Designing low emissions, efficient, high renewable energy systems resilient to climate change

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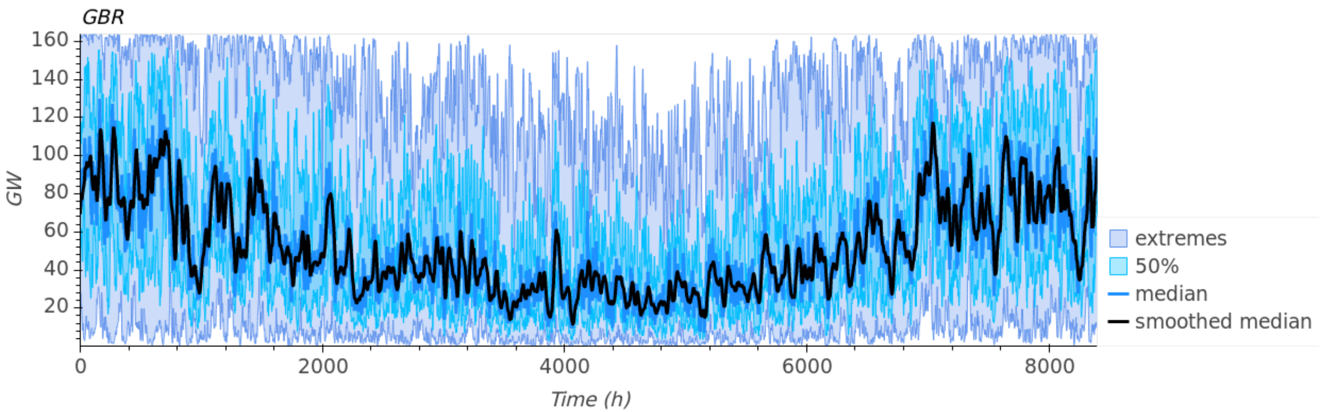
CREDS

Mismatch between (variable) renewables and (variable) demand

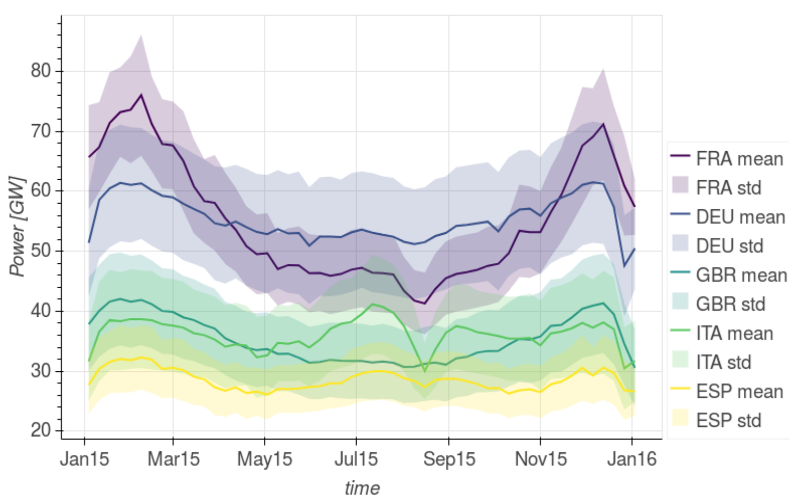
Wind varies across hours, months and years (+-10%):



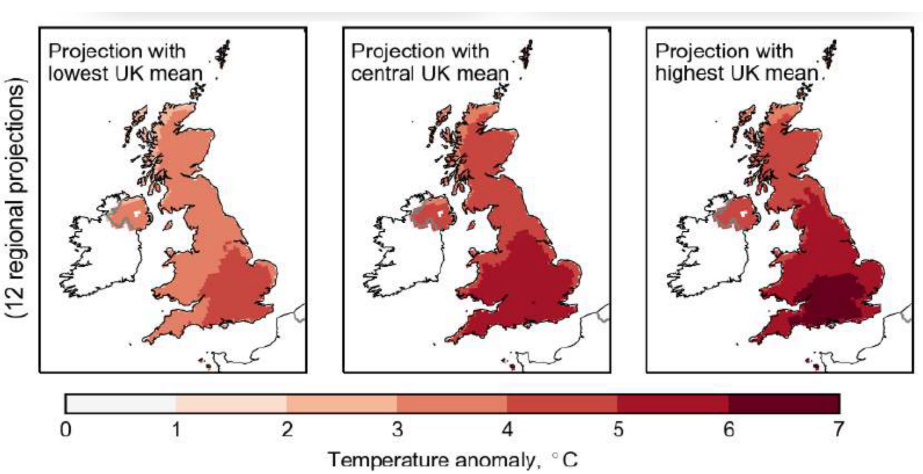
Sources:

- Gallo Cassarino et al. Applied Energy, 2018
- UKCP18 National Climate Projections. MetOffice, 2018

Changes in demand due to weather and human activity:

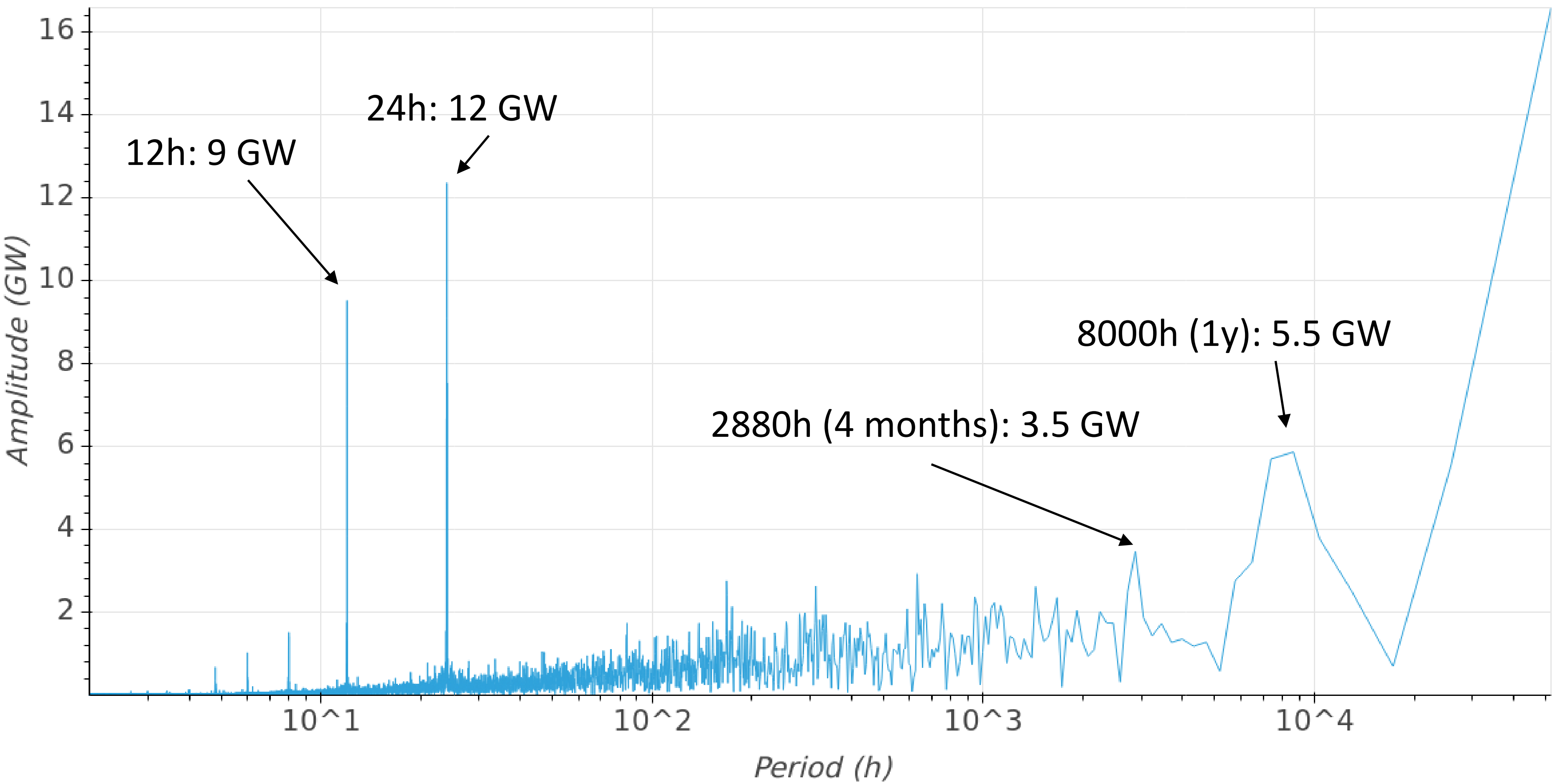


Increase in the frequency and intensity of extremes: consequences for heating/cooling?



Storage need patterns can help designing better energy systems

Fourier analysis. Periods of electricity residual demand, de-trended (UK 2010-2015):



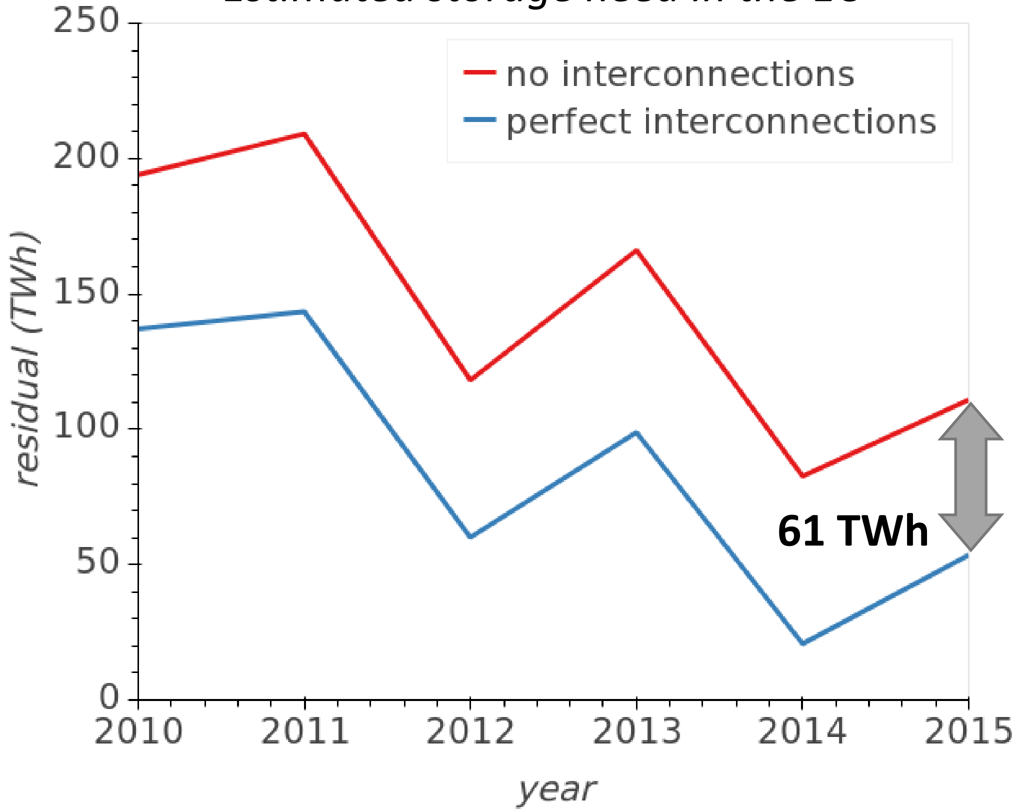
Interconnections can substantially help reducing storage

Residual demand (i.e. storage need) = cumulative demand – variable renewables

The UK would need 10-15% annual demand (equivalent to ~50 TWh storage) in a high-renewable system.

We estimated that EU would need **30%-75%** (depending on the year) **less storage**, assuming **perfect interconnections among countries**.

Estimated storage need in the EU



Can either storage or interconnections meet demand on its own?

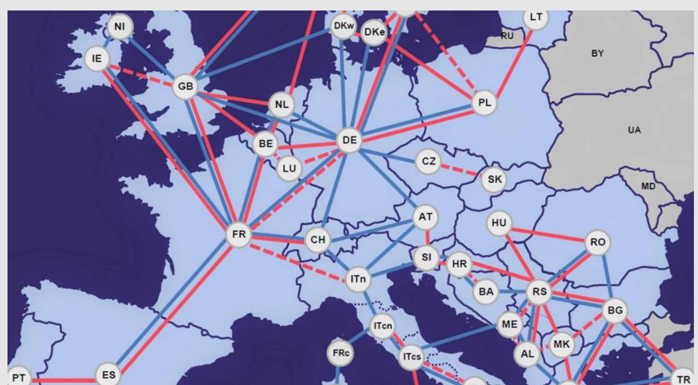
Storage

- ✓ Available immediately
- ✓ Near demand
- ✓ Long term
- ✓ High capacity
- ✓ Multiple vectors

- ✗ Space constraints
- ✗ Expensive

Interconnections

- ✓ Smooth demands and renewables
- ✓ Reduce storage
- ✓ Reduce curtailment and installed capacity
- ✓ Security through interdependence and diversity



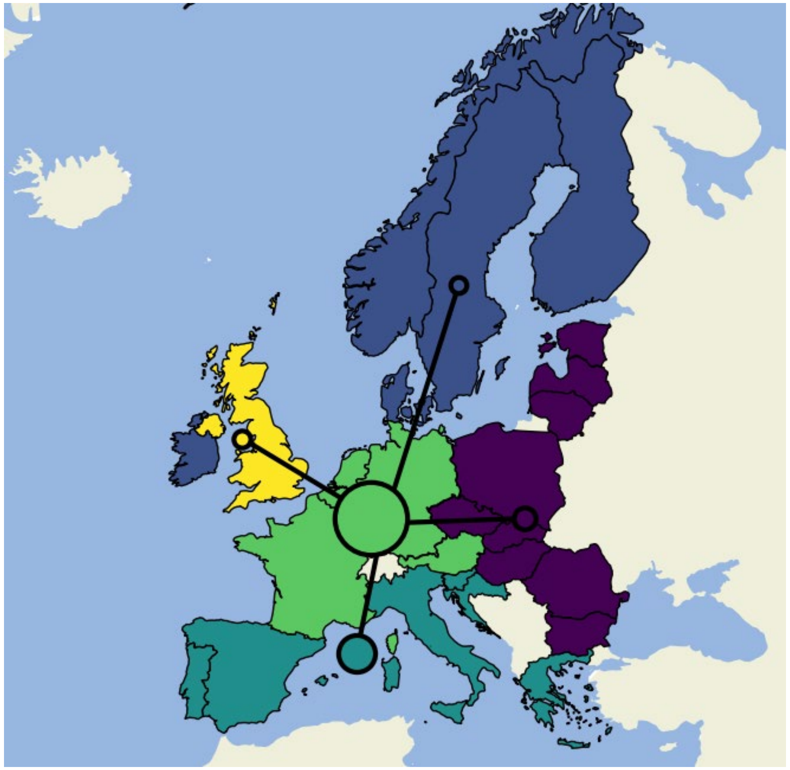
- ✗ Depends on surplus/deficit
- ✗ Only electricity

ESTIMO – Energy Space Time Integrated Model Optimiser

Objective: near zero net greenhouse gas emission at least cost.

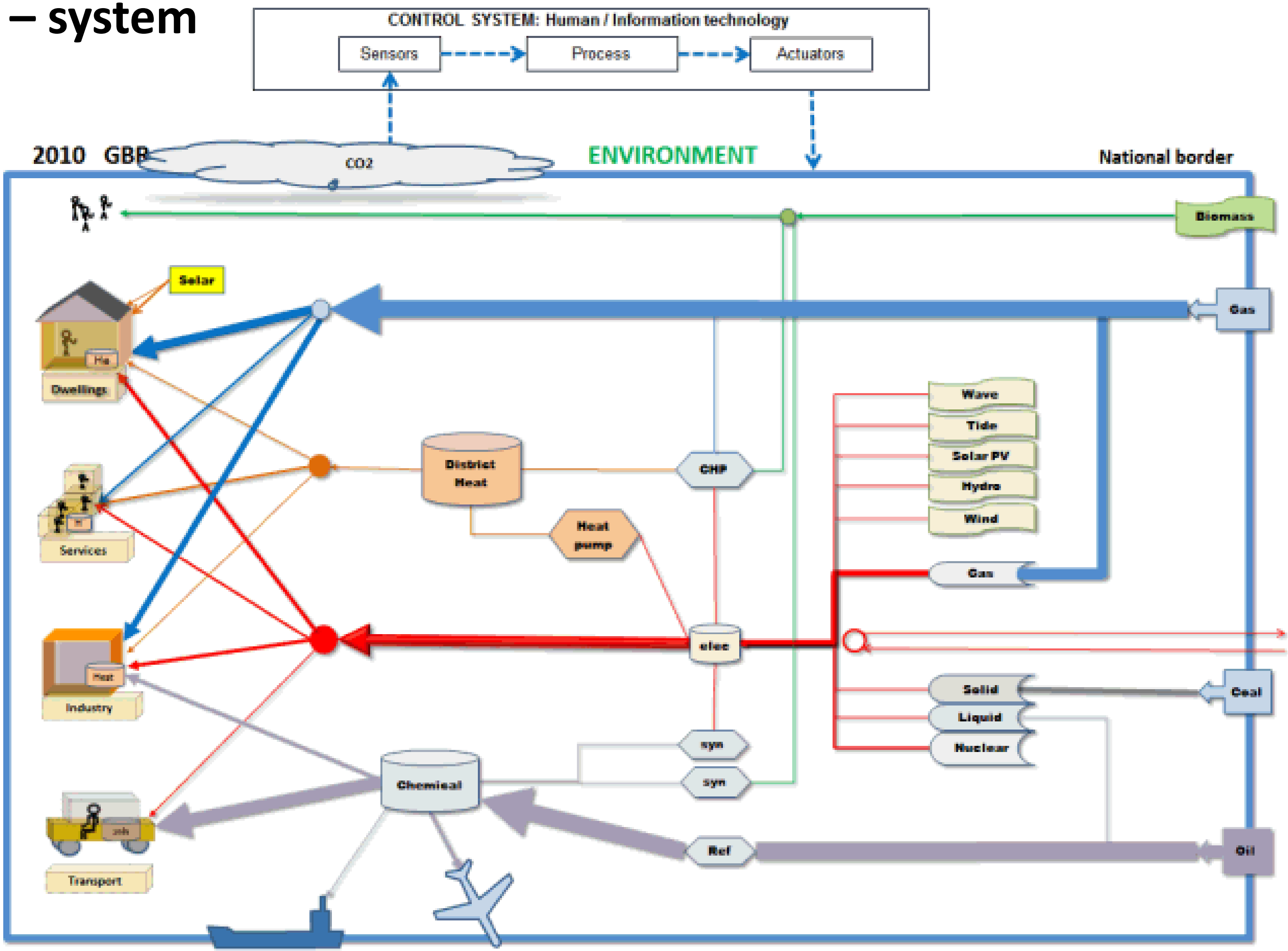
Problems:
- Mismatch between demand and ***variable*** renewable generation.
- With ***climate change***, the heat:cool ratio will be different and we need to design systems resilient to these uncertainties.

What is the **optimal mix of storage and transmission** for balancing demand and supplies in **highly electrified**, renewable systems given the possible impacts of **climate change**?



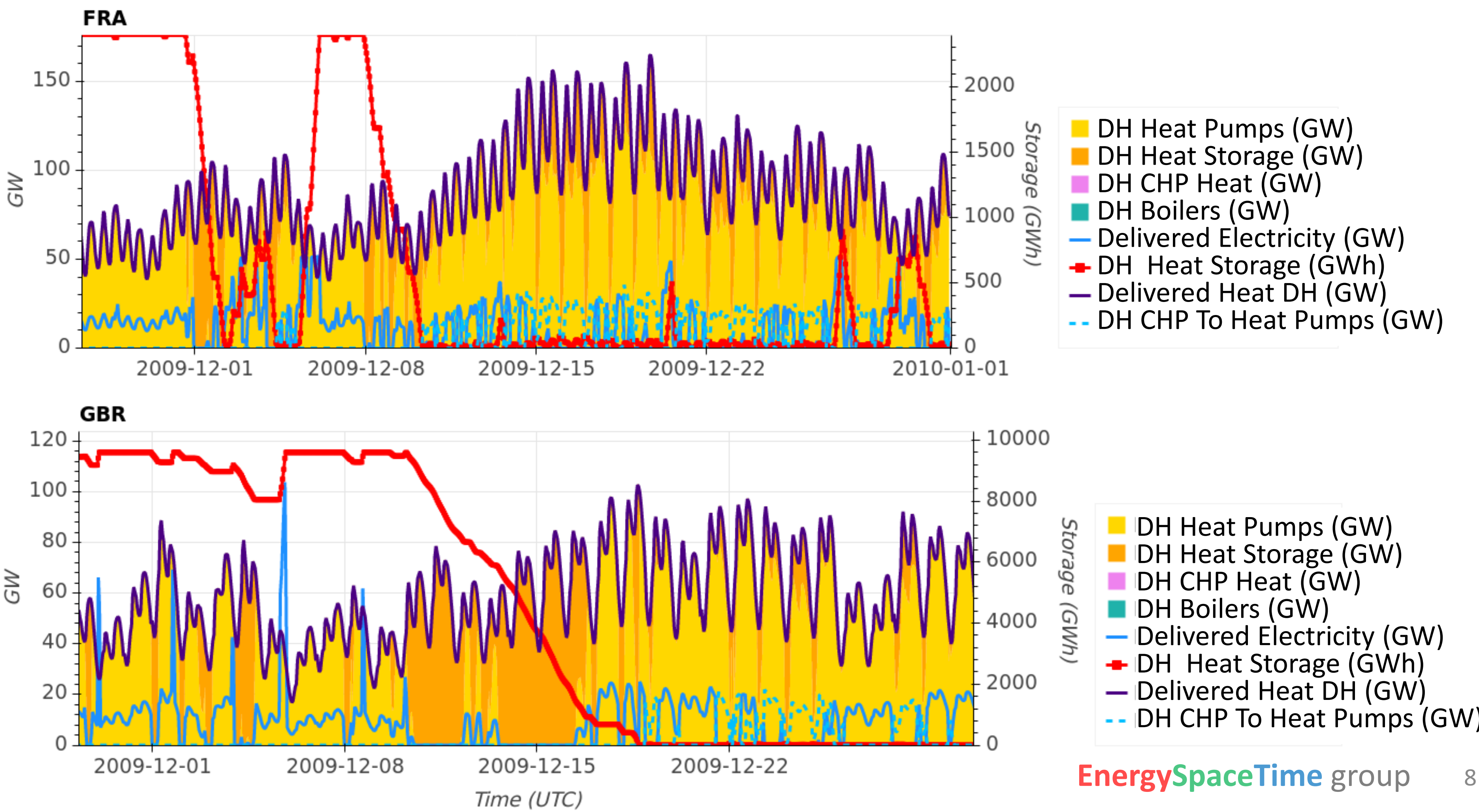
- 30+ countries at hourly time step
- 37 years of weather data (hourly, at 0.5 degree lat/lon resolution)
- multiple scenarios for demand & supply

ESTIMO – system



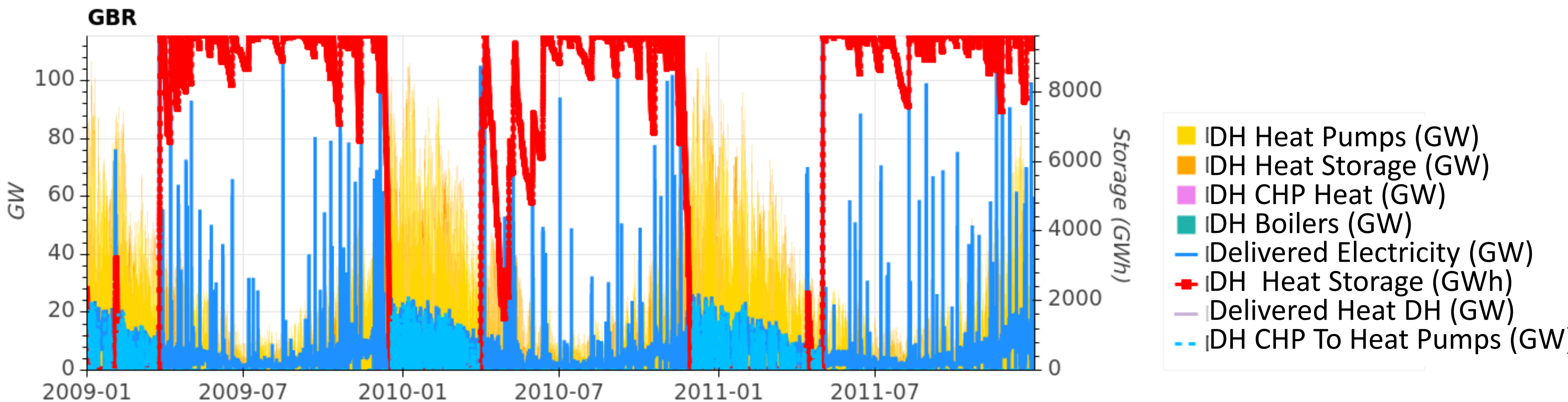
A 100% renewable system can meet heat demand by balancing DH heat pumps with heat storage

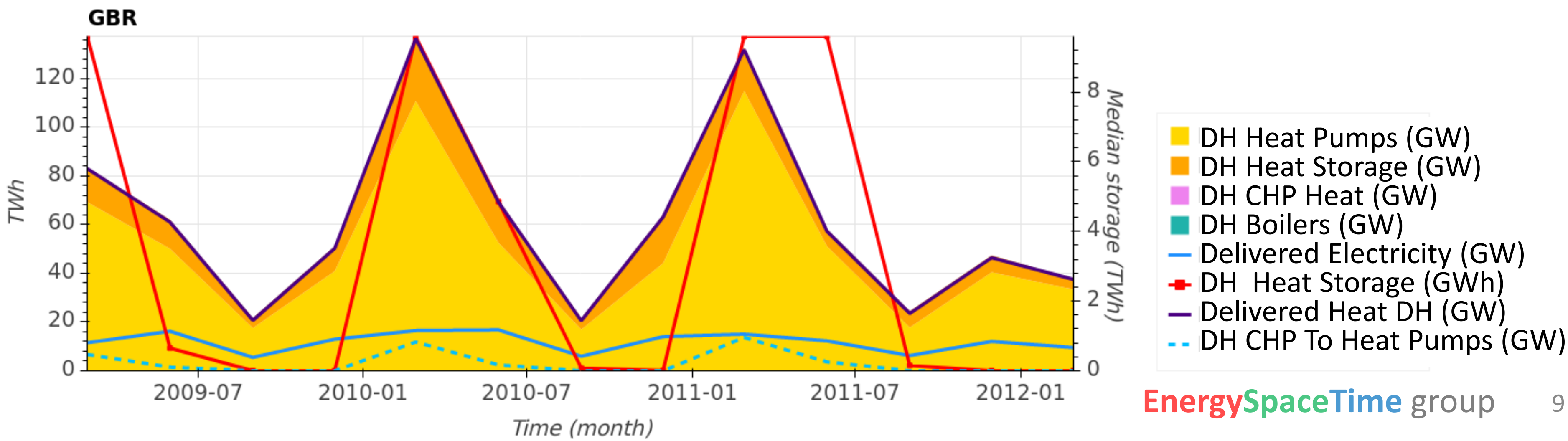
Scenario with 80% DH, 20% consumer HPs, current demand, building losses, and efficiencies



Multiple weather years are crucial to understand long term heat storage dynamics and requirements

Heat storage level depends on charge and discharge patterns across years





Conclusions

To design low emission systems it is essential to detail:

- Technology efficiencies
- behaviour demand drivers
- the impact of meteorology on demands and renewable generation

The overall process has been developed for the design of renewable, near zero emission system for providing services to stationary, land and sea transport sectors.

Prototype of **dynamic spatiotemporal control system** has been developed.

Next 'easy' steps: elaboration, costing, optimisation

Known unknowns (and future developments):

- aviation
- cement, etc.

EnergySpaceTime group

Decarbonisation of heat

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Thank you for your attention!