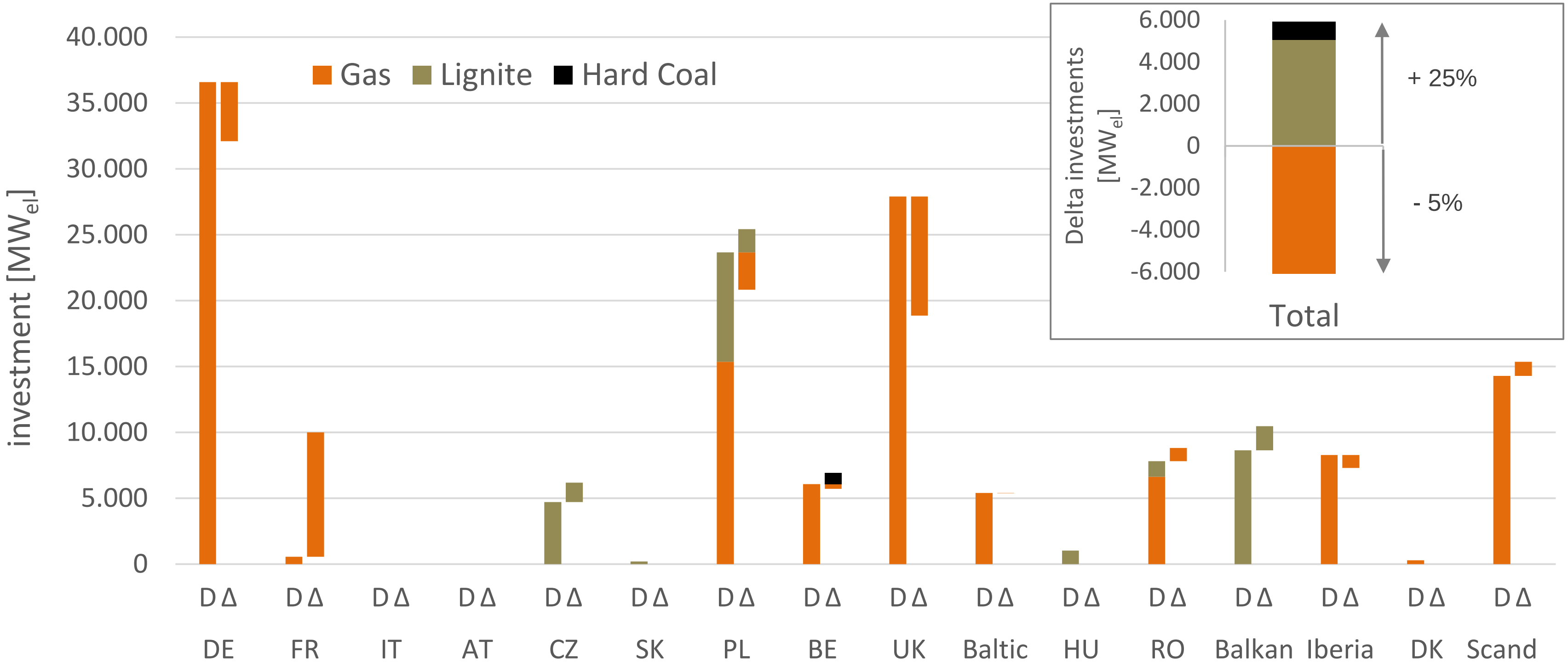

I. Majority of investments into gas-fired technologies

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

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Value of stochastic solution (VSS)
or expected cost of ignoring uncertainty (ECIU)

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:

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

	Total costs	Expected costs of ignoring uncertainty
Stochastic	€ 247,078 M	
Stochastic*	€ 247,143 M	
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%

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Expected value of perfect information (EVPI)

I. Solve each scenario separately as a deterministic model;

II. EVPI is the difference between the expected costs of the stochastic solution and the probability-weighted average of the scenarios' deterministic costs:

$$VSS = f^{stoch} - \sum_{s} \rho_s \cdot f_s^{determ}$$

	Total costs	Saving resulting from a perfect information
Stochastic	€ 247,078 M	
Deterministic		
Scenario 1 (Low dem)	€ 223,432 M	€ 23,646 M
Scenario 2 (Ref dem)	€ 245,533 M	€ 1,545 M
Scenario 3 (High dem)	€ 271,125 M	-€ 24,047 M
EVPI		€ 381 M
EVPI (%)		0.154%

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

EVPI (%) = 3.02%

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)

EVPI (%) = 0.012%

Conclusions

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- We develop an integrated stochastic model considering both gas and electricity sectors
- We focus on effects of gas demand uncertainty on the integrated system
- We observe (i) an overall decrease and (ii) a reallocation of investments in gas-fired technologies.
- We quantify and compare the VSS and EVPI metrics. The findings support the hypothesis that the economic impact of uncertainty should be evaluated using an integrated modelling approach.

- Further research should be conducted to fully understand the impact of different uncertainty drivers on all the planning decisions across the integrated energy system.

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References

Prognos AG, final report “Current Status and Perspectives of the European Gas Balance”, January 2017. Available at: https://www.prognos.com/uploads/tx_atwpubdb/20170406_Prognos_study_European_Gas_Balance_final_1_01.pdf

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