



# Economic impacts of uncertainty in integrated electricity and gas markets

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## Motivation & Research idea

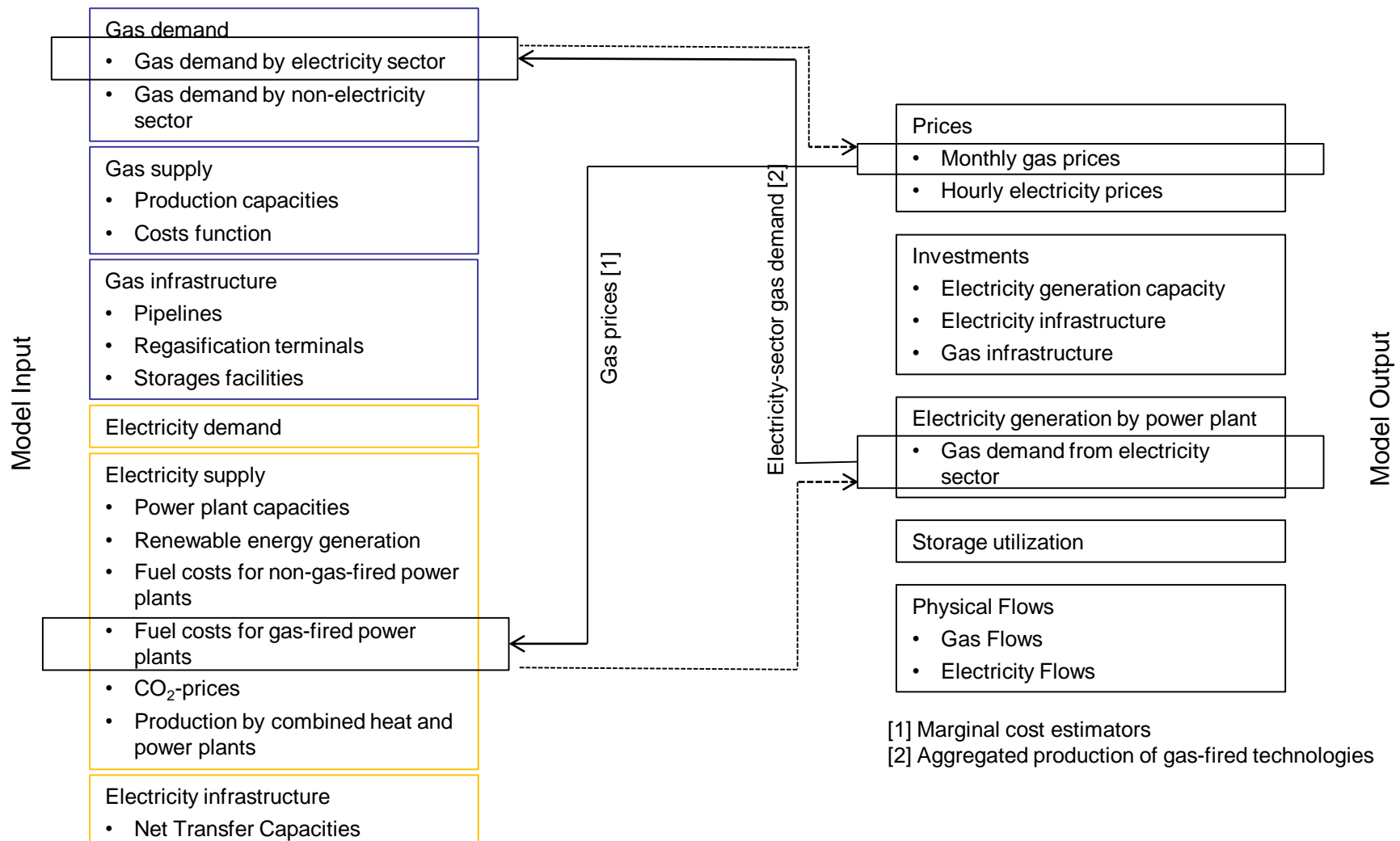
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- Many quantitative models (and studies) focus on single energy sectors, such as electricity OR gas.
- Many large-scale state-of-the-art optimization models remain deterministic.

**We evaluate the economic impacts of different uncertainty drivers on the integrated electricity and gas system.**

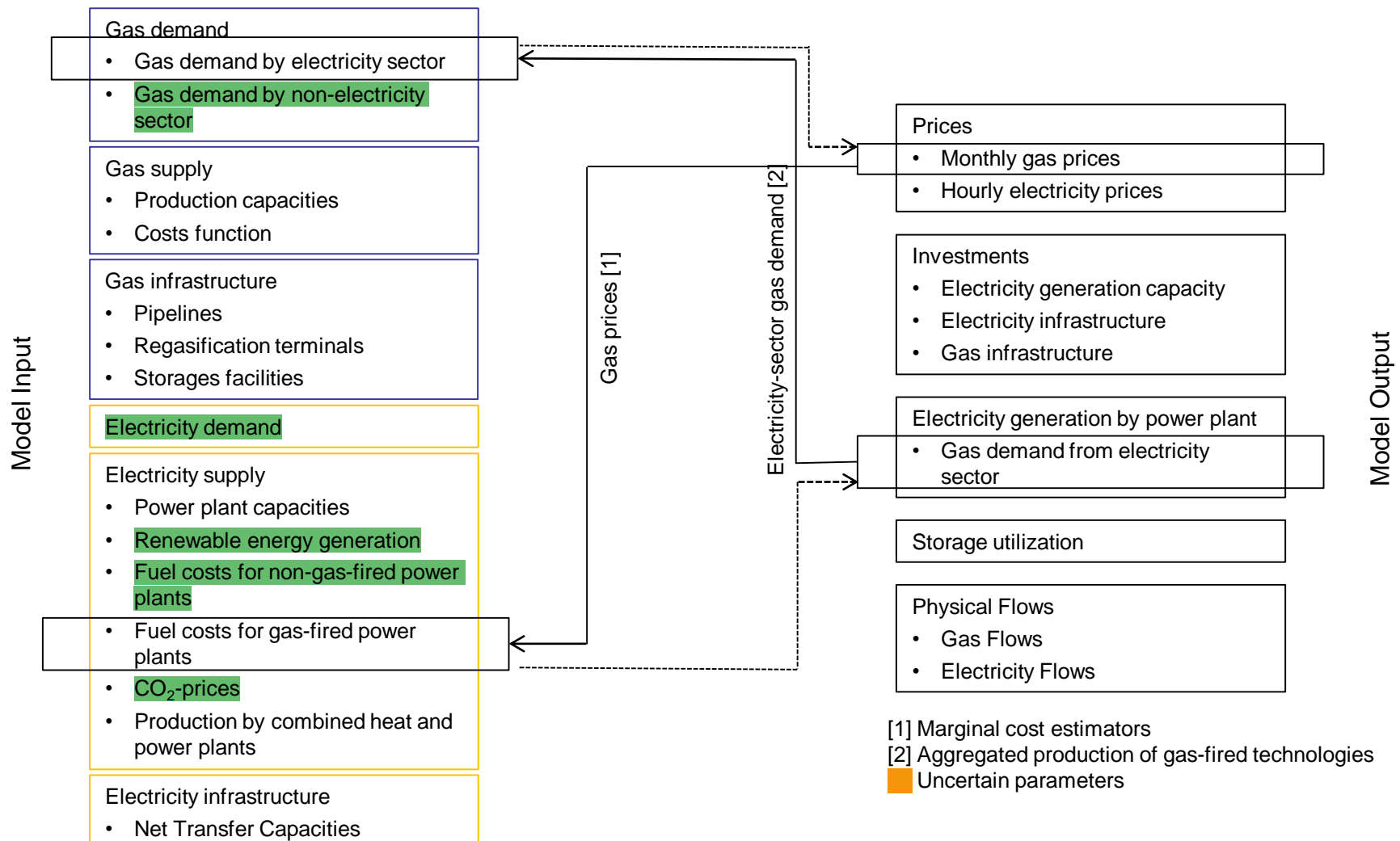
Our analysis includes feedback effects across the markets.

# Model integration (fuel link)

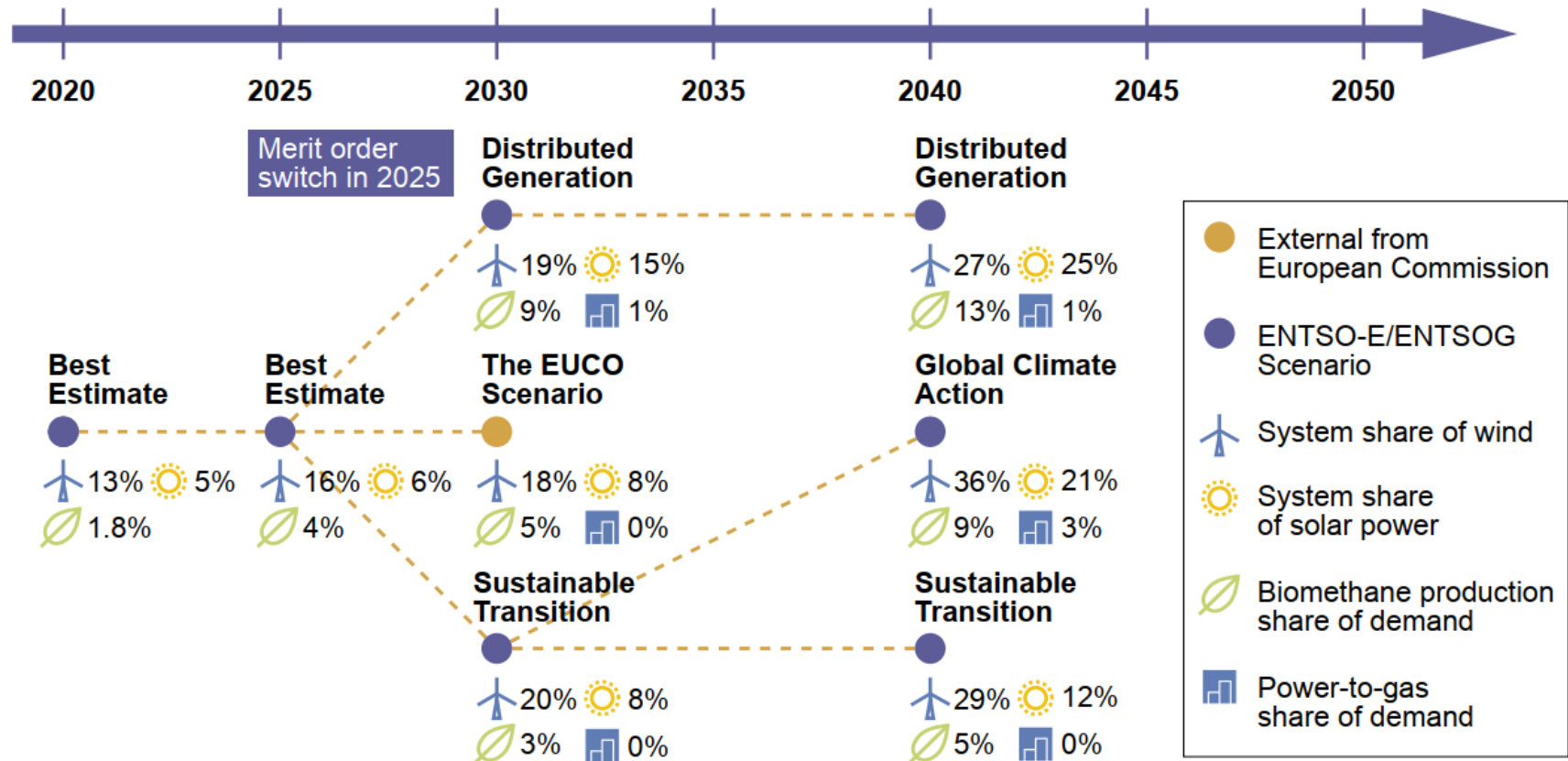


[1] Marginal cost estimators  
[2] Aggregated production of gas-fired technologies

# Model integration (fuel link)

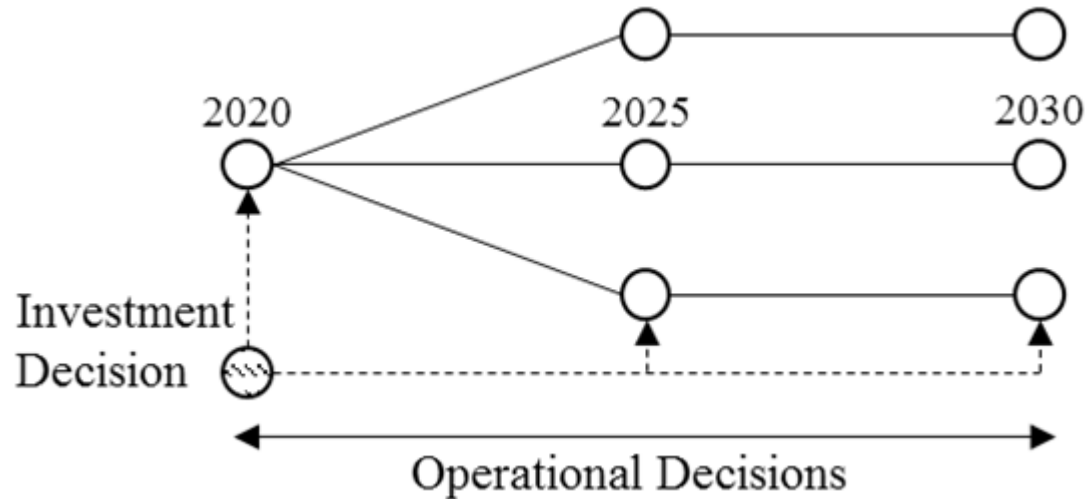


# Implementing uncertainty



Source: The TYNDP 2018 scenarios for 2030 and 2040

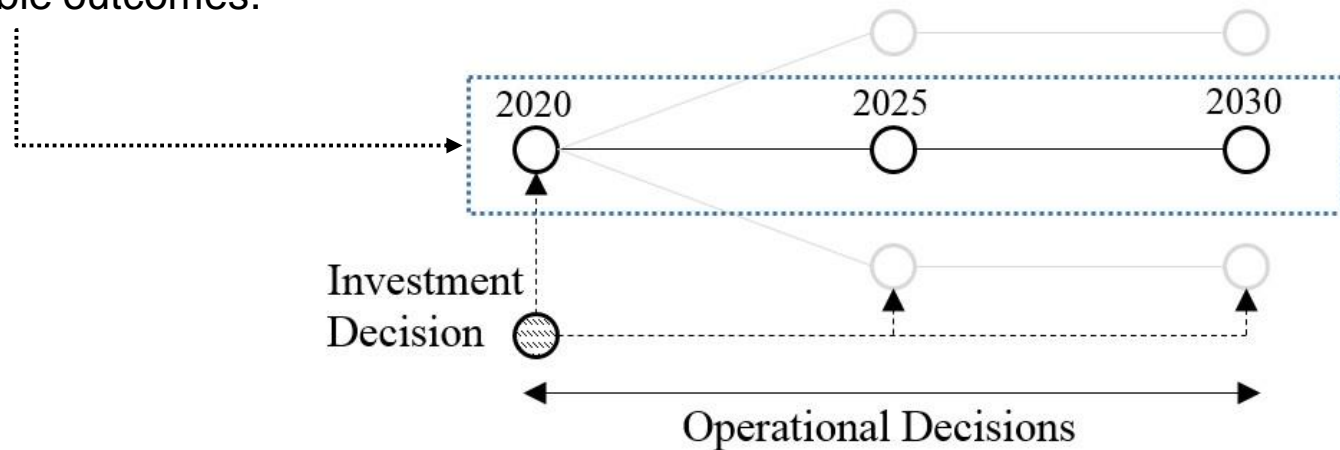
## Implementing uncertainty



- i. Stochastic two-stage model is formulated as a linear optimization model.
- ii. Each branch represents one of the three TYNDP 2018 scenarios.
- iii. The 'stochastic solution' (in the sense of minimization of expected total costs) defines:
  - the optimal endogenous capacity extension plan (that has to hold for all scenarios);
  - scenario-dependent optimal dispatch decisions.

# The Expected Cost of Ignoring Uncertainty (ECIU) or the value of the stochastic solution

Imagine a situation in which a central planner in the first stage naively plans for one specific scenario, even though that scenario is only one from several possible outcomes.



$$ECIU = F_{inv}^{stoch}(fix(EVP)) - F^{stoch}$$

ECIU describes the value of considering the full range of uncertainties in a stochastic model, rather than using a less realistic deterministic model.

# The Expected Cost of Ignoring Uncertainty (ECIU) or the value of the stochastic solution

Parametric uncertainty	Expected costs of ignoring uncertainty <sup>1</sup> [Million Euro <sub>2015</sub> ]	Expected costs of ignoring uncertainty [% of total costs]	Expected costs of ignoring uncertainty <sup>1</sup> [Million Euro <sub>2015</sub> ]	Expected costs of ignoring uncertainty [% of total costs]
	1 <sup>st</sup> stage decisions are based on EUACO30		1 <sup>st</sup> stage decisions are based on EVP	
Gas demand <sup>2</sup>	€ 51 M	0,02%	€ 2 M	0,00%
Electricity demand	€ 1.101 M	0,40%	€ 533 M	0,19%
Installed RES capacity	€ 154 M	0,06%	€ 43 M	0,01%
Fuel price <sup>3</sup>	€ 163 M	0,06%	€ 1 M	0,00%
CO <sub>2</sub> price	€ 463 M	0,16%	€ 9 M	0,00%

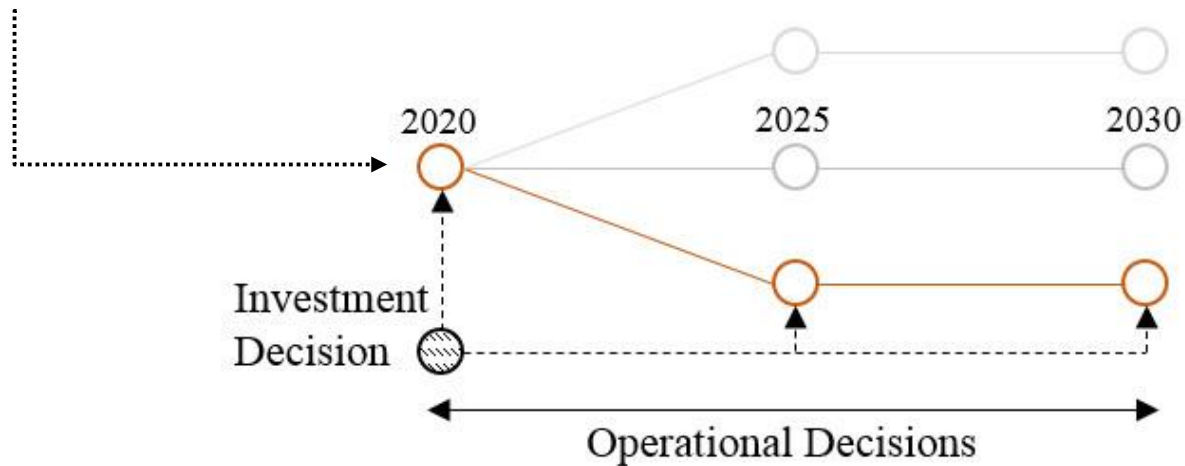
- i. Costs are computed for four representative years (2015, 2020, 2025, 2030).
- ii. Scenario reflects uncertainty in non-power sector of gas demand.
- iii. Fuel price scenario reflects uncertainty in lignite, hard coal and oil prices.

Preliminary results  
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## Expected value of perfect information (EVPI)

Imagine a situation in which a central planner in the first stage knew exactly which scenario would happen.



$$EVPI = F^{stoch} - \sum_s \rho_s \cdot F_s^{det}$$

The EVPI measures the maximum amount a decision maker would be ready to pay in return for complete (and accurate) information about the future.

# Expected value of perfect information (EVPI)

Parametric uncertainty	Total (expected) costs [Million Euro <sub>2015</sub> ]	Saving resulting from a perfect information [% of total costs]
<b>Gas demand - Stochastic</b>	€ 285.432 M	
<i>TYNDP 2018 ST</i>	€ 291.963 M	-€ 6.531 M
<i>TYNDP 2018 EUCO30</i>	€ 279.153 M	€ 6.280 M
<i>TYNDP 2018 DG</i>	€ 285.149 M	€ 285 M
EVPI		☆ € 11 M
EVPI (%)		0,004%
<b>Electricity demand - Stochastic</b>	€ 285.759 M	
<i>TYNDP 2018 ST</i>	€ 281.427 M	€ 4.332 M
<i>TYNDP 2018 EUCO30</i>	€ 284.288 M	€ 1.471 M
<i>TYNDP 2018 DG</i>	€ 290.733 M	-€ 4.974 M
EVPI		★ € 276 M
EVPI (%)		0,097%
<b>Installed RES capacity - Stochastic</b>	€ 285.960 M	
<i>TYNDP 2018 ST</i>	€ 287.854 M	-€ 1.895 M
<i>TYNDP 2018 EUCO30</i>	€ 291.791 M	-€ 5.832 M
<i>TYNDP 2018 DG</i>	€ 277.765 M	€ 8.195 M
EVPI		★ € 156 M
EVPI (%)		0,055%
<b>Fuel price - Stochastic</b>	€ 285.274 M	
<i>TYNDP 2018 ST</i>	€ 284.721 M	€ 553 M
<i>TYNDP 2018 EUCO30</i>	€ 286.339 M	-€ 1.065 M
<i>TYNDP 2018 DG</i>	€ 284.721 M	€ 553 M
EVPI		☆ € 14 M
EVPI (%)		0,005%
<b>CO<sub>2</sub> price - Stochastic</b>	€ 284.924 M	
<i>TYNDP 2018 ST</i>	€ 297.390 M	-€ 12.465 M
<i>TYNDP 2018 EUCO30</i>	€ 272.576 M	€ 12.348 M
<i>TYNDP 2018 DG</i>	€ 283.714 M	€ 1.210 M
EVPI		★ € 364 M
EVPI (%)		0,128%

Preliminary results  
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## Take aways

### For people who formulate energy models by day and try to solve them at night:

- The added value of incorporating uncertainty strongly depends on which scenario is chosen as the reference, e.g.:
  - i. In case of EVP, the ECIU is low for all parameters tested except for electricity demand.
  - ii. In case of EUCO30, the ECIU is high for electricity demand and moderate CO<sub>2</sub> price.
- The ECIU for non-power sector gas demand is always very low.

### For everyone:

- The added value of improved information about the future is the highest for CO<sub>2</sub> price uncertainty.
- Under the TYNDP 2018 energy future settings, the expected savings resulting from the removing non-power sector gas demand and hard coal / lignite price uncertainties are negligible.



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## ECIU vs EVPI

Both ECIU and EVPI compare the expected value of the (investment) decision with another decision made without uncertainty.

- For ECIU an investment decision is made when the uncertainty is ignored (although it is there).
- While for EVPI an investment decision is made after the uncertainty is removed by obtaining perfect information about the future.

To sum up:

- The ECIU is the additional expected cost of assuming that future is certain.
- The EVPI is the expected cost of being uncertain about the future.