Lunchtime Webinar

The role and value of inter-seasonal grid-scale energy storage in deep decarbonisation

Caroline Ganzer
Centre for Environmental Policy,
Centre for Process Systems Engineering

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energy futures lab
An institute of Imperial College London

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CleanFaB

21st May 2020

The role and value of inter-seasonal grid-scale energy storage in deep decarbonisation

Caroline Ganzer, Yoga W. Pratama, Niall Mac Dowell

Centre for Process Systems Engineering
Centre for Environmental Policy
niall@imperial.ac.uk
caroline.ganzer17@imperial.ac.uk

TOTAL

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energy saving trust — On the path to net zero: renewable energy

BEIS Public Attitudes Tracker
7th May 2020
Department for Business, Energy & Industrial Strategy

Renewables

Support for renewable energy remained steady at 82% in March 2020.

INDEPENDENT 28 April 2020

Climate crisis: UK hits coal-free record for power generation amid coronavirus lockdown

Closure of fossil-fuel plants and fall in demand due to Covid-19 sees CO2 emissions cut by one-third

The Guardian Tue 19 May 2020

How renewable energy could power Britain's economic recovery

Harnessing power from sun, wind and sea could spur UK's post-pandemic economy while tackling climate crisis, say experts

REUTERS 13.05.2019

Does renewables pioneer Germany risk running out of power?

SPIEGEL
Climate Stasis JULY 18, 2019

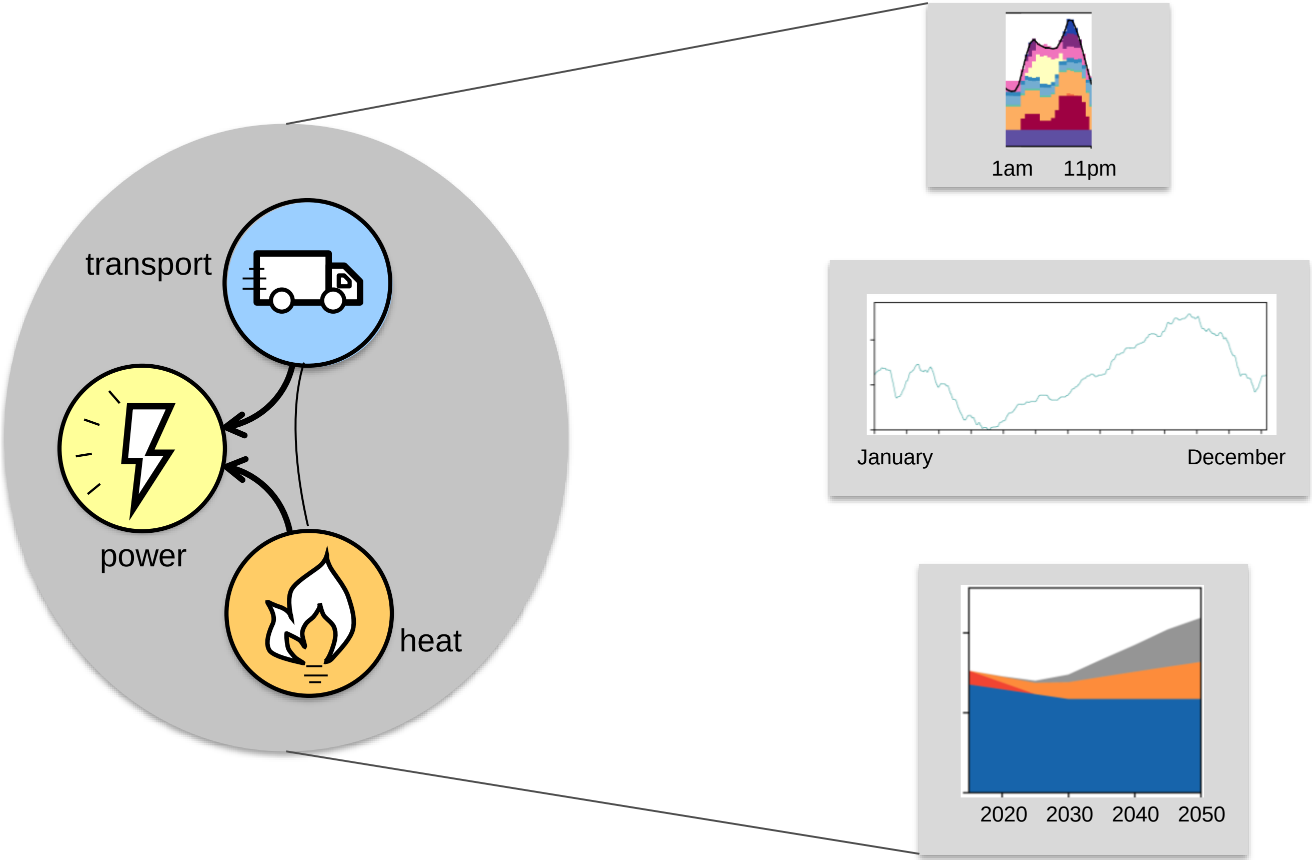
German Failure on the Road to a Renewable Future

Forbes Sep 4, 2019

Why Renewables Can't Save the Climate

FINANCIAL TIMES MAY 14 2019

Falling renewables investment stalls Paris climate goals


transport
power
heat
1am
11pm
January
December
2020
2030
2040
2050

Energy transition, electrification & renewables integration – risks and potential mitigation

- outages (social & economic loss)
- missing climate targets (social & economic loss)
  - variability of power supply & power demand
    - spatial variation
      - grid transmission expansion
      - interconnection
    - hourly / daily intermittency
      - daily energy storage
    - seasonal intermittency
      - dispatchable zero-carbon generation
      - inter-seasonal energy storage
  - grid stability / ancillary services
    - reserve
      - dispatchable zero-carbon generation
      - energy storage
    - inertia
      - synchronous compensator
      - dispatchable zero-carbon generation
  - speed of capacity expansion & transition
    - policy instruments
    - diverse technology portfolio
    - negative emissions

Questions

What is the potential for inter-seasonal grid-scale energy storage in the UK when explicitly accounting for the electrification of heat and transport?

Which function does inter-seasonal storage take on depending on the capacity mix?

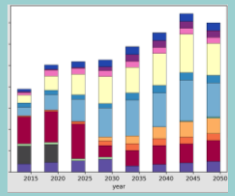
What are priorities for the development of power-to-gas technologies?

What are cost optimal combinations of renewables, storage, low-carbon dispatchable technologies, negative emissions technologies?

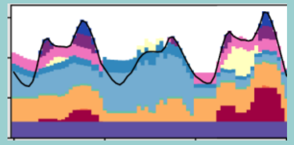
Energy Systems Optimisation Model (ESO(NE))

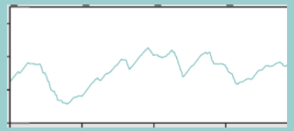
$\forall i \in I$ $\forall a \in A$	**Capacity expansion**	Initial supply and transmission capacity Build rate constraints (supply, store, transmiss.) Life time constraints Maximum resource constraints
$\forall c \in C$	**System-wide constraints**	Electricity demand Demand for commodities Reserve requirements Inertia requirements Emission target & carbon price
$\forall z \in Z$	**Transmission**	Transmission between zones
$\forall t \in T$	**Tech.-wise constraints** **Integer scheduling**	Power, Reserve, inertia provision Flexibility of generation/storage units Carbon emissions by technology Uptime and downtime Import and export of commodities
$\sum$	**Objective**	min { CAPEX + OPEX }

technology deployment until 2050

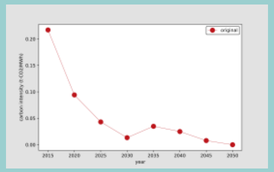


power dispatch schedule, storage levels, technology utilisation



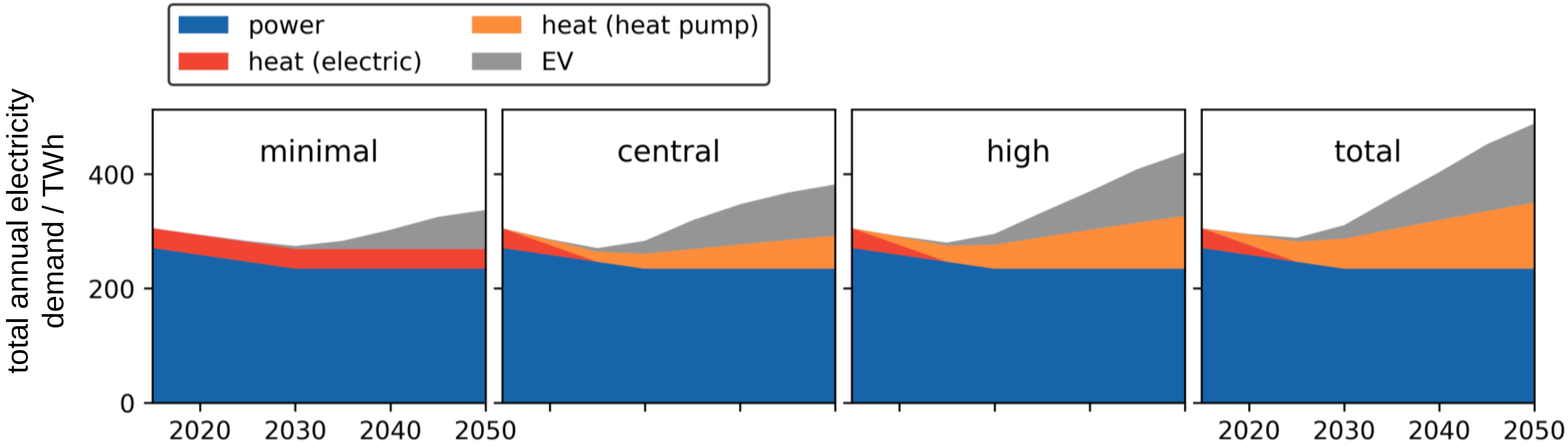


carbon intensity, total costs, electricity price



[1]-[3]

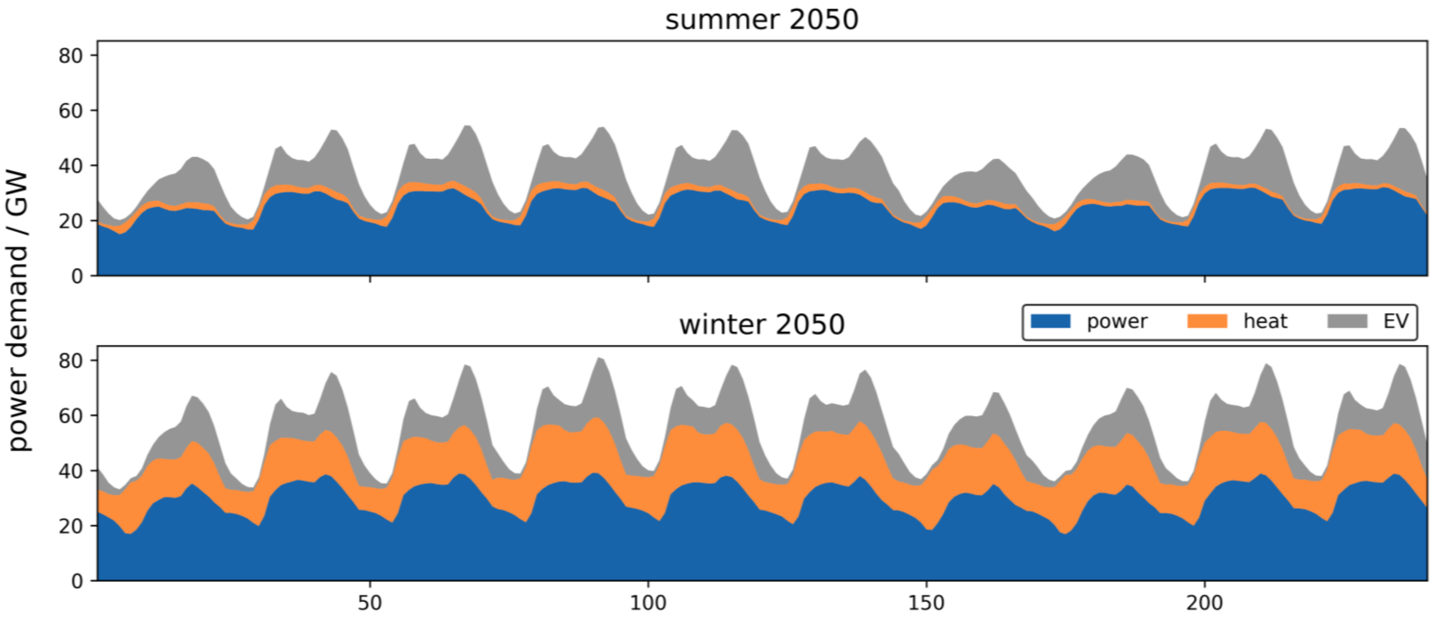
Electrification scenarios



power	efficiency improvements until 2030, further improvements offset by growth			
EV	steady progression	~50% of road transport	~80% of road transport	~100% of road transport
heat pumps	no deployment	70% air-sourced, 30% ground-sourced heat pumps, no heat storage, profiles calculated using one year of full-hourly heat pump COP data		
		~50% of residential & commercial demand	~80% of residential & commercial demand	~100% of residential & commercial demand

[5]-[11]

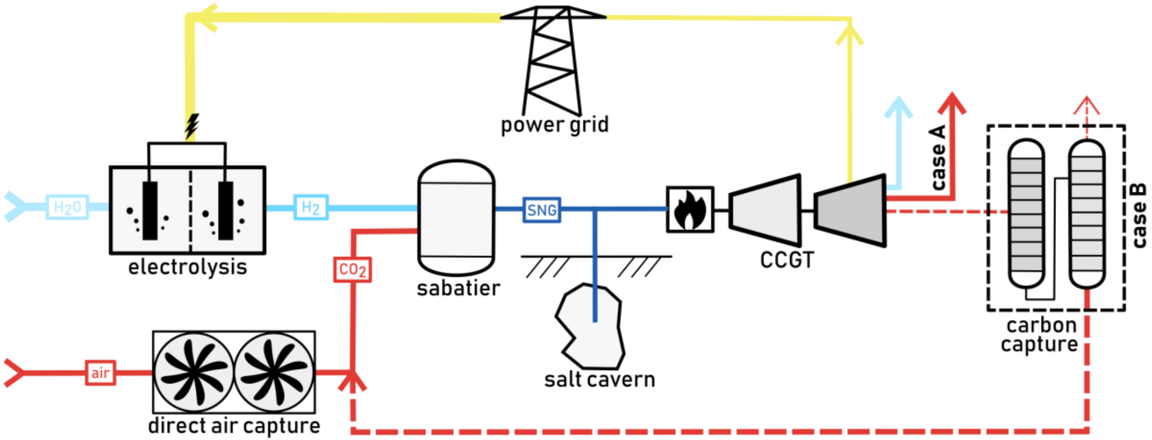
Electrification scenarios



Disaggregating by sector allows us to incorporate the changing profile of the demand, becoming more "peaky" and more seasonal.

[5]-[11]

Power-to-methane storage (P2M)



Power-to-methane has been shown in previous work to have cost advantages compared to power-to-hydrogen.

Yao et al., Sustainable Energy & Fuels 3 (11), 3147-3162), 2019.

We solve ESO-X in linear relaxation with **full-hourly demand & renewables data** in order to allow inter-day storage and analyse seasonal effects.

	CAPEX	Round-trip efficiency	Storage duration	Self-discharge
Pumped hydro storage	1,200 £/kW	0.75	5 h	0
Battery storage	1,800 £/kW	0.85	5 h	0.000050 /h
Power-to-methane storage (P2M)	2,400 £/kW	0.29	8400 h	0

Critical assumptions

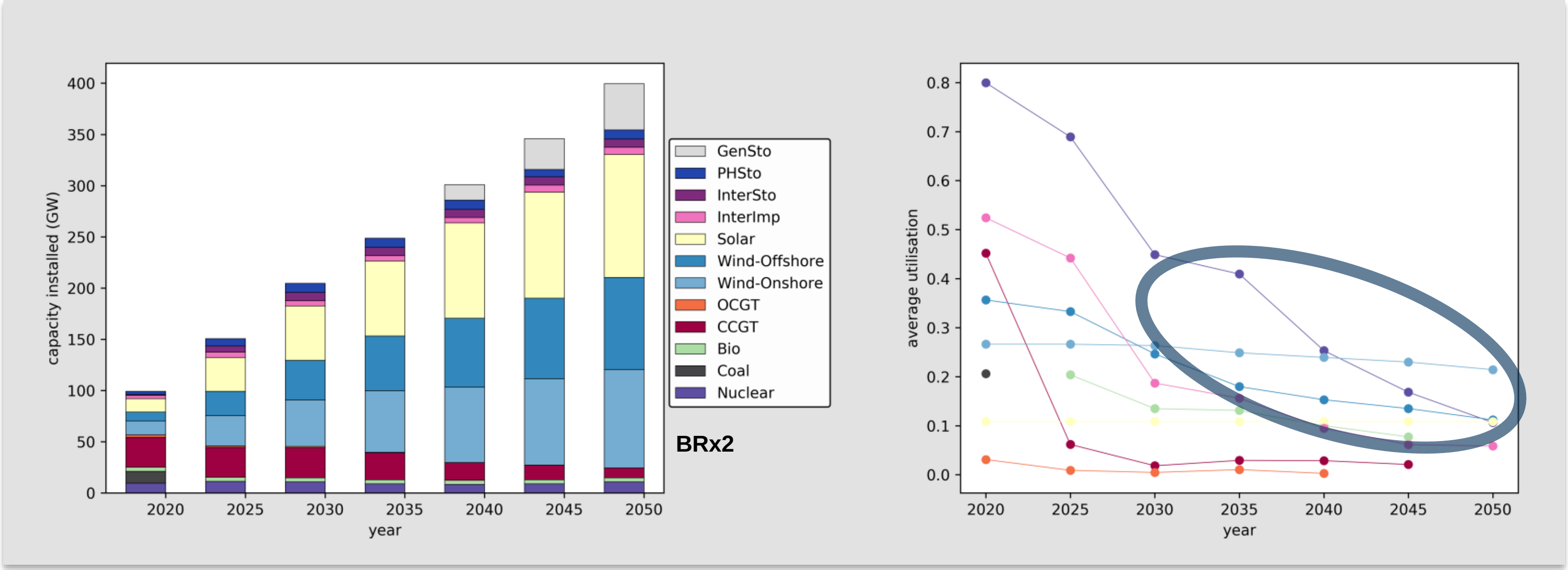
Net-zero carbon target in 2050 without a specific trajectory.
Carbon price on CO_2 emissions ramping up from 18 £/tCO_2 in 2020 to 236 £/tCO_2 in 2050.

Biomass has embodied emissions of 0.25 tCO_2/t caused by the supply chain, which are counted toward the carbon target and penalised by the carbon price.

Plant **flexibility** is constrained via up time & down time, all plants are assumed to be able to start up and shut down within one hour; storage is always running.

Build rates (BR) are constrained based on historical date and increased by a factor when needed.

High-iRE system without seasonal storage or dispatchable technologies



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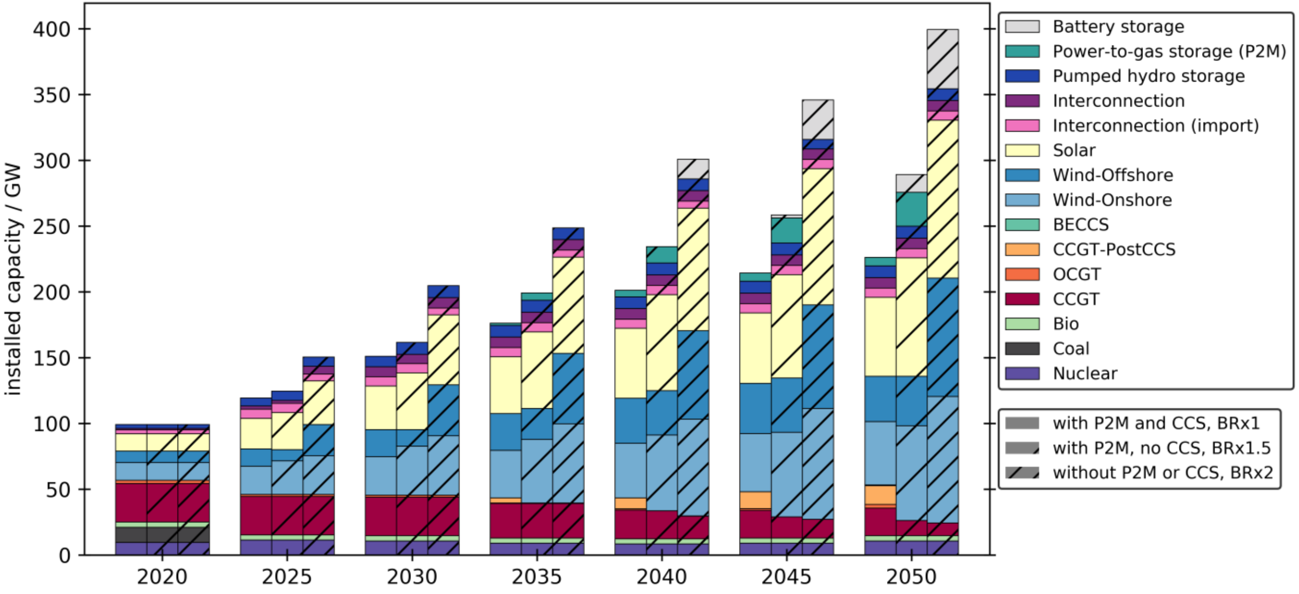
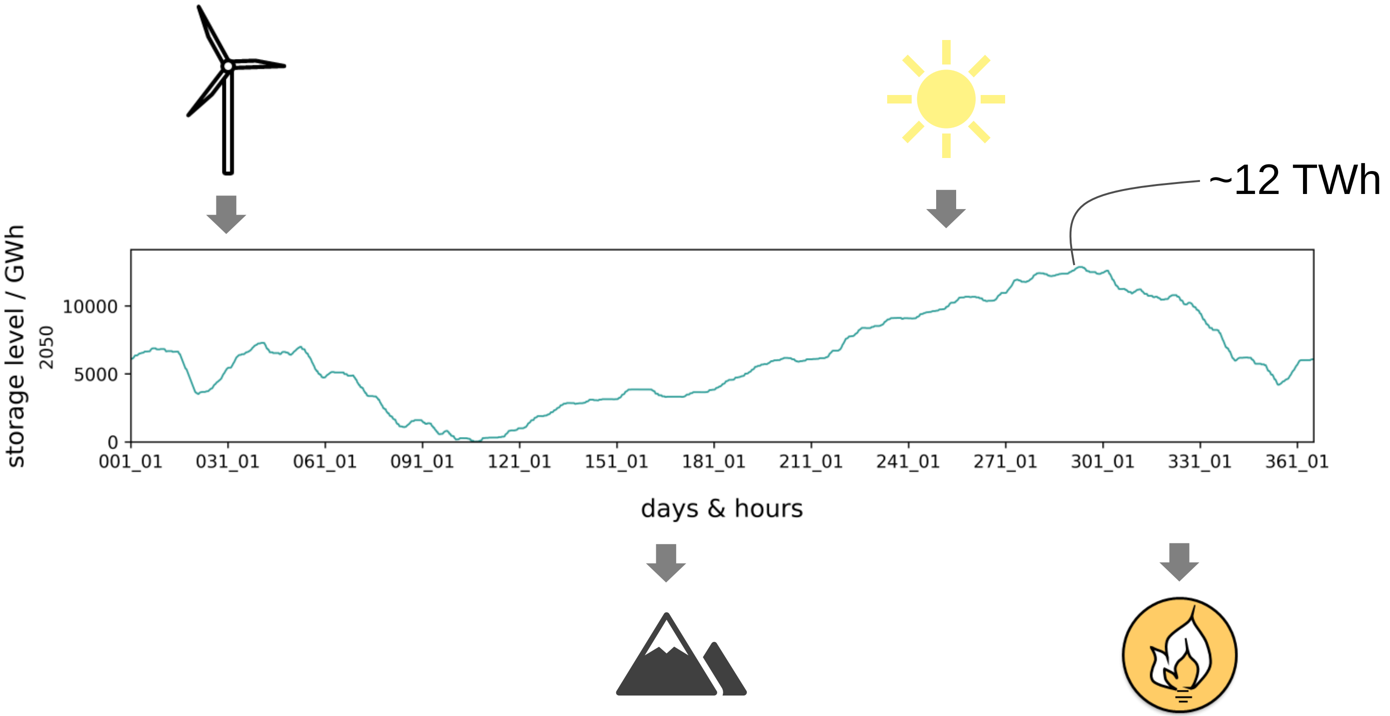
iREs with & without CCS and/or P2M – capacity expansion



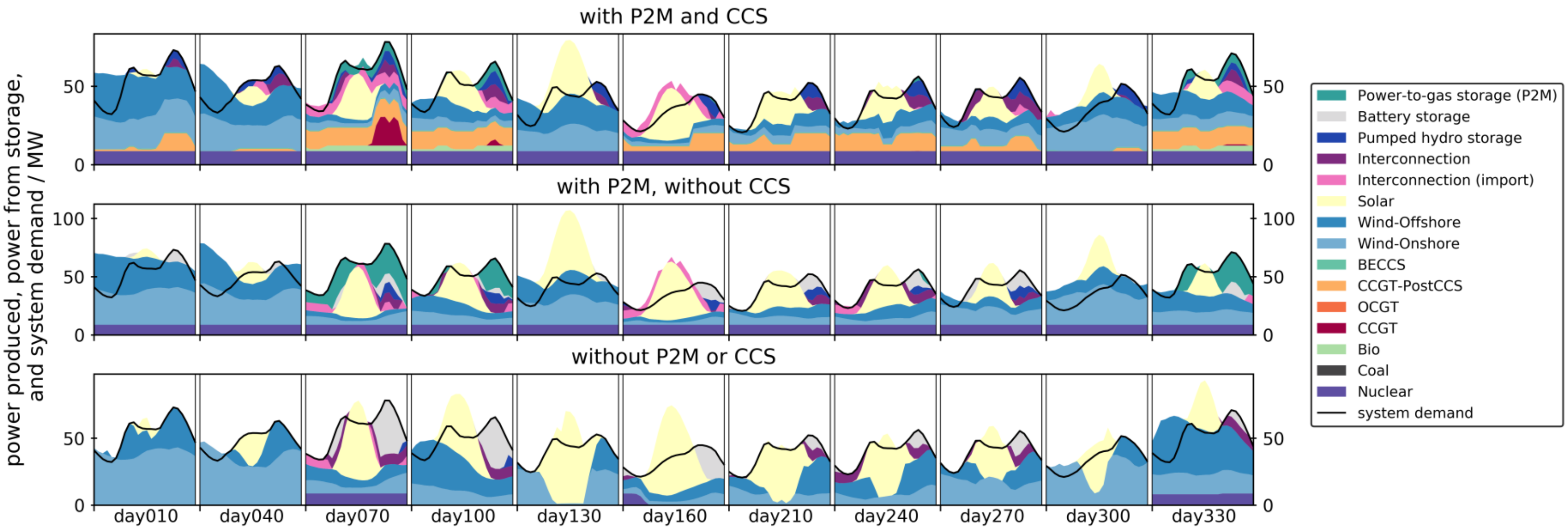
Adding P2M allows the system to reach net-zero with **lower build rates**.

With CCGT-CCS and BECCS added, build rates required for the transition can be reduced further.

P2M storage level (without CCS, central electrification)



iREs with & without CCS and/or P2M – dispatch in 2050

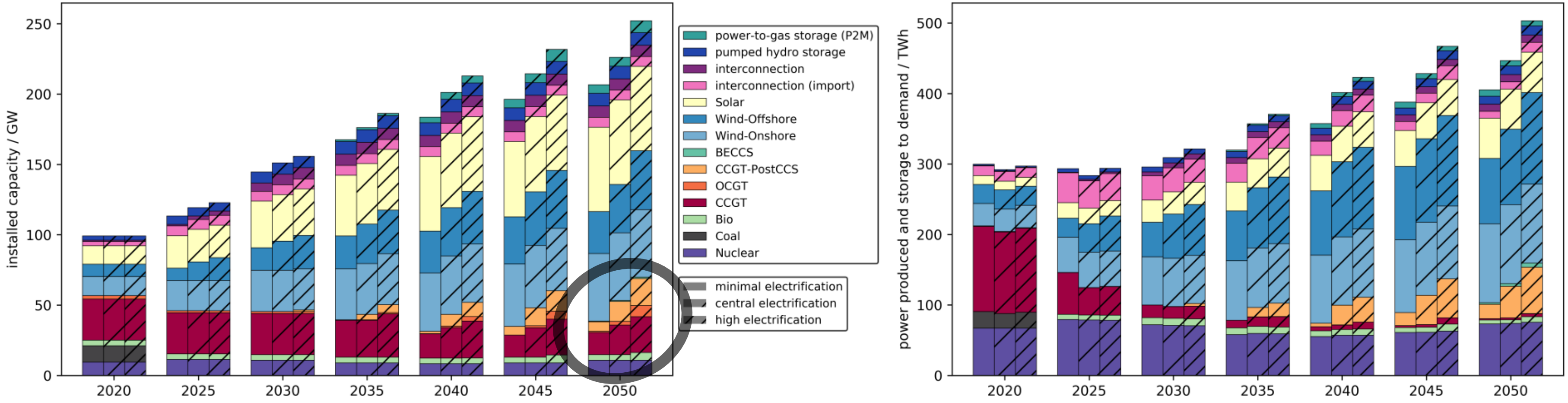


Power-to-gas storage absorbs high amounts of renewable power and provides power during peak hours and on days with low renewable energy available. Long-term storage allows better utilisation and **avoids curtailment** and **lost load**. It can also provide **reserve** and **inertia**.

Seasonal generation can also be provided by the combination of CCGT-CCS (load-following), CCGT (peak), and BECCS (negative emissions).

Flexibility (daily & seasonal) has great value.

Minimal, central, high electrification – with CCS



When renewables deployment is constrained, dispatchable generation is needed to achieve higher levels of electrification.

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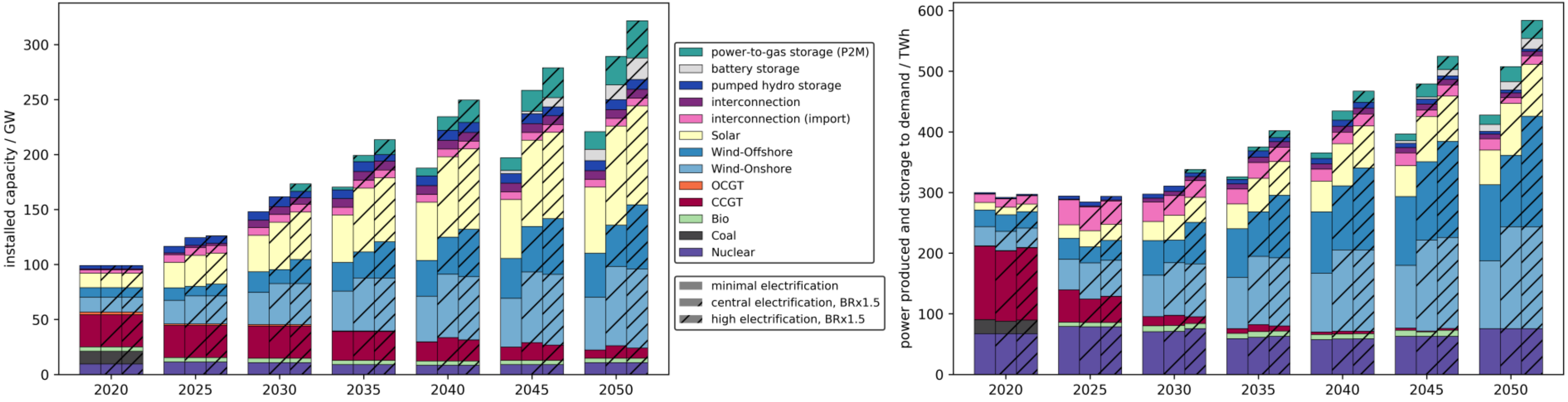
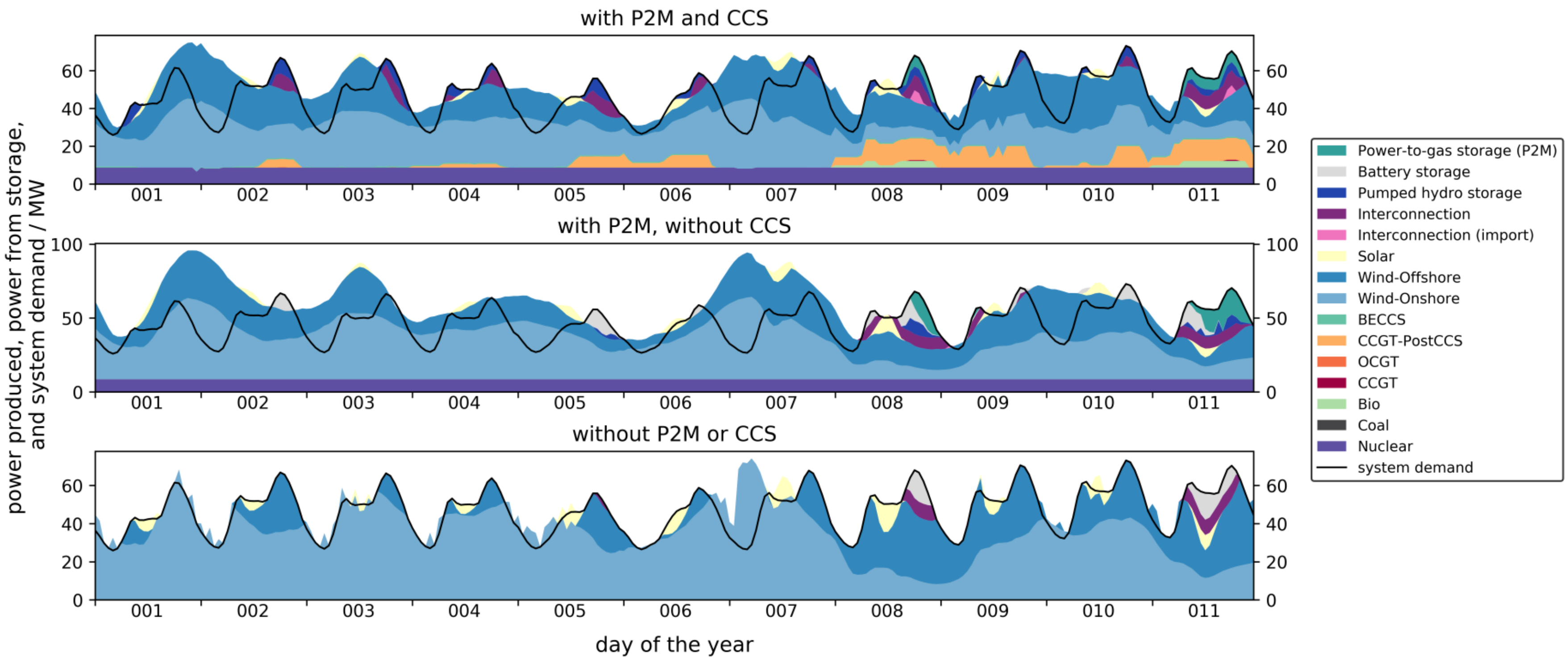
Minimal, central, high electrification – without CCS

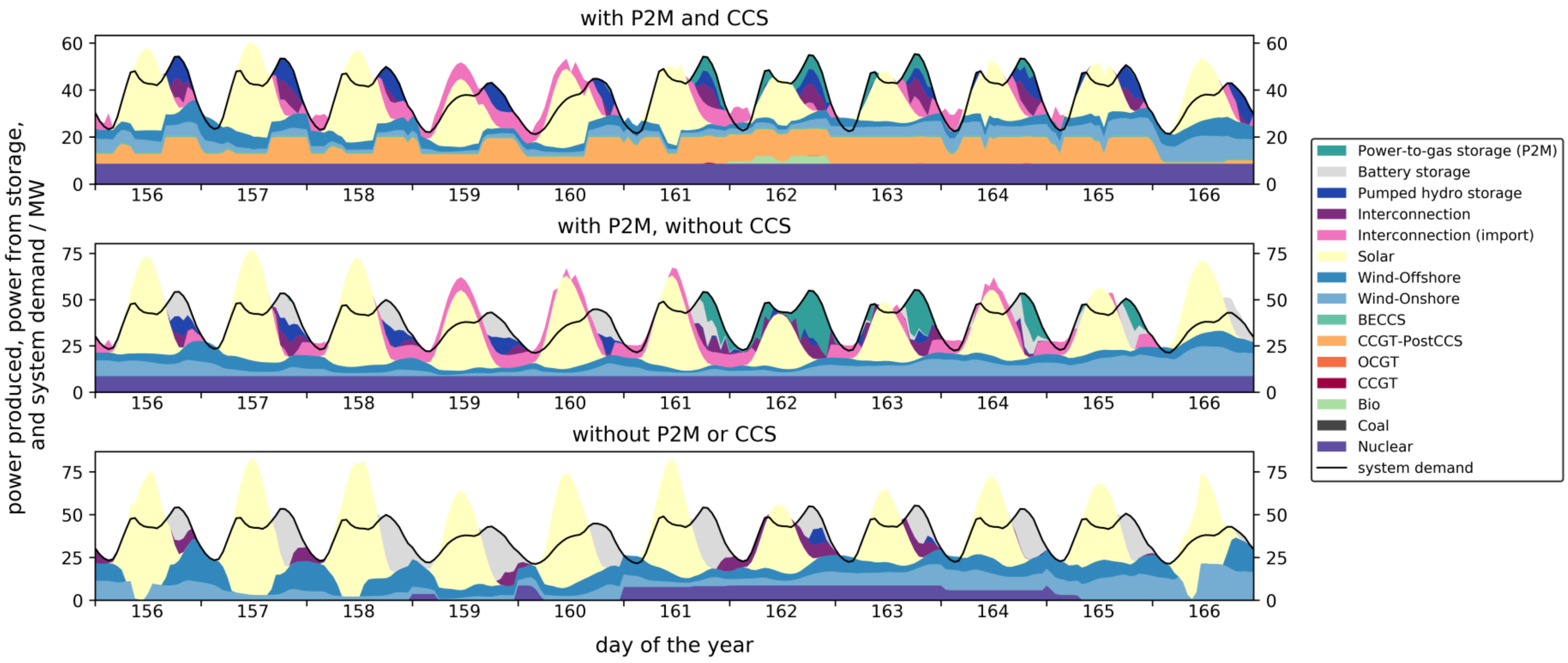


Higher levels of electrification require higher amounts of dispatchable generation and/or long-term storage.

Bottlenecks – low solar availability



Bottlenecks – low wind availability



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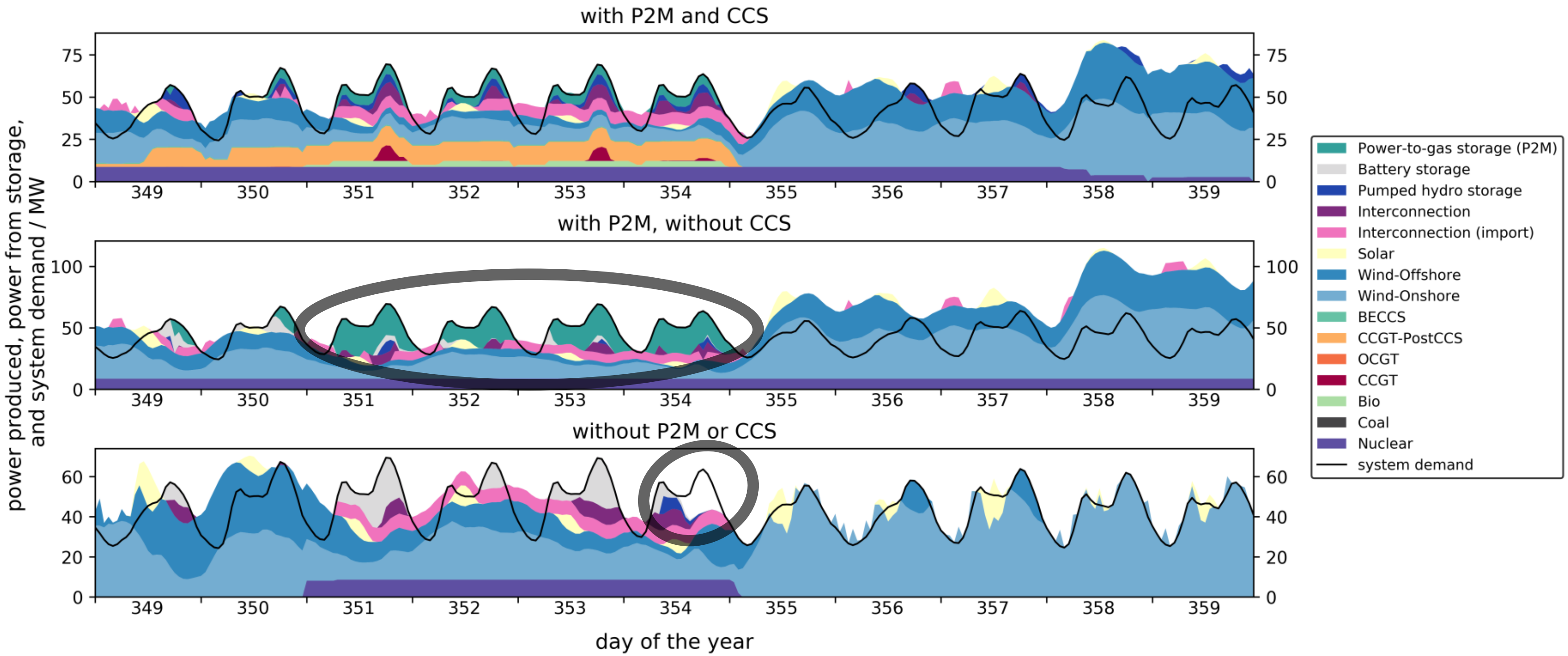
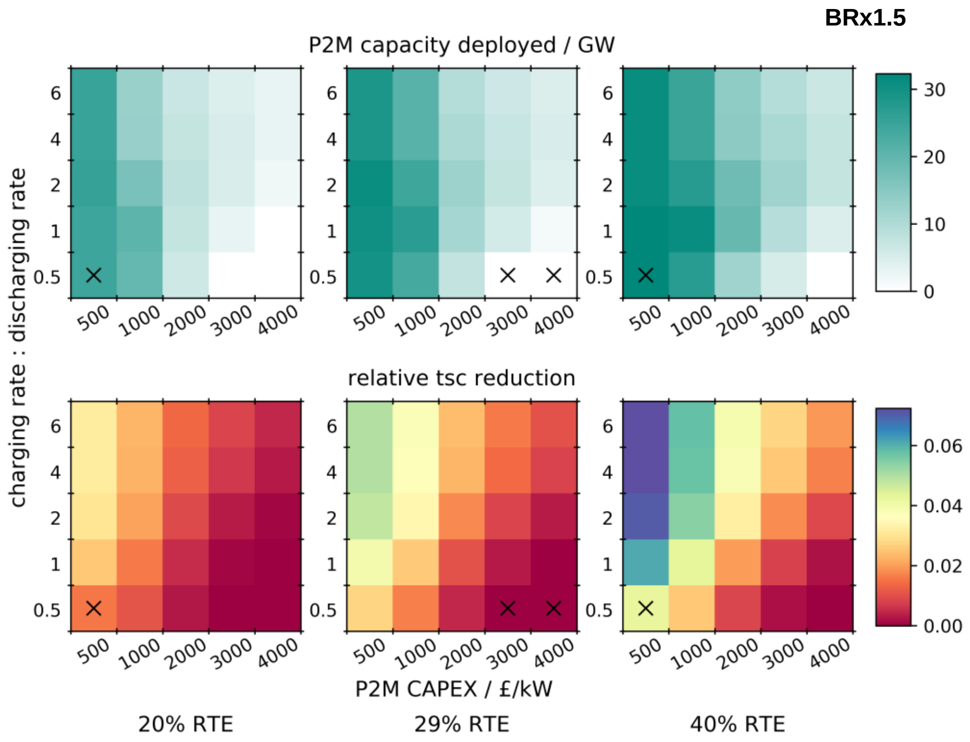
Bottlenecks – low solar & wind availability



Charging ratio and round trip efficiency



If higher charging-to-discharging power or higher round-trip efficiency come at higher technology CAPEX, they may not provide additional value to the system.

Low round-trip efficiency does not prevent power-to-gas storage from adding value in a seasonal system. This might be partly due to renewable power having near-zero marginal cost. Evaluating this technology from the system's perspective is key.

Investigating the potential flexibility of power-to-gas systems and the implications on cost could provide further insights.

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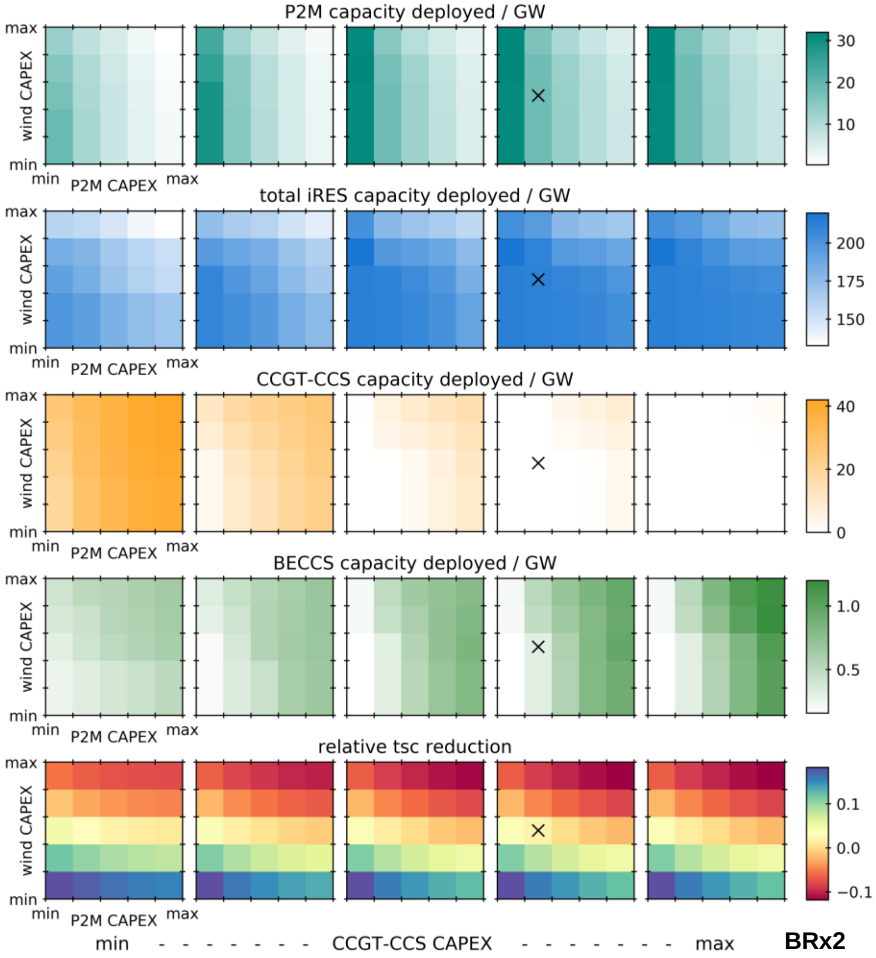
CAPEX sensitivity

The value of power-to-gas storage depends on the deployment of intermittent renewables, but seems to remain to an extent when their deployment is limited.

If the deployment of renewables is limited, low-carbon dispatchable technologies and negative emissions are key. If the deployment of CCS is limited, inter-seasonal storage becomes crucial.

A diverse portfolio could reduce the likelihood of missing climate targets and could lead to a system resilient to uncertainties (level of electrification, renewables availability, etc.).



Conclusions

caroline.ganzer17@imperial.ac.uk

How much value inter-seasonal storage such as power-to-gas storage can add to the energy system depends on its cost, other technologies deployed, build rates of renewables, and the level of electrification. When deployment of low-carbon dispatchable technologies is limited, it becomes essential.

The optimal system design is of course uncertain and depends on technology CAPEX assumptions, emissions accounting, policy, etc.

Seasonal effects impact the design, especially with rising share of renewable energy and electrification of heat.

Analysing the role of a technology in the system and in synergy with other technologies enables the assessment of its value.

It is of interest to investigate how to incentivise the deployment of CAPEX-driven technologies such as wind, solar, and storage.

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