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Towards a near zero emission power system in Europe

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The Zero Emission Power system

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What is needed to achieve 90%emission cuts in 2050?

- Transmission versus storage
- How does the role of natural gas develop
  - With CCS?
  - Or without.
- The "winter package": Active consumers and demand response. An alternative to transmission?

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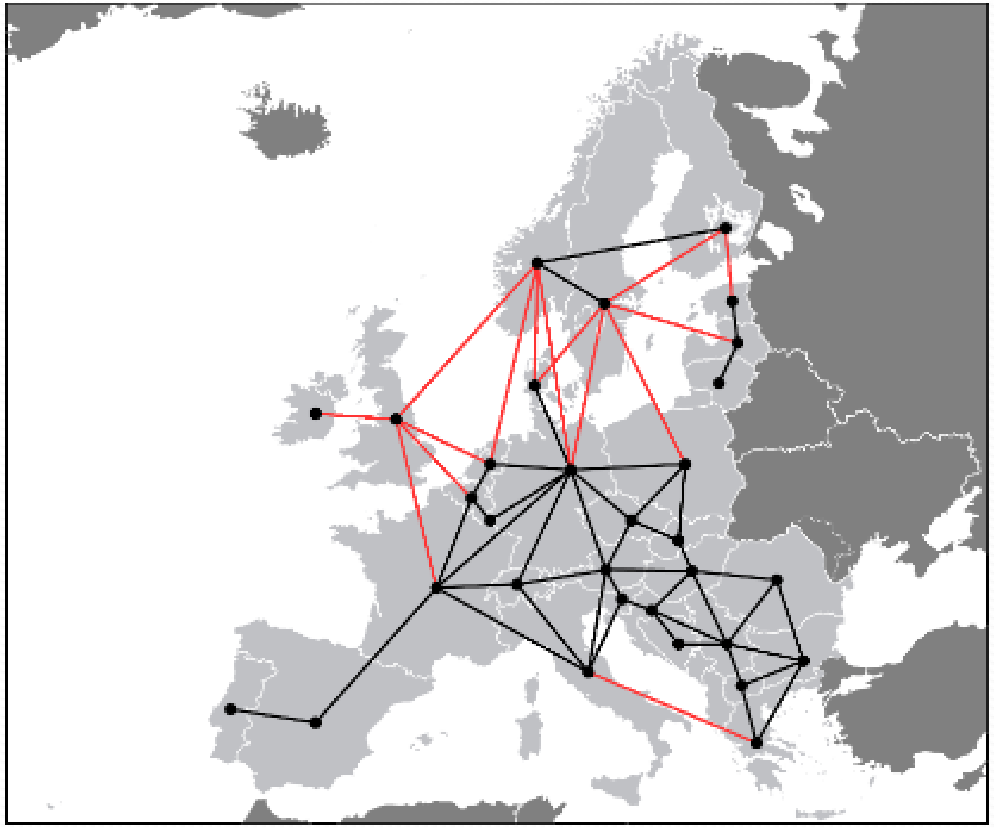
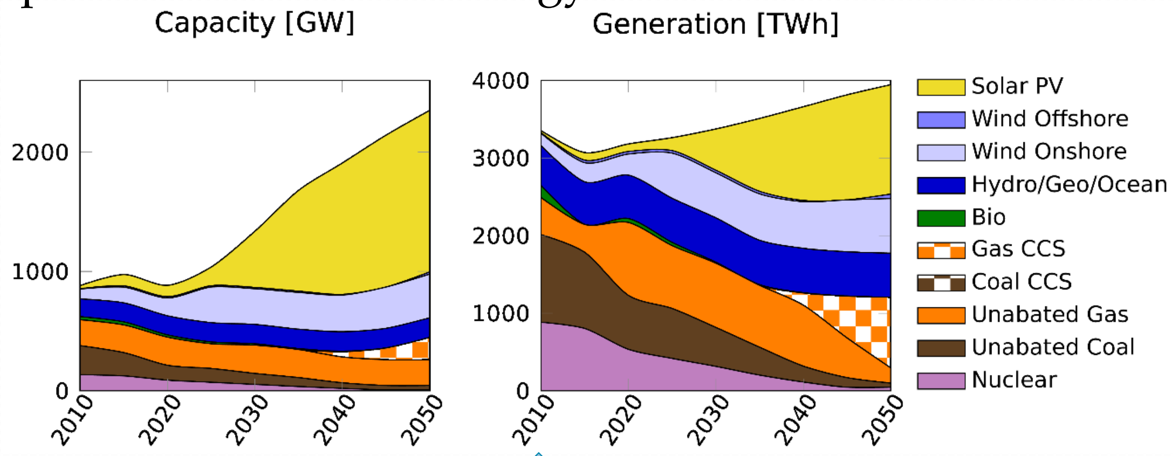
Co-optimization of strategic and operational decisions

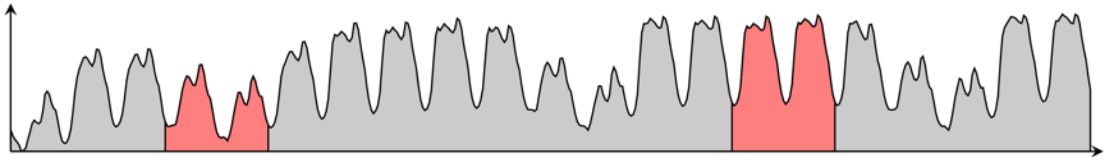


Optimal investment strategy 2010-2015



Coupled optimization problem to minimize total system costs

Optimal dispatch for a number of representative 48-hour blocks



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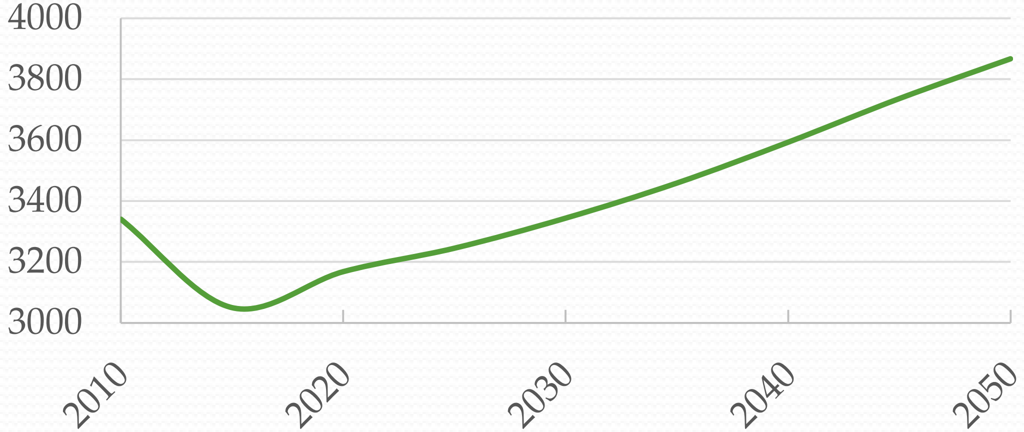
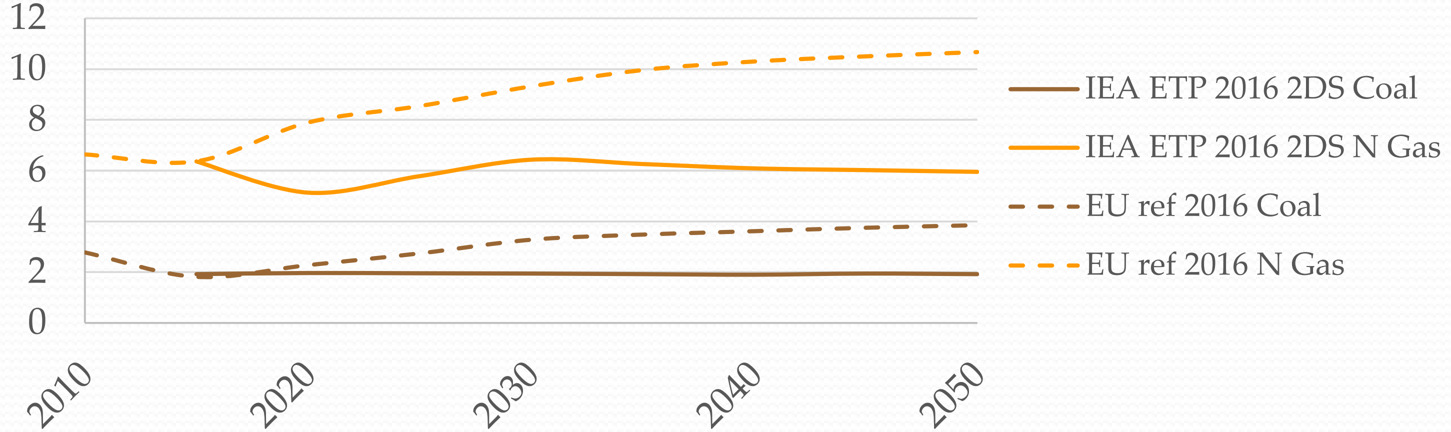
Assumptions

European demand for electricity [TWh/an]

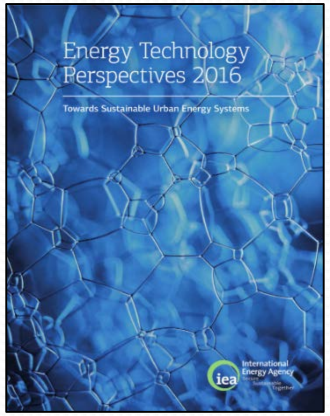


Fuel Prices [€2010/GJ]



EU reference scenario 2016

IEA Energy Technology Perspective 2016



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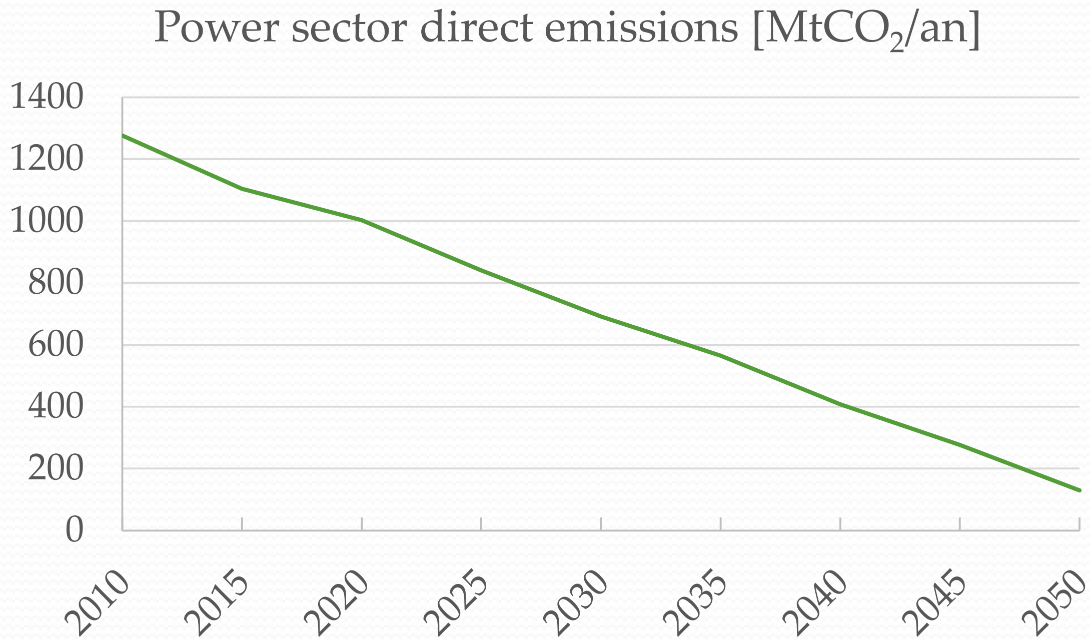
Scenario assumptions

1. Baseline decarbonization: **90 % emission reduction from 2010 to 2050**
   - i. Grid expansion towards 2020 fixed to ENTSO-E's 2016 TYDP reference capacities.
     - i. Beyond 2020: expansion limit of 4 GW for each interconnector every five year period
   - ii. Capacity limits for selected technologies
     - i. Wind onshore capacity potential from IEA's NETP 2016.
     - ii. Solar limited to cover no more than 14% of a country's area (assuming 150 W/m^2)
     - iii. Nuclear capacities limited
   - iii. RES targets defined for Germany, France, Great Britain and Spain
   - iv. Development of Norwegian hydro power predefined

2. Alternative scenario NoCCS: same as baseline but no carbon capture and storage available



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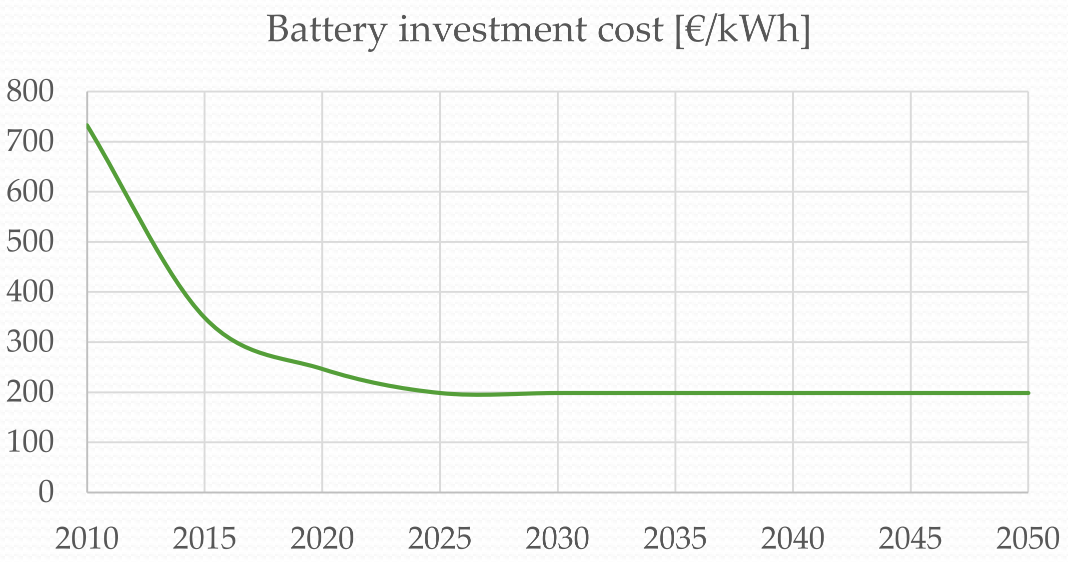
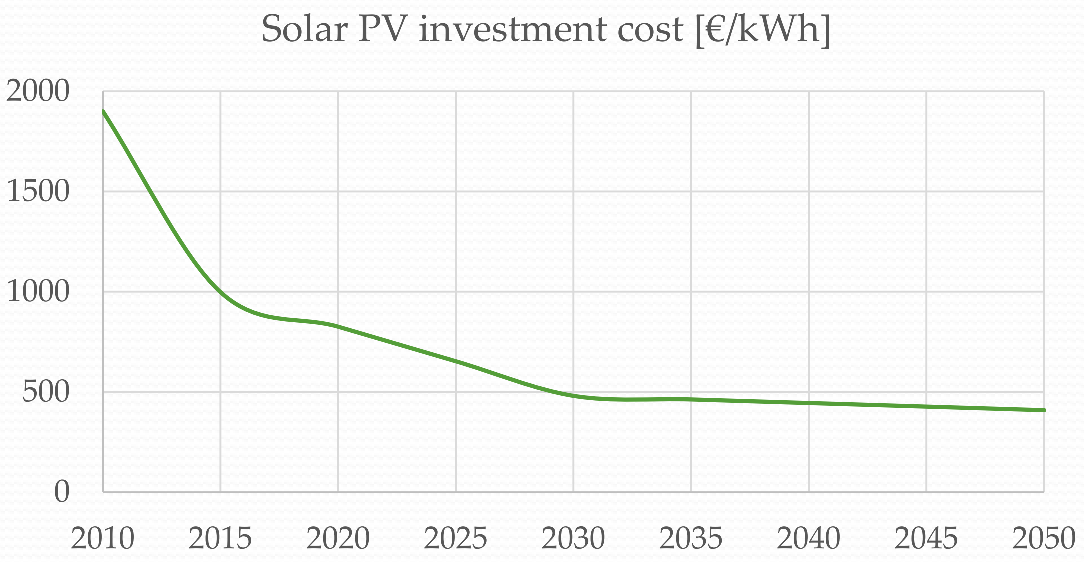
Medium optimistic assumptions for "decentral" technologies



Source: Cole, W. J., Marcy, C., Krishnan, V. K., & Margolis, R. (2016). Utility-scale lithium-ion storage cost projections for use in capacity expansion models. DOI:doi.org/10.1109/NAPS.2016.7747866



Source: PV: Fraunhofer ISE. (2015). Current and Future Cost of Photovoltaics. Long-term Scenarios for Market Development, System Prices and LCOE of Utility-Scale PV Systems. Agora Energiewende.

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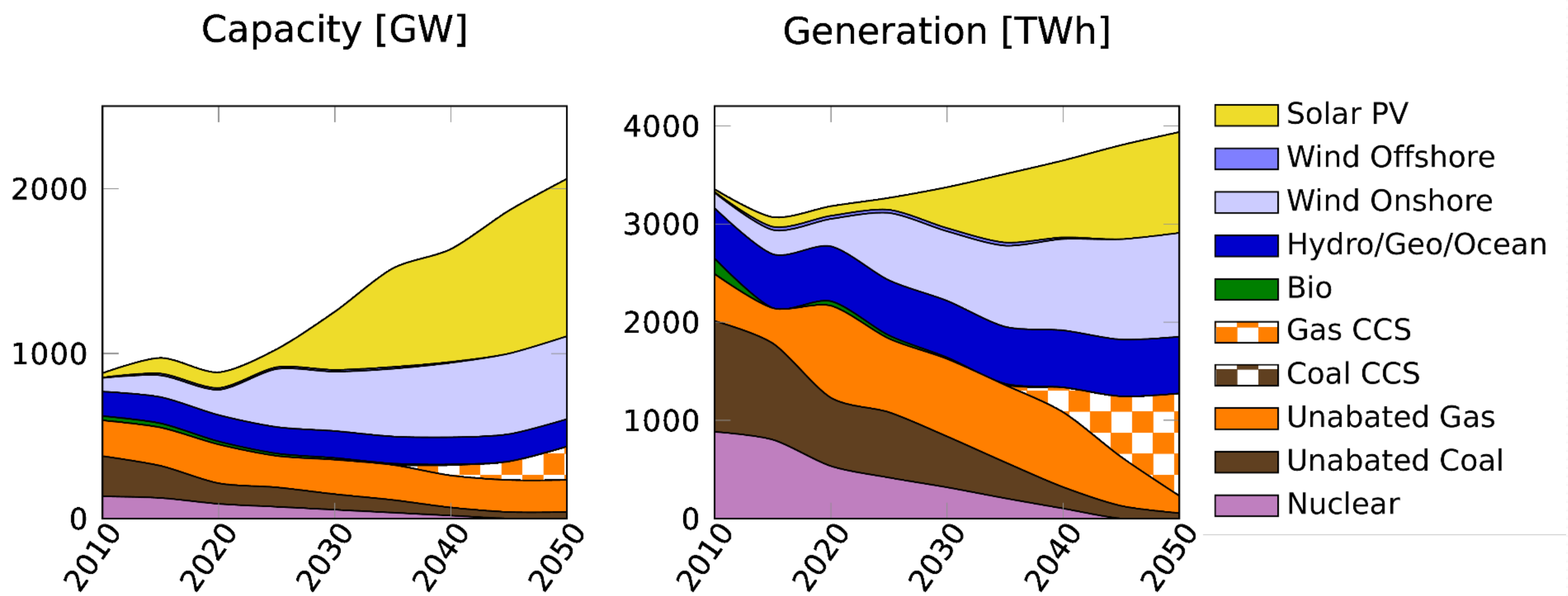
Baseline scenario: 90 % emission reduction



Technology/fuel (2050)	Capacity [GW]	Generation [TWh]
Solar	954 (46%)	1026 (26%)
Wind	503 (24%)	1057 (27%)
Gas CCS	204 (10%)	1043 (26%)
Coal CCS	0 (0%)	0 (0%)
Fossil unabated	233 (11%)	231 (5%)
Others	166 (8%)	578 (15%)

Battery energy storage by 2050: 99 GWh

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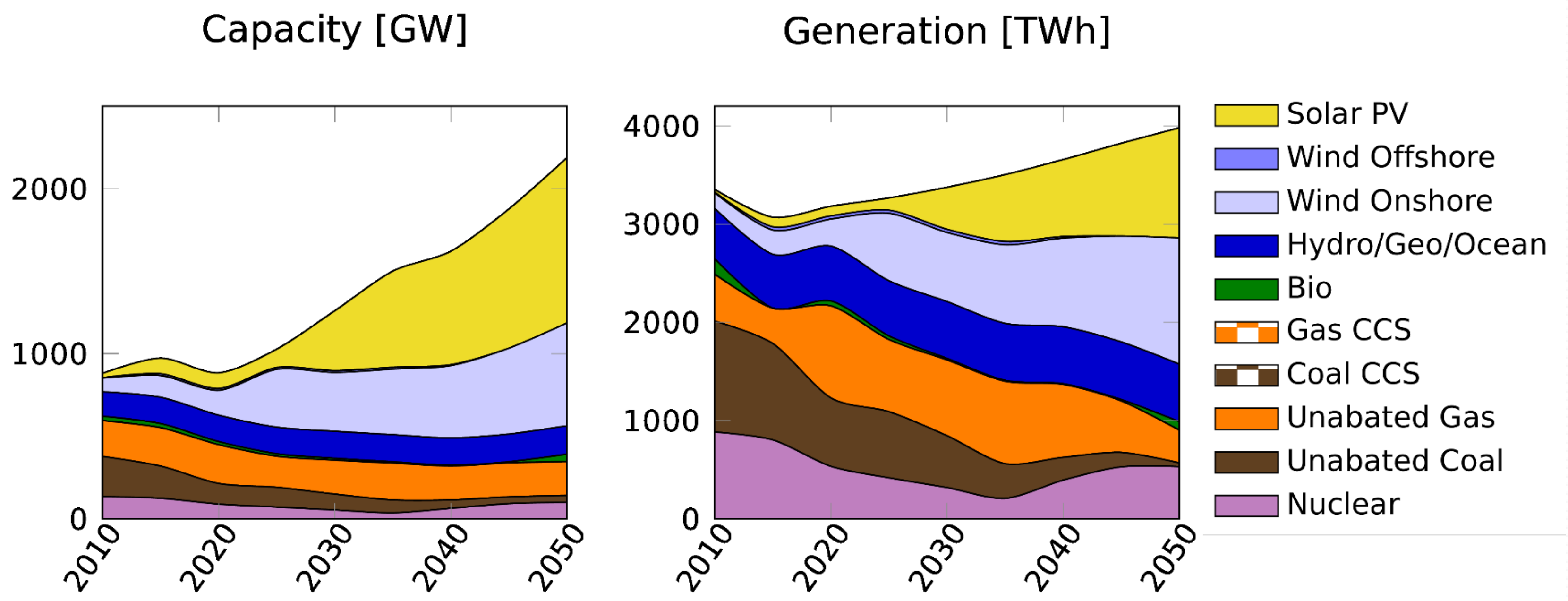
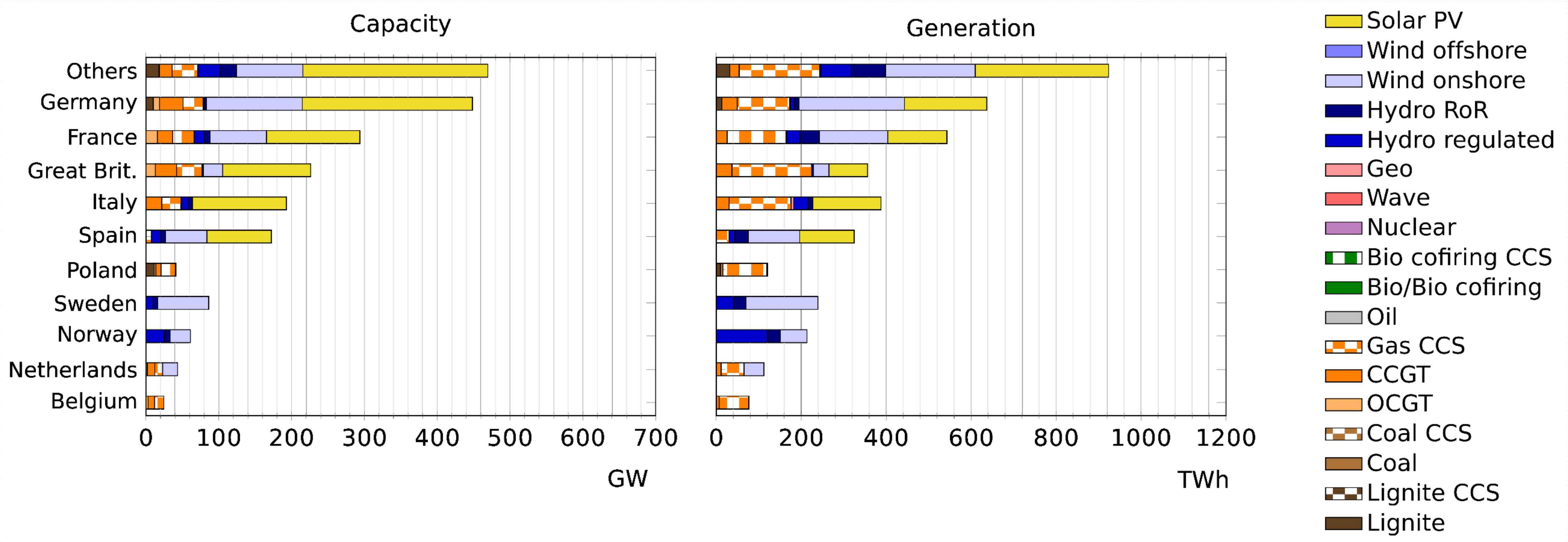
NoCCS scenario: 90 % emission reduction



Technology/fuel (2050)	Capacity [GW]	Generation [TWh]
Solar	1001 (46%)	1120 (28%)
Wind	623 (28%)	1284 (32%)
Gas CCS	0 (0%)	0 (0%)
Coal CCS	0 (0%)	0 (0%)
Fossil unabated	247 (11%)	371 (9%)
Others	316 (15%)	1204 (30%)

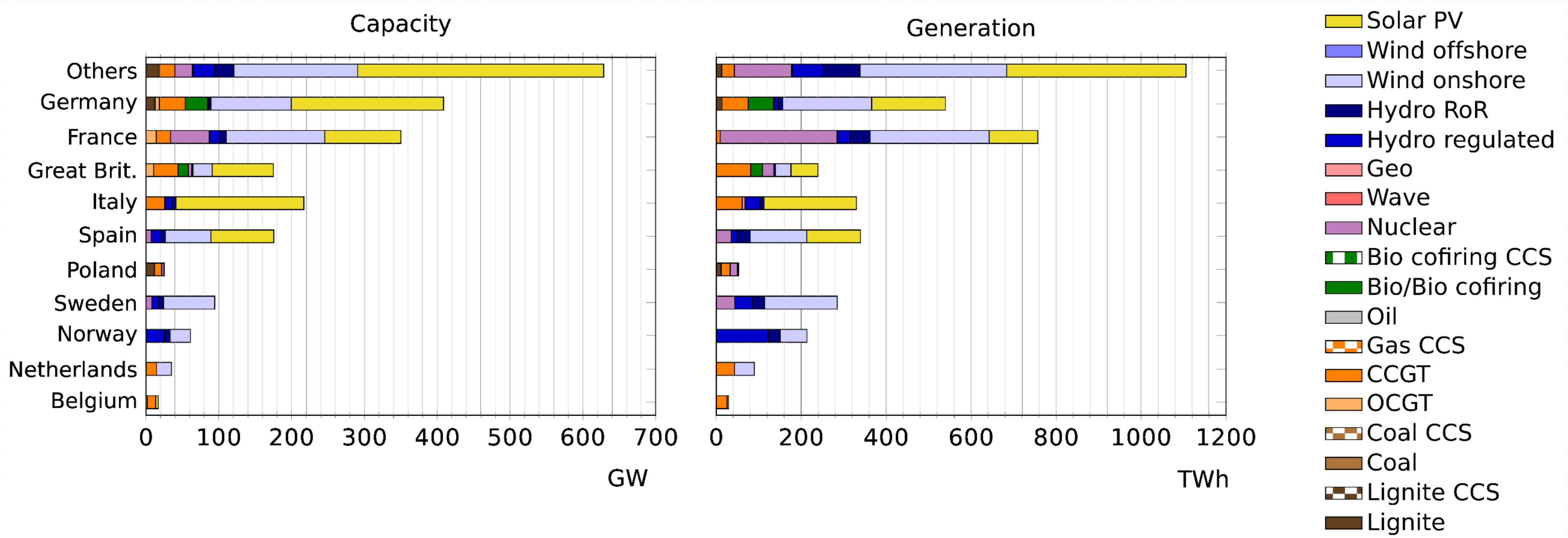
Battery energy storage by 2050: 339 GWh

Baseline country results 2050



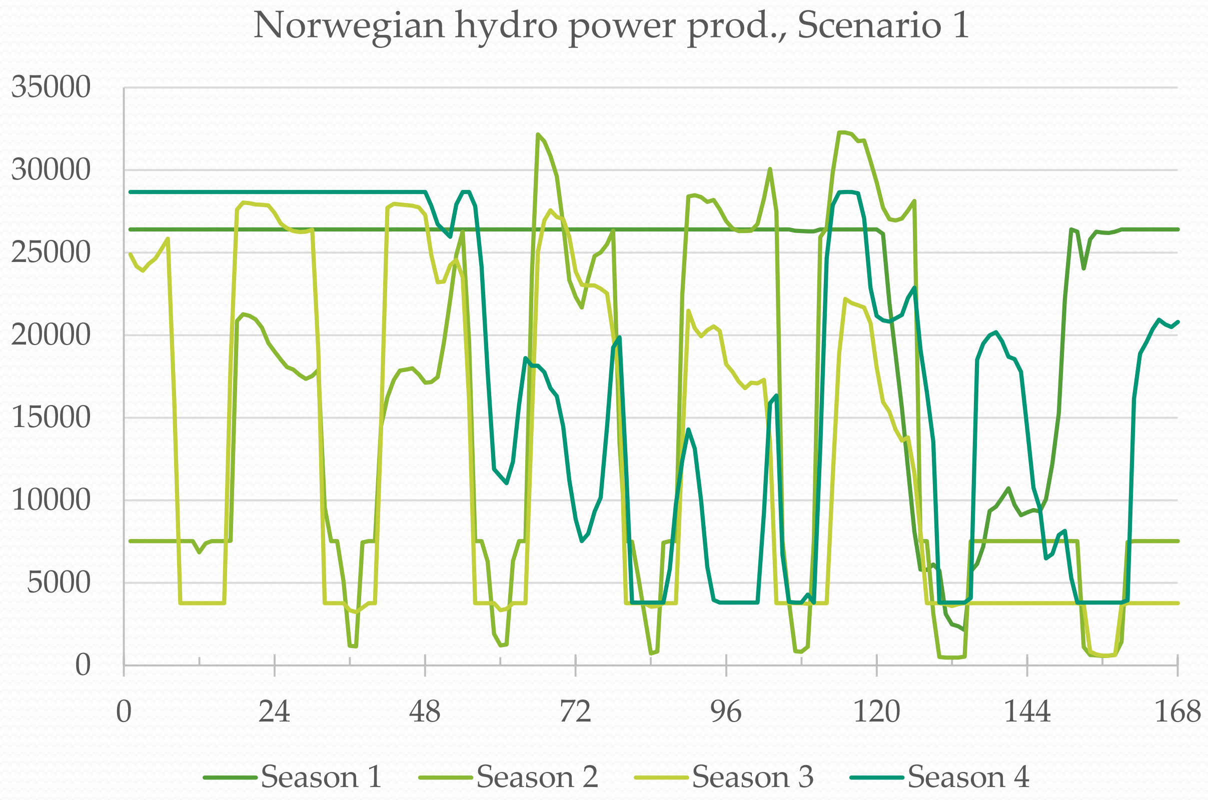
Source: CenSES position paper Norway as a flexibility provider to Europe, in preparation.

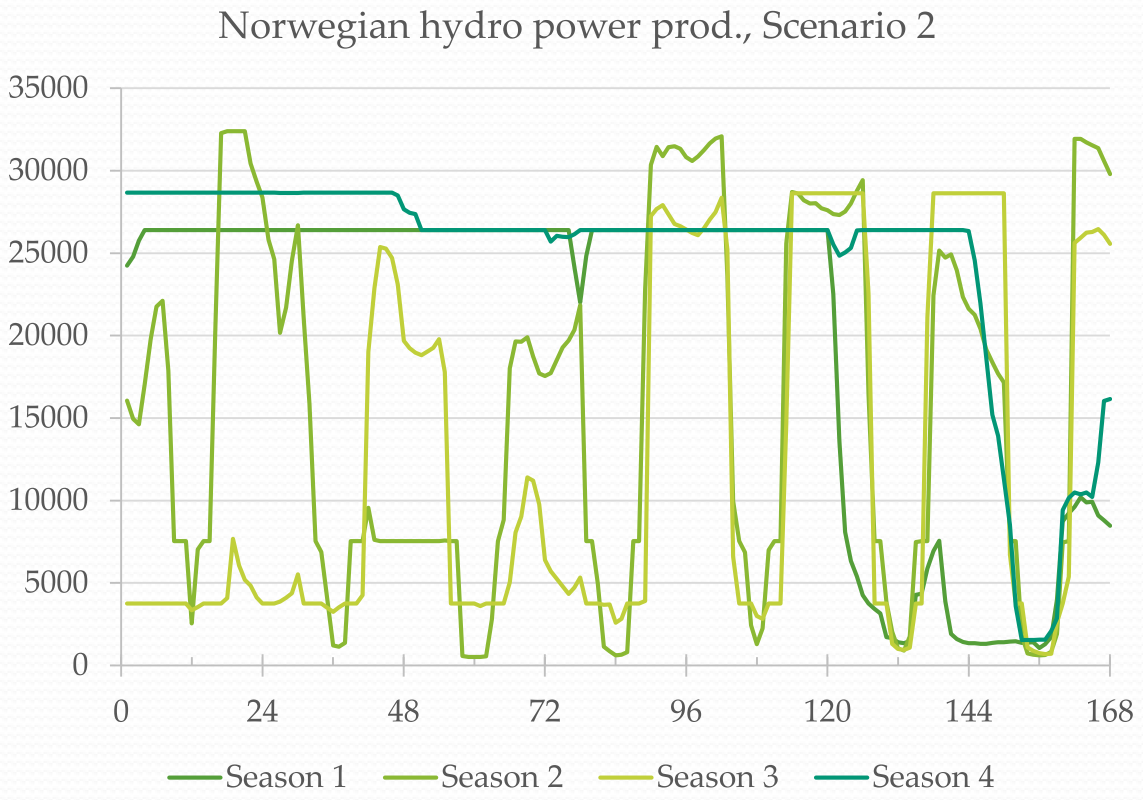
NoCCS country results 2050



Source: CenSES position paper Norway as a flexibility provider to Europe, in preparation.

Baseline Norwegian hydro power production





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Baseline Great Britain natural gas production

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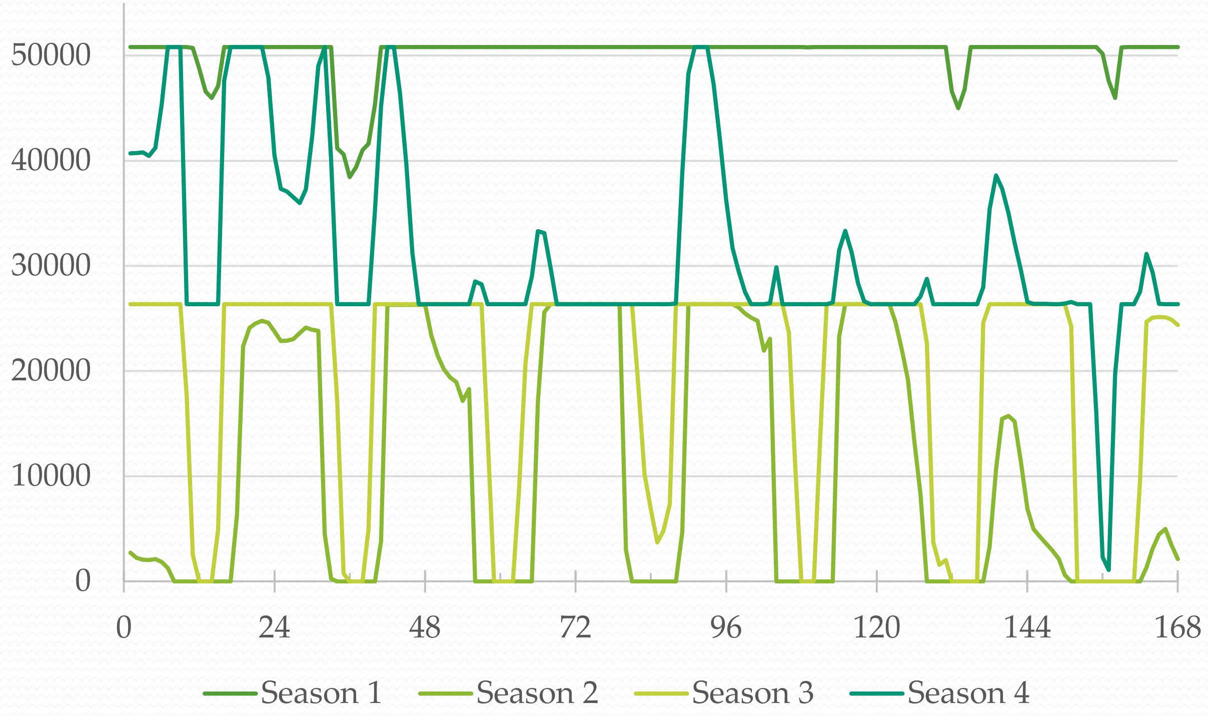
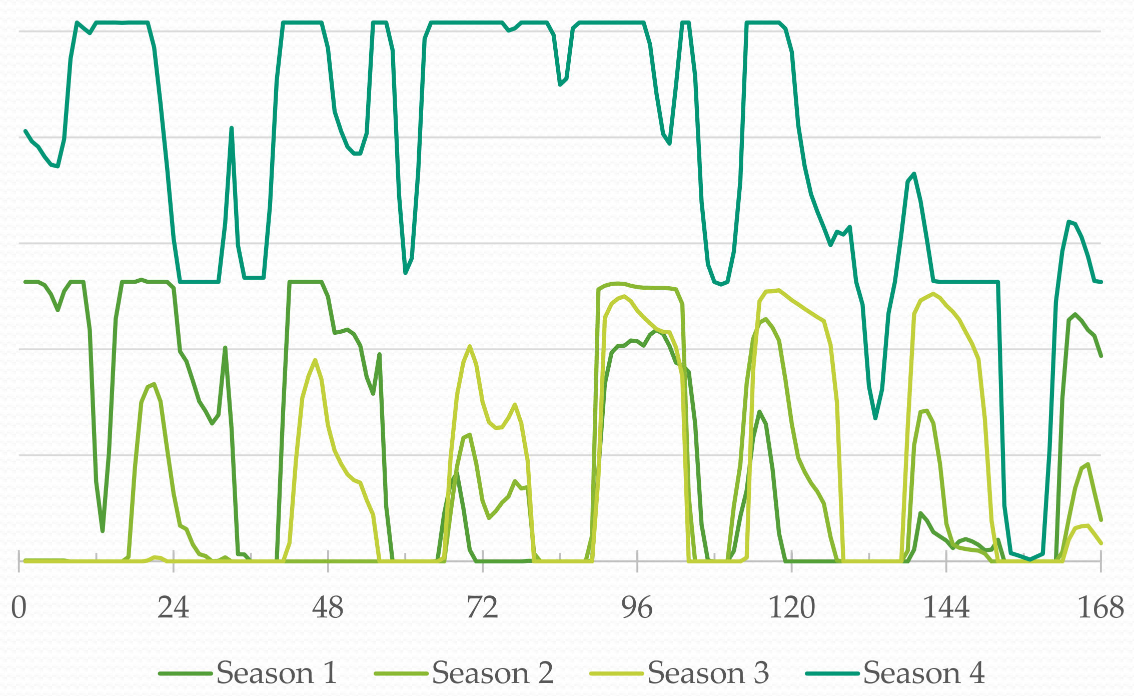
Great Britain natural gas power prod., Scenario 1



Great Britain natural gas power prod., Scenario 2



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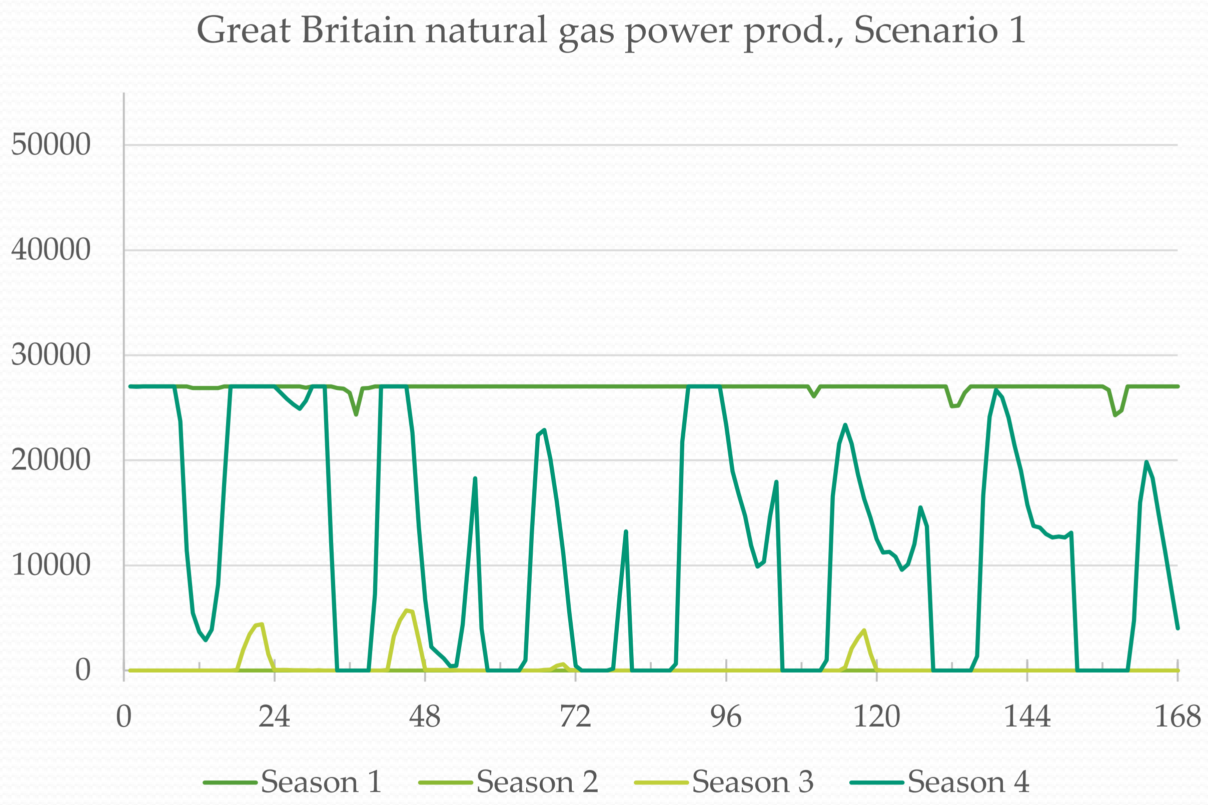
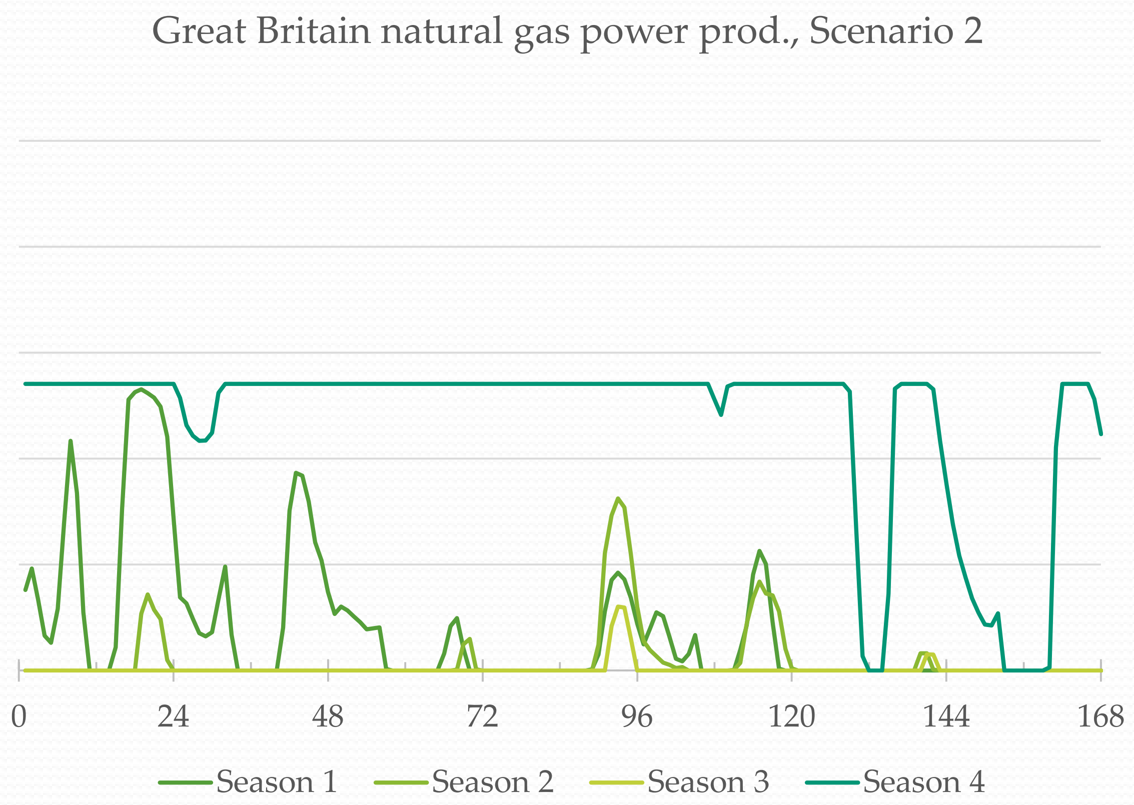
NoCCS Great Britain natural gas production





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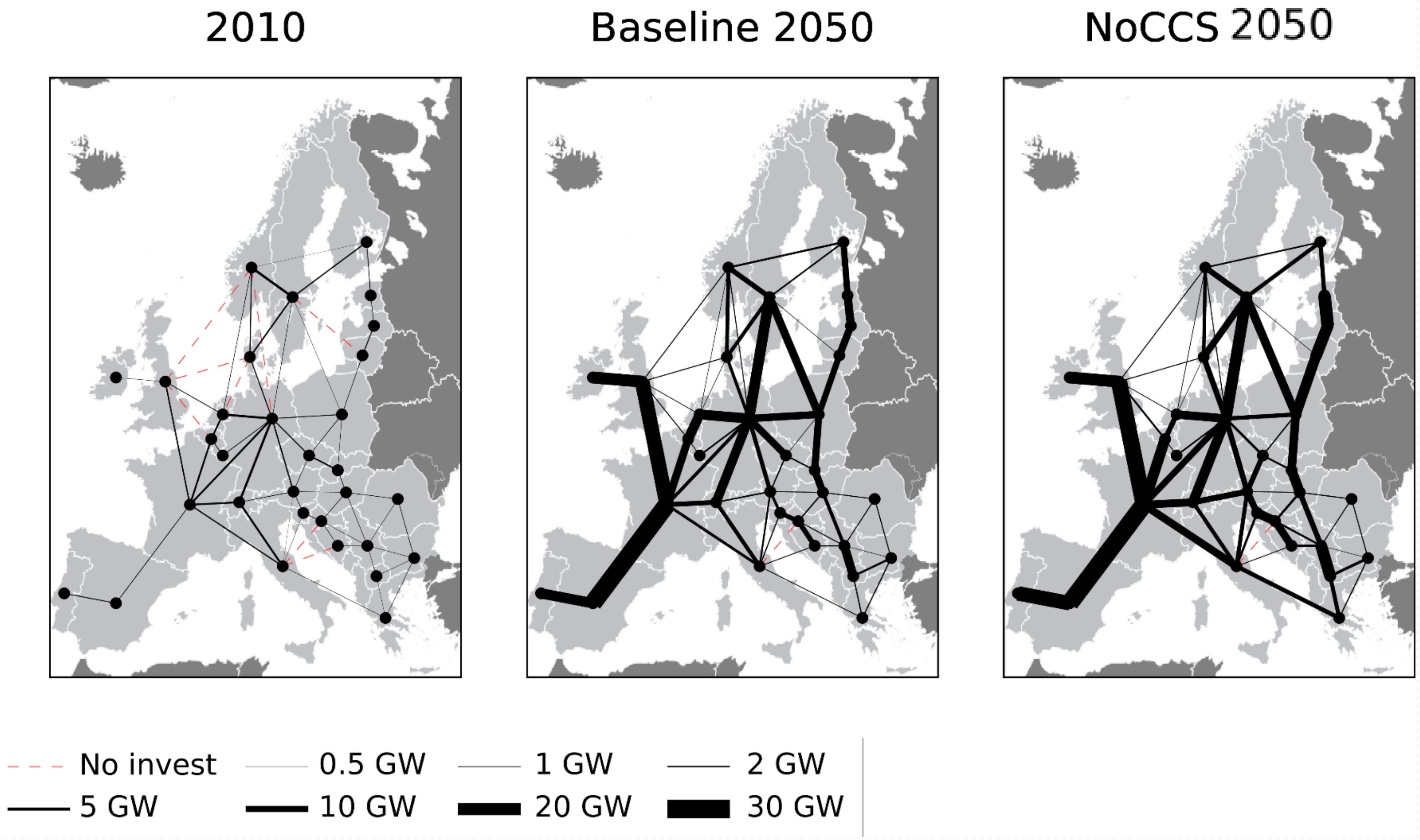
Transmission



Baseline
European cross-boarder interconnector expansion: capacity increases by 644 % from 2010 to 2050

NoCCS
Capacity increases by 826 % from 2010 to 2050

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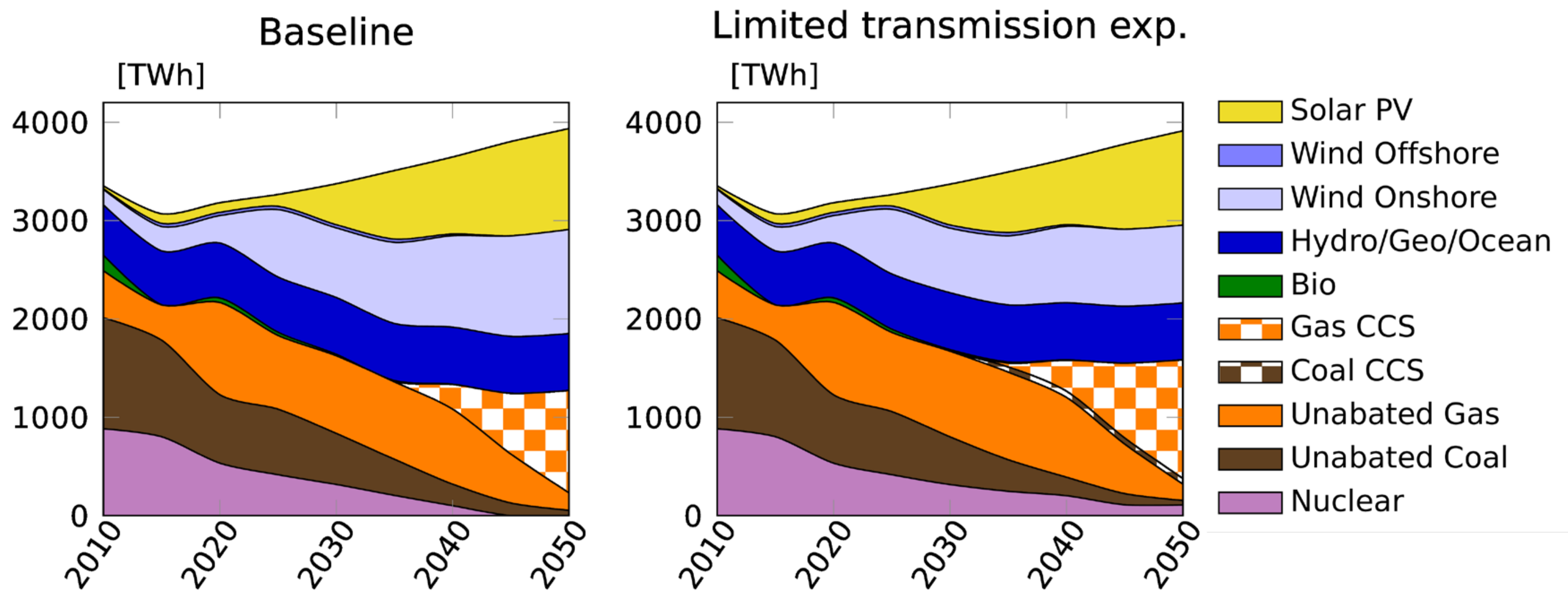
Selection of flexibility options 2050

Scenario	Baseline			NoCCS		
	Gas (GW)	Trans. (GW)	Battery (GWh)	Gas (GW)	Trans. (GW)	Battery (GWh)
With transmission exp.	398	416	99	206	533	339
Limited transmission exp.	442	121	86	247	121	646

Scenario	Baseline		NoCCS	
	Curtail energy (TWh/an)	Avg. elec. Cost (€/MWh)	Curtail energy (TWh/an)	Avg. elec. Cost (€/MWh)
With transmission exp.	84	51	104	64
Limited transmission exp.	60	54	74	56

Sensitivities: Transition to a low-carbon European power sector



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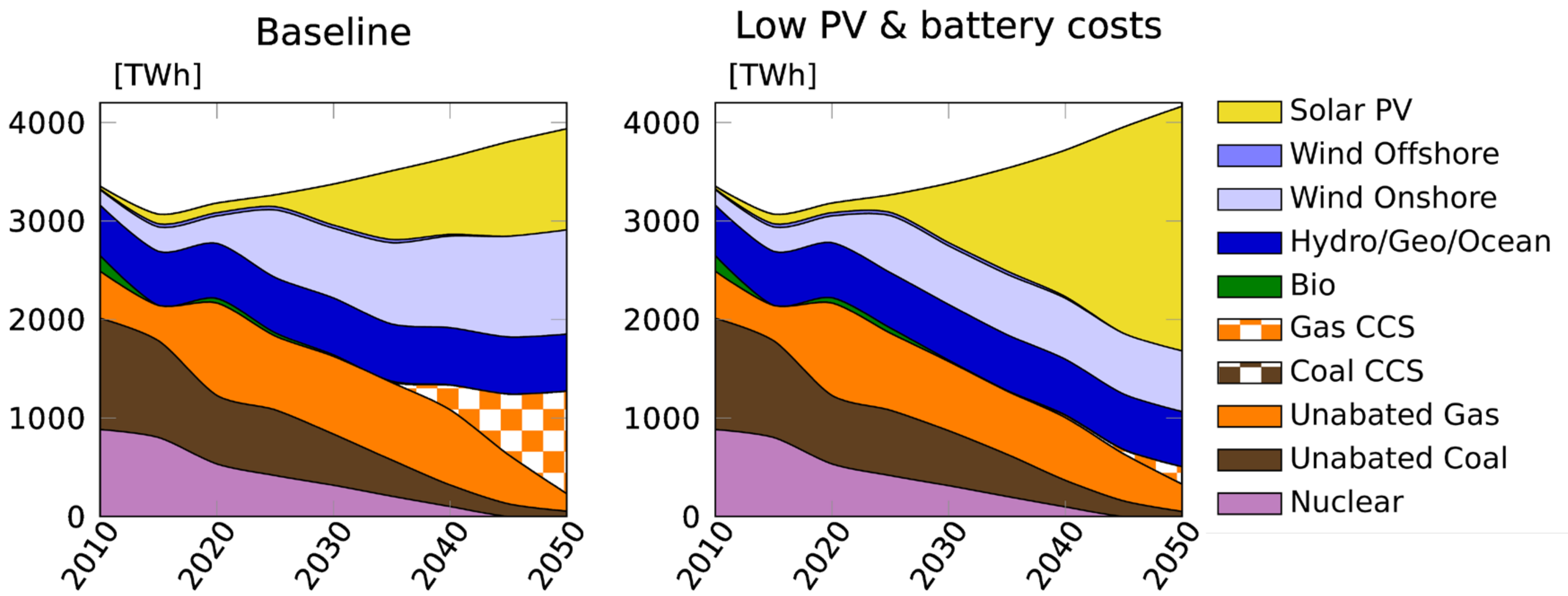
Sensitivities: Transition to a low-carbon European power sector



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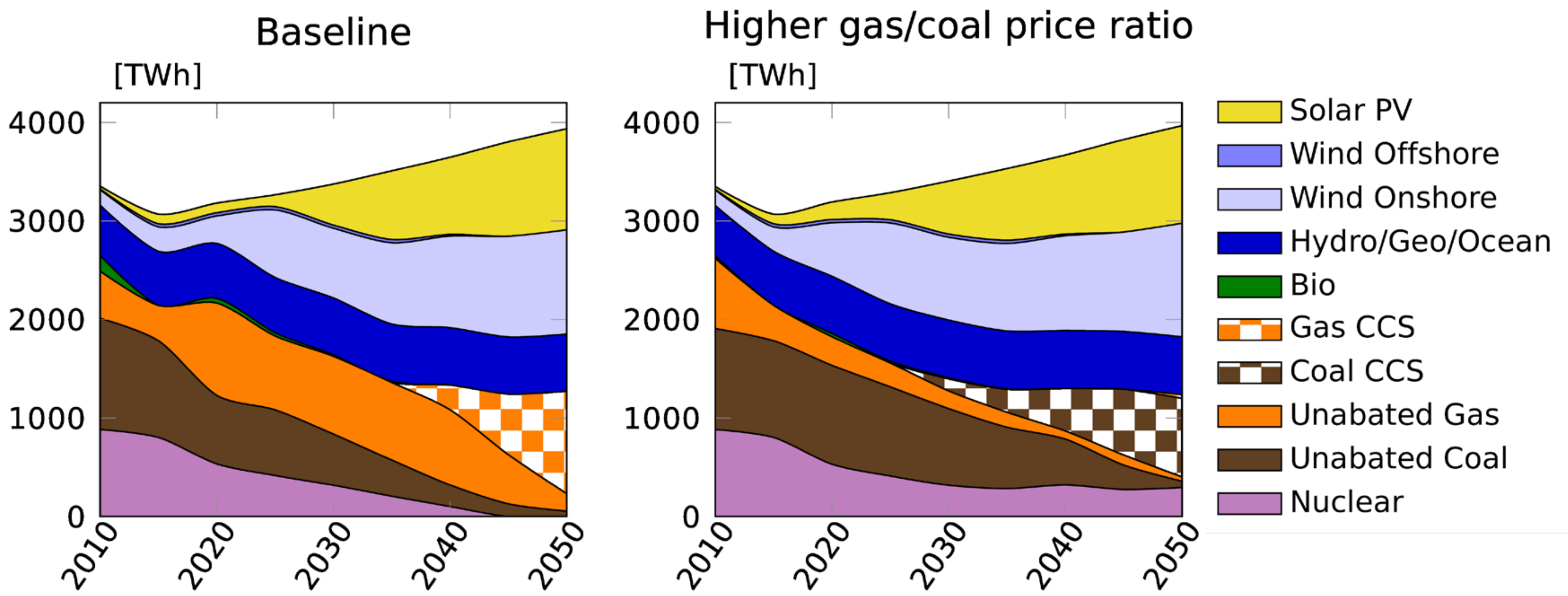
Sensitivities: Transition to a low-carbon European power sector



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Conclusions

- Availability of CCS makes a significant difference in the cost-optimal transition to a low carbon European power system
- The role of natural gas depends on availability of CCS and on the gas/coal price ratio
  - With CCS: natural gas with CCS is used for baseload, unabated for balancing. Total share 31%.
  - Without CCS: natural gas is mostly used for balancing. Total share 8%.
- Without CCS a combination of options are used to achieve low-carbon power generation, including solar, wind and (some) bio, but also nuclear and unabated natural gas
- If solar PV and battery costs follow the most optimistic cost reduction curves available solar can become the dominant technology in the mix (share almost 60%)

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