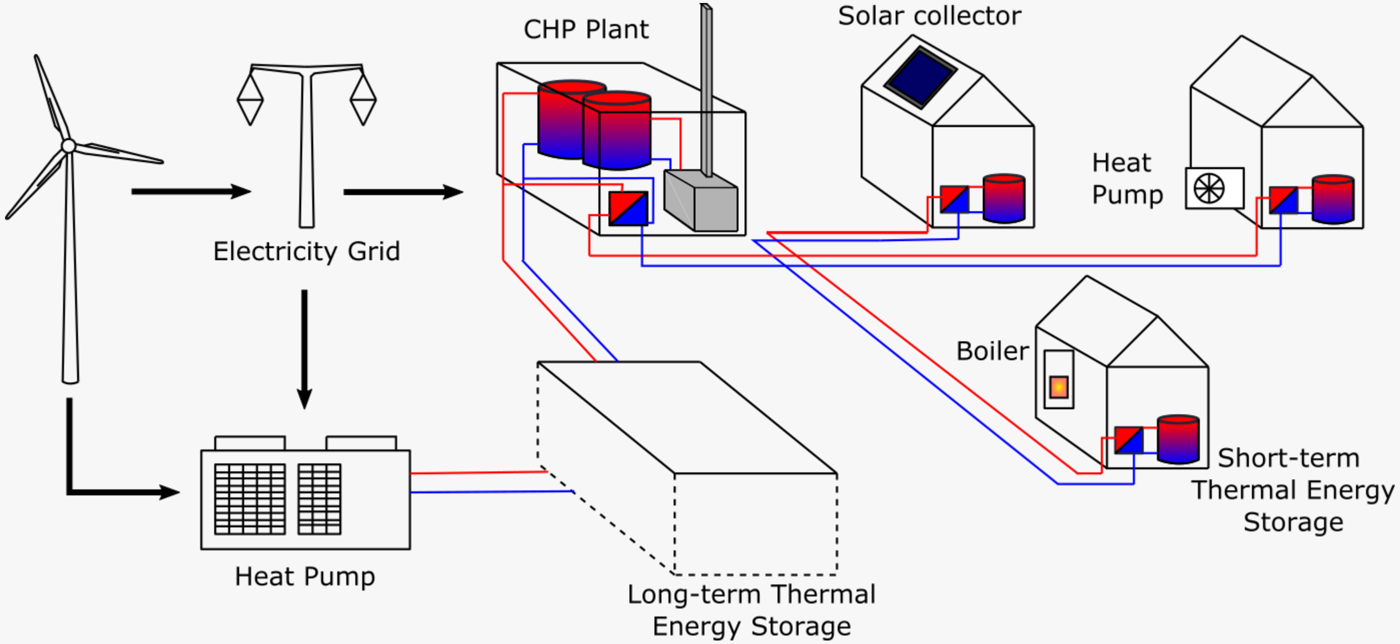
Seasonal thermal energy storage in smart energy systems to provide flexibility services



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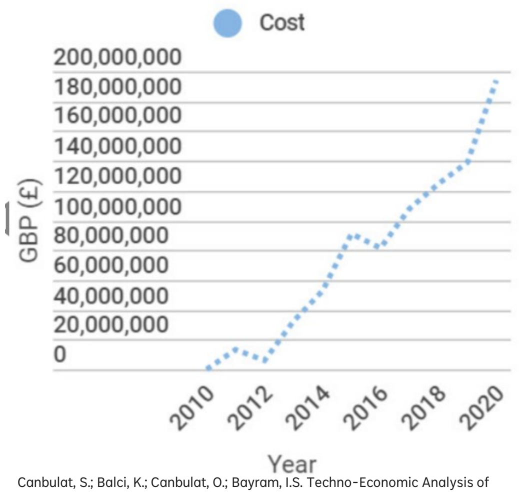
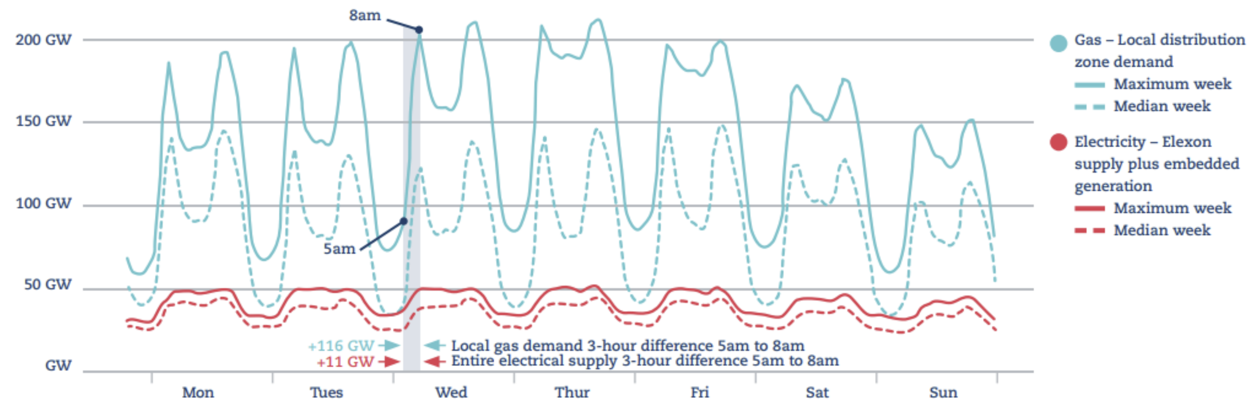
INTEGRATE Integrating seasoNal Thermal storagE with multiple enerGy souRces to decArbonise Thermal Energy

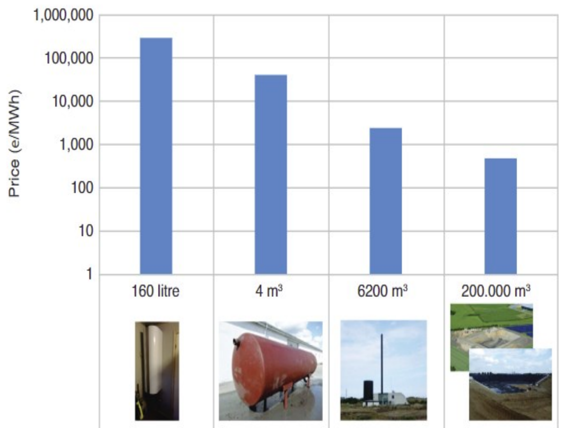
New system flexibility is needed



Canbulat, S.; Balci, K.; Canbulat, O.; Bayram, I.S. Techno-Economic Analysis of On-Site Energy Storage Units to Mitigate Wind Energy Curtailment: A Case Study in Scotland. *Energies* **2021**, *14*, 1691. https://doi.org/10.3390/en14061691



Wilson et al., Challenges for the decarbonisation of heat: local gas demand vs electricity supply Winter 2017/2018



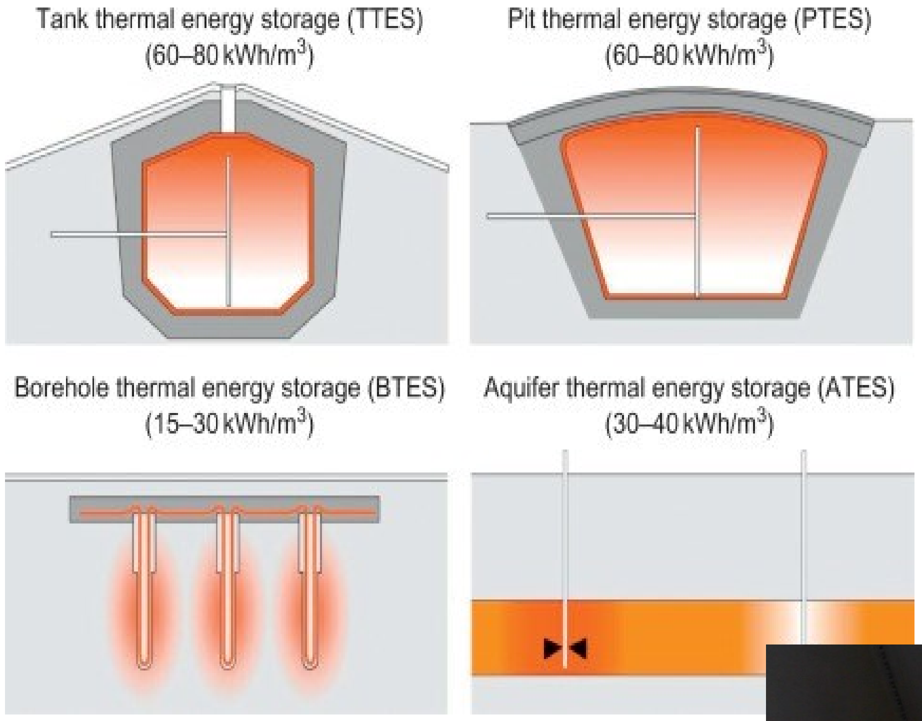
Source: Lund, H., Østergaard, P. A., Connolly, D., Ridjan, I., Mathiesen, B. V., Hvelplund, F., Thellufsen, J. Z., & Sorknæs, P. (2016). Energy Storage and Smart Energy Systems. *International Journal of Sustainable Energy Planning and Management*

- Level of wind curtailment is increasing due to network constraints and demand/supply mismatch
- This will increase further (CCC) with estimates low-carbon generation needs to quadruple from 2019 levels
- Peak daily and hourly gas demand up to four times the electricity demand
- 1 hour difference in demand over 7 times larger for gas compared to electricity
- Seasonal thermal energy storage could provide flexibility at low cost

Seasonal thermal energy storage (STES)

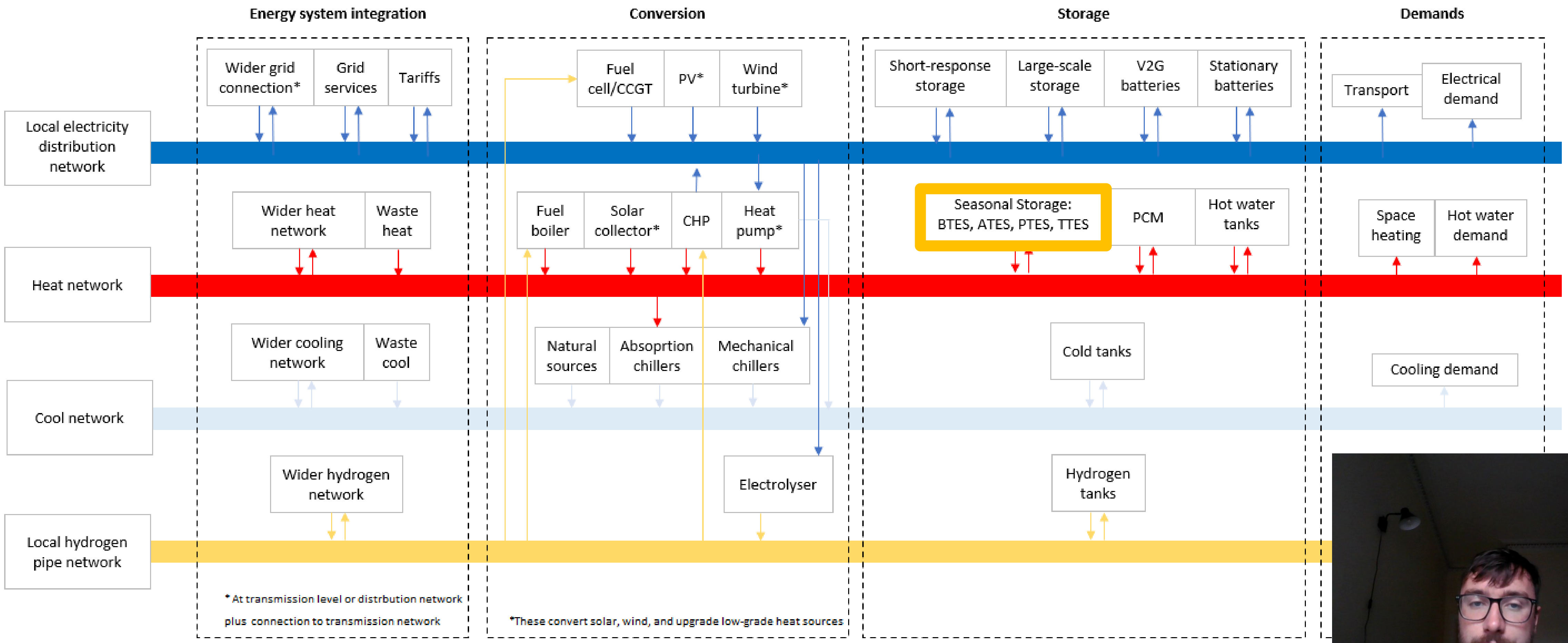
- Four main types: Tank, Pit, Borehole, and Aquifer
- Used in solar district heating, but potential for using multiple energy sources in smart energy systems

Presentation content:
1. Smart applications
2. Energy system modelling



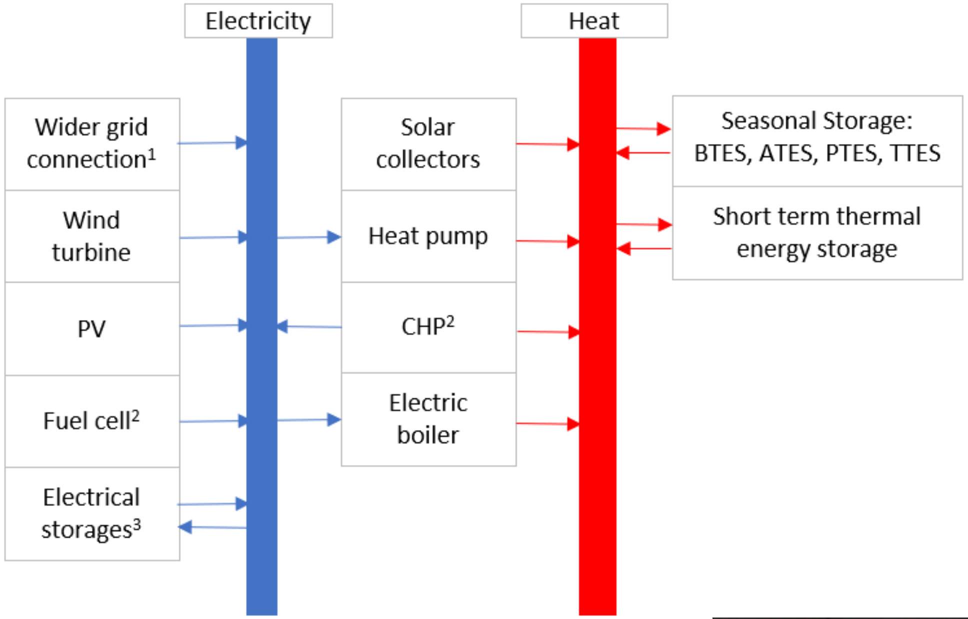
Source: Solites

District-level smart energy systems



Utilisation of renewable energy sources

- Coupling of electricity and heat sectors using heat pumps and CHP
- Seasonal and short-term electrical and thermal storage have a role to play
- STES has been installed to increase utilisation of solar collectors, but can be a role to increase utilisation of wind and PV generation
- District-scale energy systems should be integrated with the wider energy system



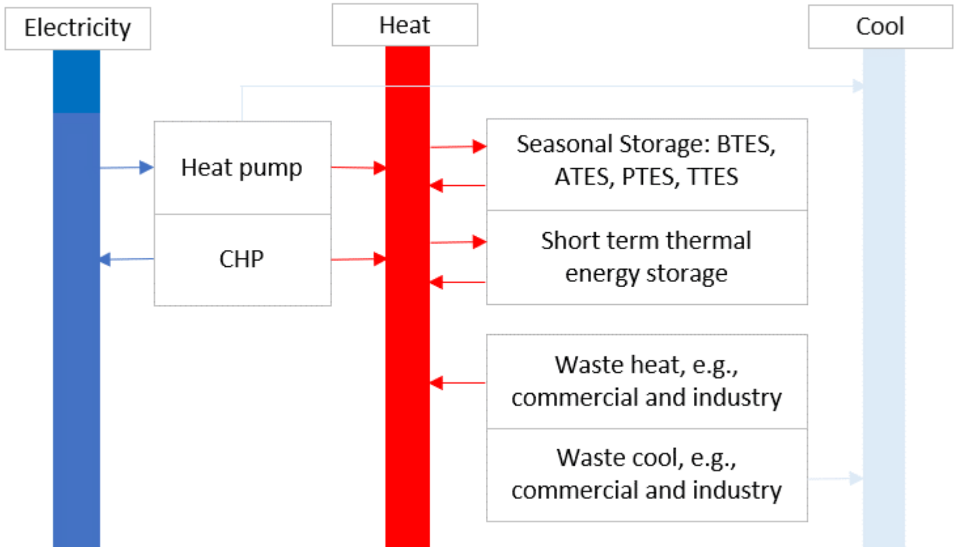
1 - Wider grid connection with electricity from RES

2 - Where using synthetic fuel generated from RES

3 - Electrical storages which have been charged with electricity from RES

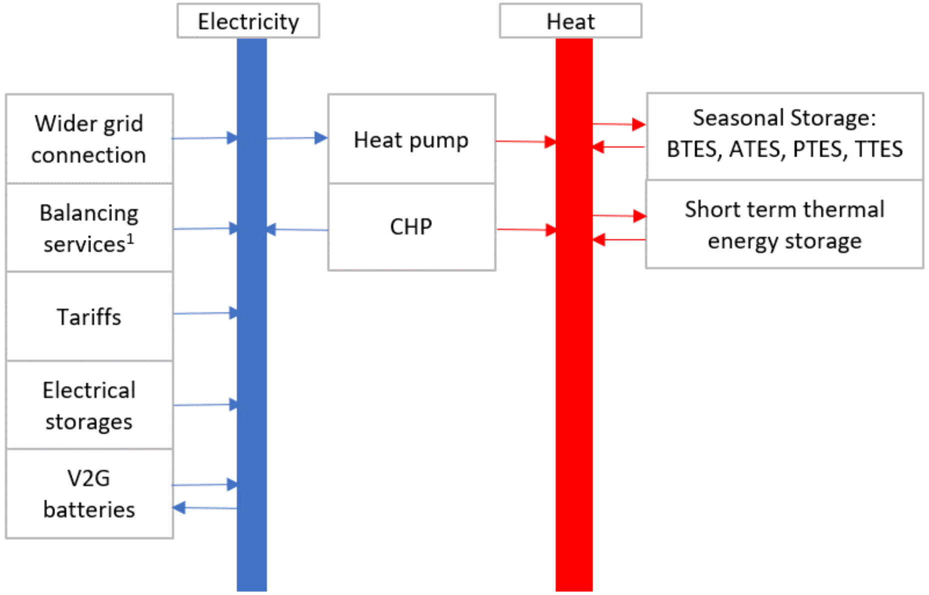
Waste heat and cool

- Waste heat is possible from industry and commercial sectors, as well as power generation
- Huge waste heat potential in UK – estimates vary between 10-40 TWh
- Potential for geographical and temporal mismatch to heat demands
- STES can contribute to decoupling supply and demand
- Waste heat can be used to meet cooling demands



Electrical network balancing

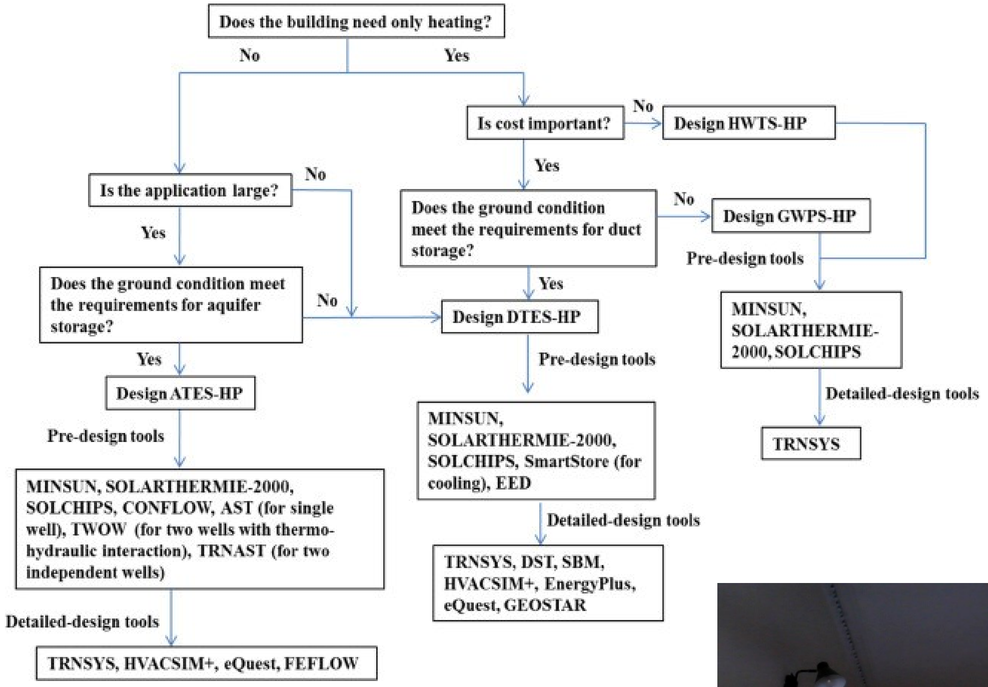
- Electrical heat production units can provide distribution and transmission electrical network services if they operate flexibly
- STES slow charge/discharge but can still allow increased flexibility of other fast-response tech
- Potential mechanisms: frequency response, demand/supply matching, responding to time-of-use price signals
- Received little attention in literature



1 - examples include balancing mechanism, frequency response, demand side response, short-term operating reserve

Seasonal thermal energy storage in energy system modelling tools

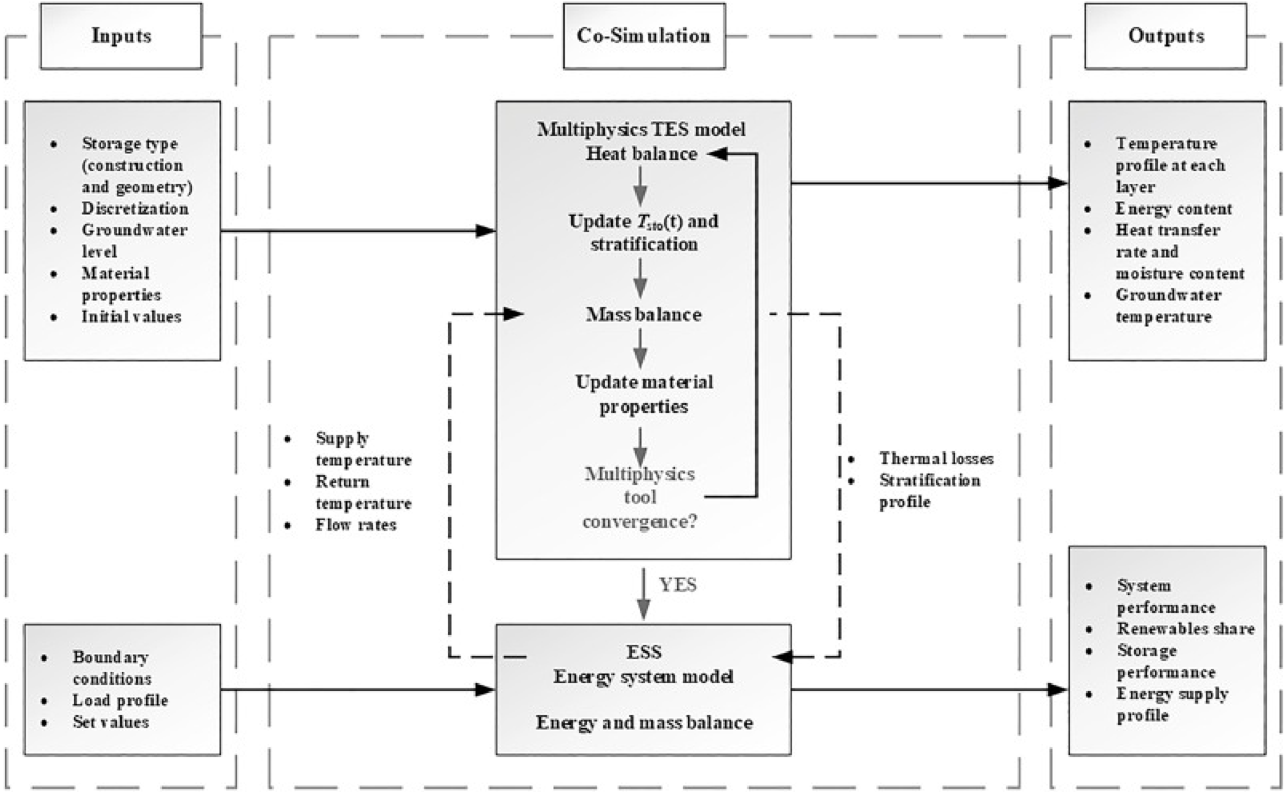
- Reviews exist of modelling approaches, but focus on integration with solar energy and typically single sector focus
- Underrepresented in planning tools, typically treated as energy flow without considering temperature and mass flows
- TRNSYS dominates the state-of-the-art studies for borehole thermal energy storage
- More detailed physics tools can represent underground STES more accurately, and power system modelling tools can capture wider energy system



Source: Arefeh Hesaraki, Sture Holmberg, Fariborz Haghighat, Seasonal thermal ener
temperatures in building projects—A comparative review, Renewable and Sustainab

Co-simulation methods

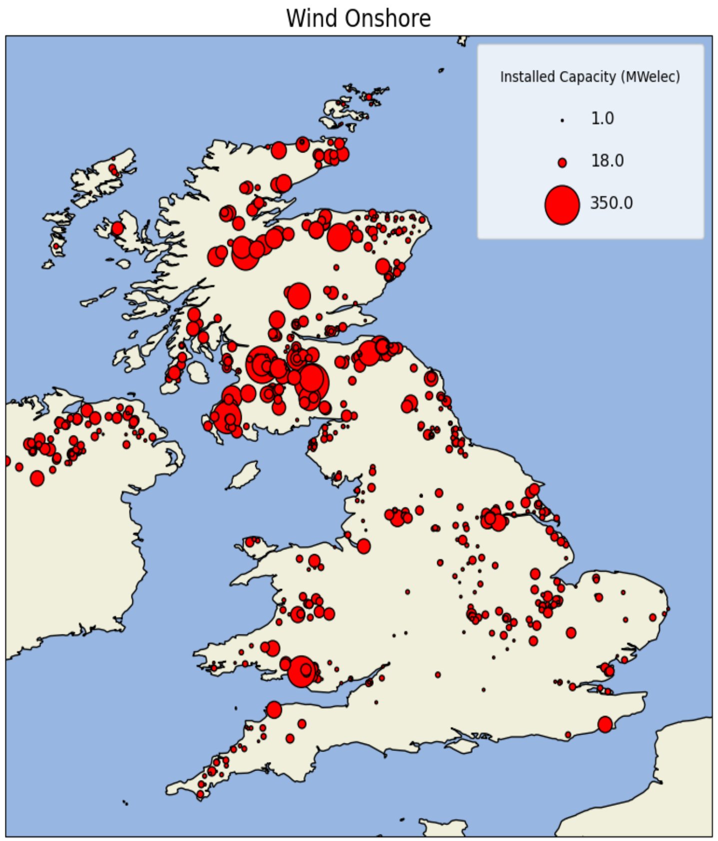
Co-simulation process diagram of multiphysics storage model and energy system model

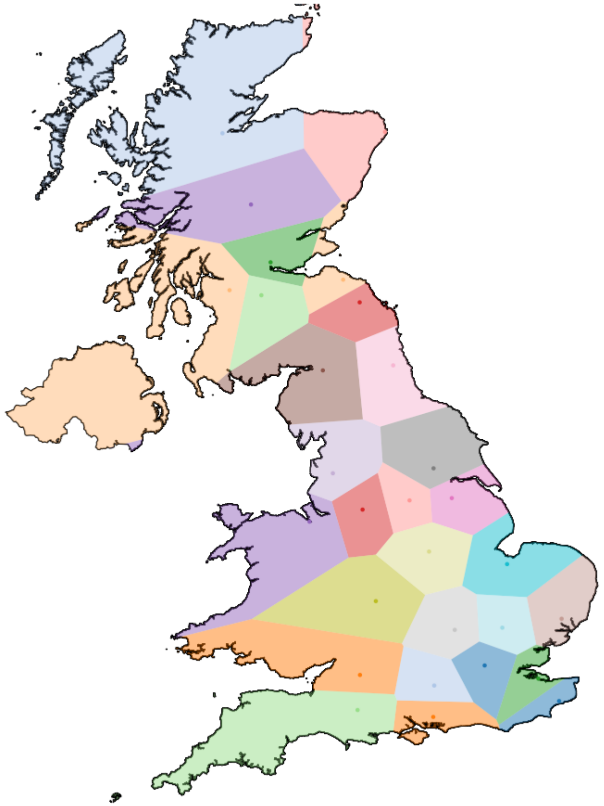


Source: Abdulrahman Dahash, Fabian Ochs, Michele Bianchi Janetti, Wolfgang Streicher, Advances in seasonal thermal energy storage for solar district heating applications: A critical review on large-scale hot-water tank and pit thermal energy storage systems, Applied Energy, Volume 239, 2019

Extend this co-simulation platform to include a power system tool?

PyPSA-GB: An open source dispatch model of the GB transmission network

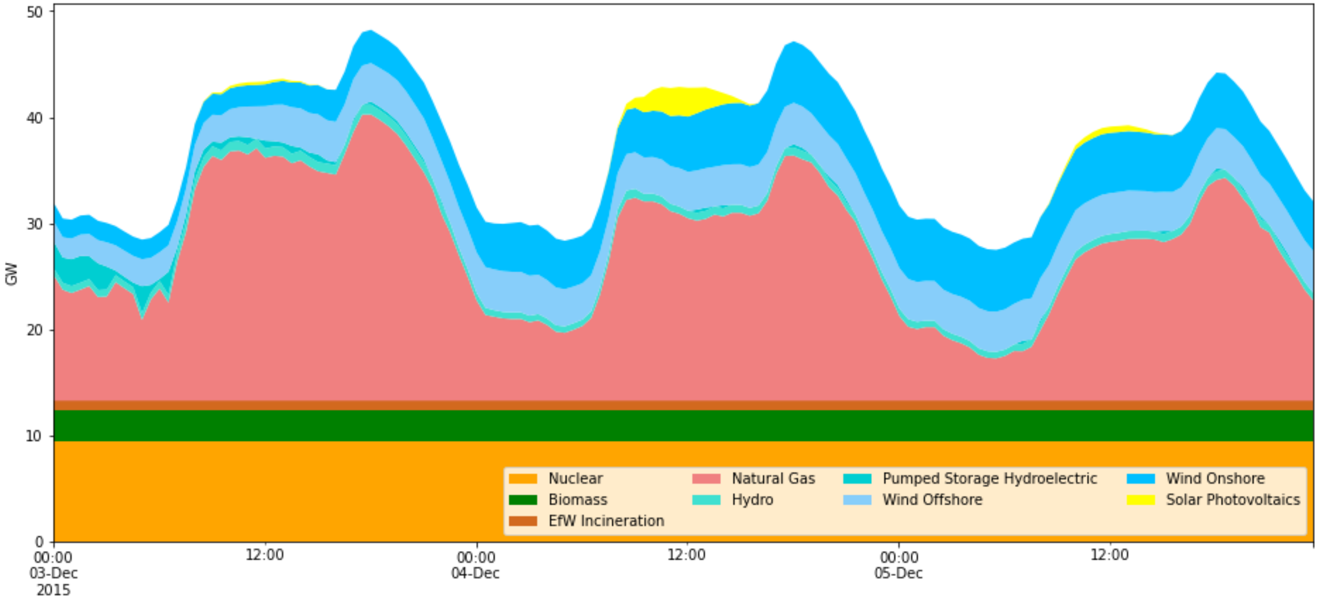


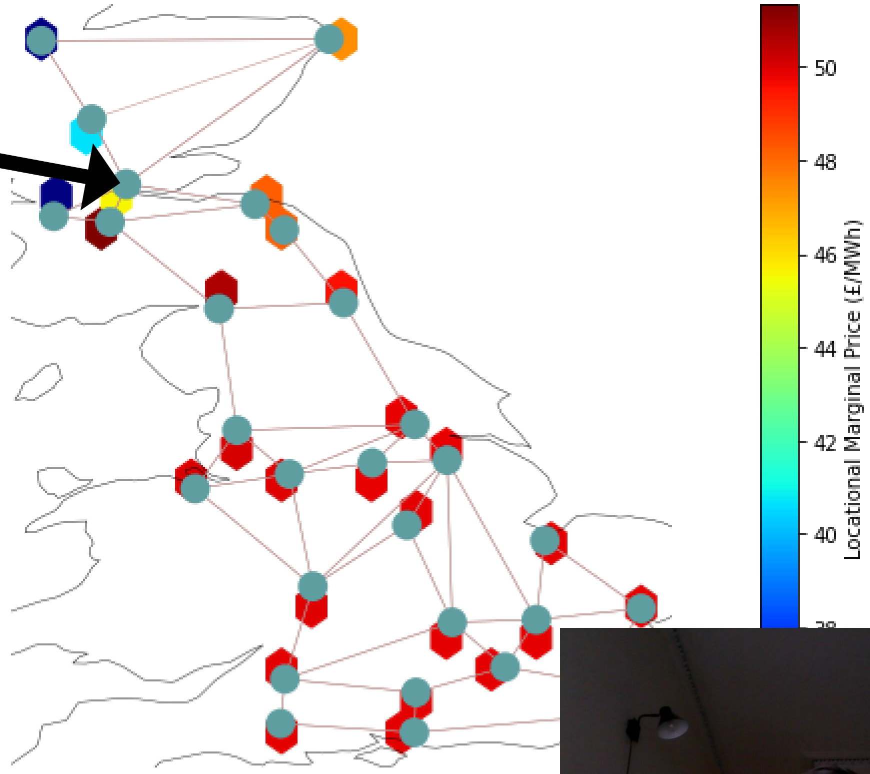


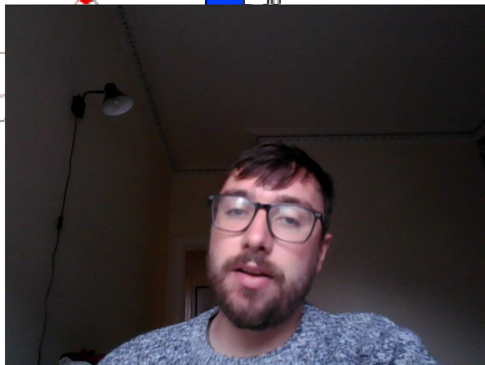
Analysing the integration of seasonal thermal energy storage

How do we design and control a seasonal thermal energy storage system at one of these buses?

1. Directly in PyPSA-GB (limited to high-level control)
2. Co-simulation with TRNSYS (implement real optimal control)







Conclusions

Smart applications

- Seasonal thermal energy storage can be useful beyond solar. Multiple energy sources can be used, e.g., wind, waste.
- Utilisation of renewable energy sources both locally and part of wider energy system
- Waste heat and cool integration to take advantage of huge potentials
- Contribute to electrical network balancing which has increasing importance towards net zero

Energy system modelling

- Limited in planning tools and TRNSYS dominates detailed studies
- Co-simulation of energy system tool with seasonal thermal energy using detailed physics tools and power system tools
- Transmission network model of GB (PyPSA-GB) to be used to analyse integration of seasonal thermal energy storage
    - Co-simulation with TRNSYS
    - Direct implementation in PyPSA-GB