Agenda

INTEGRATE launch event

- 2:05 - Introduction, Dr Daniel Friedrich, University of Edinburgh
- 2:20 - Subsurface modelling, Prof Gioia Falcone, University of Glasgow
- 2:35 - Industrial heat recovery, Prof Ben Hughes, University of Hull
- 2:50 - Policy and regulation for seasonal storage, Dr Ronan Bolton and Dr Niall Kerr, University of Edinburgh
- 3:05 - Messages from the industrial and international partners
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INTEGRATE: Integrating seasoNal Thermal storagE with multiple enerGy souRces to decArbonise Thermal Energy

Daniel Friedrich

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School of Engineering
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INTEGRATE launch event
June 2021

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Aims of the INTEGRATE project

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

- We consider Seasonal Thermal Energy Storage (STES) systems as a vital part of a future zero carbon energy system and will evaluate the interplay between regulation and market frameworks, heating/cooling demands, energy storage systems and different energy sources.
- We will design integrated STES systems that provide affordable, flexible and reliable thermal energy for the customers while also providing flexibility services for the wider energy system.

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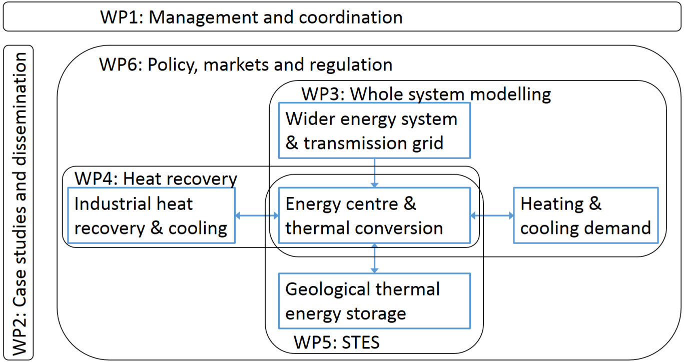
Interplay between the different teams is key



- Engineering at Edinburgh: Whole system modelling
- University of Hull: Industrial heat recovery and cooling
- University of Glasgow: Geological thermal storage
- Social & political science at Edinburgh: Policy, markets & regulation

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UK electricity and heat demand

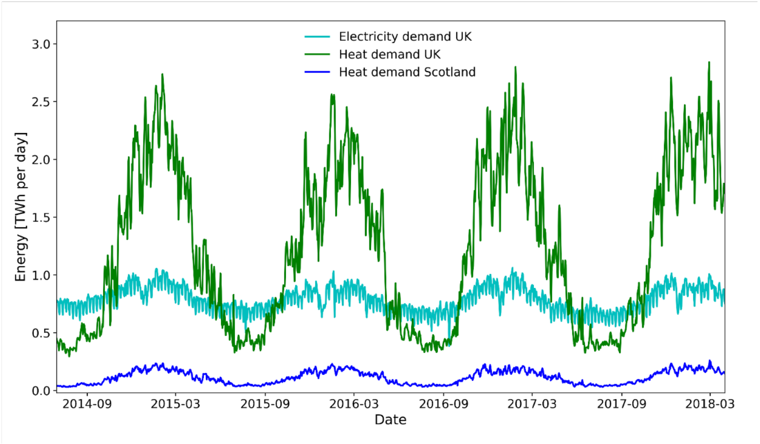
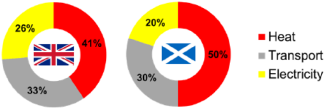
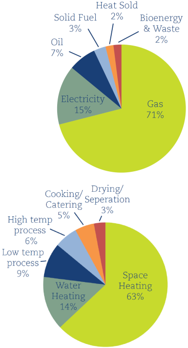


Figure inspired by Wilson et al. Historical daily gas and electrical energy flows through Great Britain's transmission networks and the decarbonisation of domestic heat, 2013.

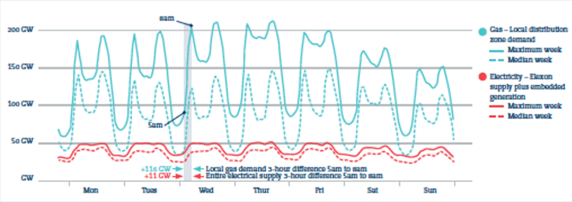




UKERC Research Report

What is the largest energy storage system in the UK?

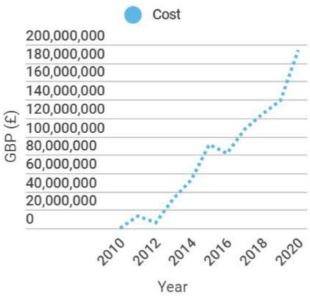
What is the largest energy storage system in the UK?

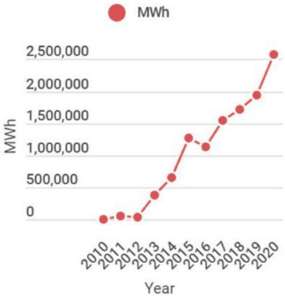


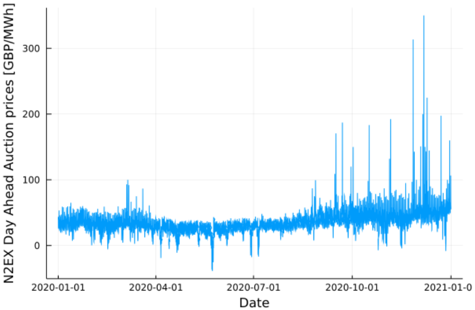
- Within-day linepack in the gas grid of up to 690 GWh
- Peak daily and hourly gas demand up to four times the electricity demand
- 1 hour difference in demand over 7 times larger for gas compared to electricity

Image from the National Transmission System
Wilson et al., Challenges for the decarbonisation of heat: local gas demand vs electricity supply Winter 2017/2018
Wilson and Rowley, Flexibility in Great Britain's gas networks : analysis of linepack and linepack flexibility using hourly data, 2019

Wind curtailment and electricity prices



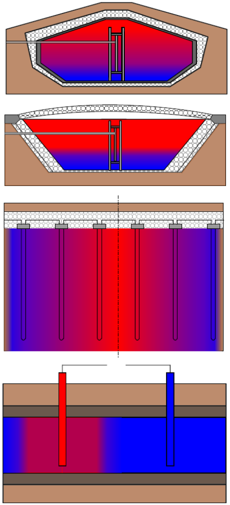




- Committee on Climate Change estimated that low carbon generation needs to be quadrupled from 2019 levels

Canbulat et al., Techno-Economic Analysis of On-Site Energy Storage Units to Mitigate Wind Energy Curtailment: A Case Study in Scotland, Energies 2021, 14(6)

Long term sensible heat storage options



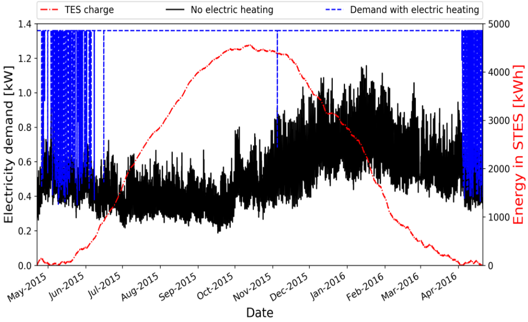
- Usually $> 1000\,\mathrm{m}^3$ to reduce surface to volume ratio
- Tank and pit require suitable space
- Borehole and aquifer require suitable sub-surface
- Round-trip efficiencies around 50%
- Large systems achieve very low costs: for $\Delta T = 70°\mathrm{C}$ it cost 0.6 € kWh^{-1}

Very brief history

- Investigation started in the early 1970s
- First system in Sweden in 1978
- Canada, Denmark, Germany, The Netherlands and Sweden are research and market leaders

Use renewable electricity and waste heat to charge STES

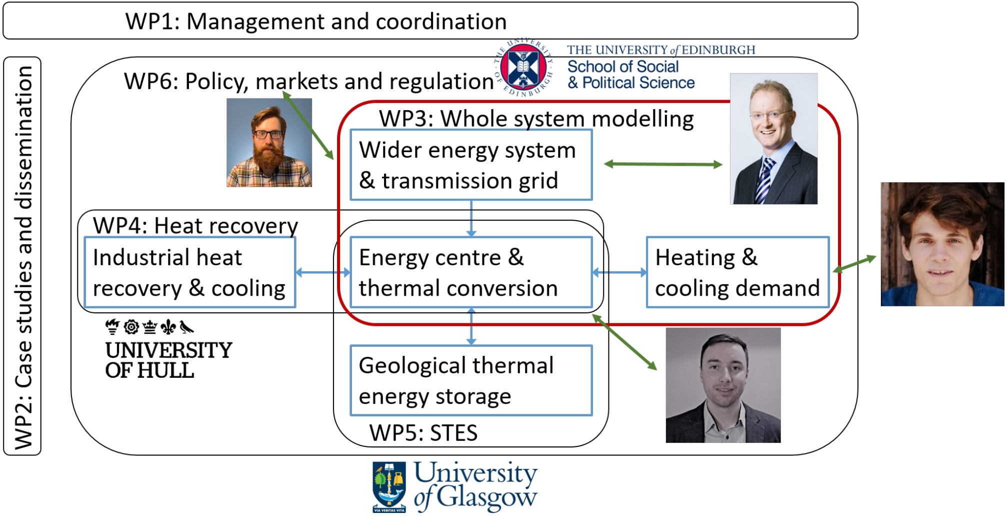
- To cover all our energy needs with non-dispatchable renewables we need either
  - Massive over-production or
  - Enough energy storage
- Heat pumps with seasonal thermal storage could play a big role



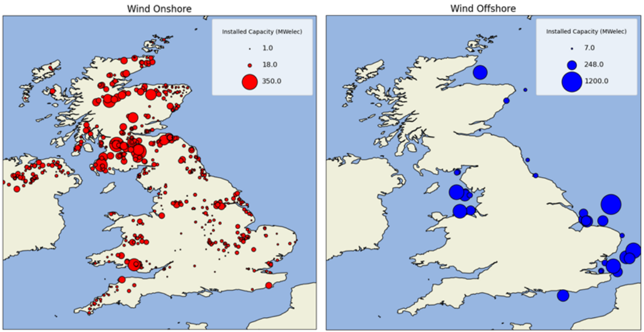
Open questions

- What is the effect on the whole energy system?
- What round-trip efficiency can we get?
- How much renewable generation do we need?

Whole system modelling

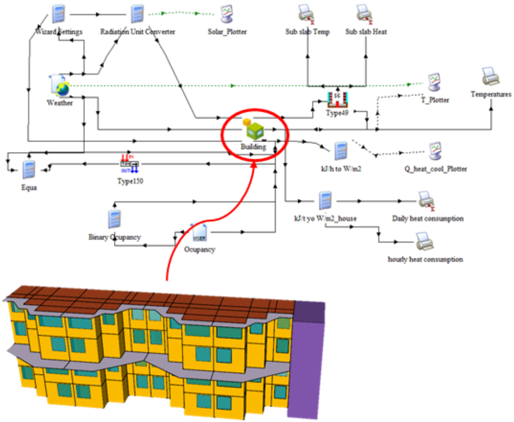


Transmission grid model



- Model the network with the Python Power System Analysis (PyPSA) package
- Use National Grid Future Energy Scenarios (FES) to define the electricity system scenarios

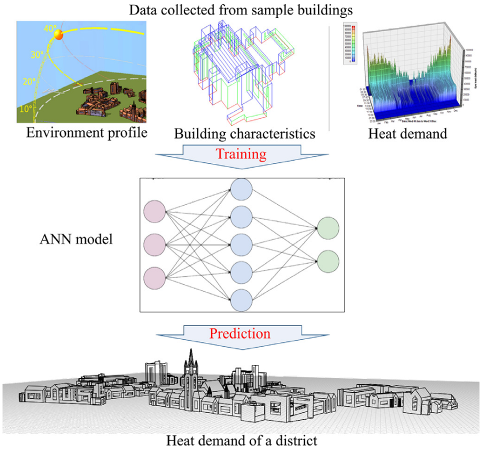
Heating and cooling demand



- Develop case studies for representative cases
  - Campus: University of Edinburgh
  - Suburban: Perth West development
  - Urban: Glasgow city centre
- Use measured data in combination with the Scottish heat map and building energy simulations

Maximov, Mehmood, Friedrich: Multi-objective optimisation of a solar district heating network with seasonal storage for conditions in cities of southern Chile, Sustainable Cities and Society, accepted

Machine learning methods to generate dynamic demand models



- Measured data is for past weather data and building characteristics
- Building energy simulations are computationally expensive
- PhD project sponsored by the Universities of Edinburgh and Hull to develop predictive models for dynamic demand

Chen et al.: Sensitivity Analysis to Reduce Duplicated Features in ANN Training for District Heat Demand Prediction, Energy and AI, 2, 2020

TRNSYS model based on Drake Landing Solar Community

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- Evolution of the market for flexibility services
- Policy and regulatory frameworks for heat and storage

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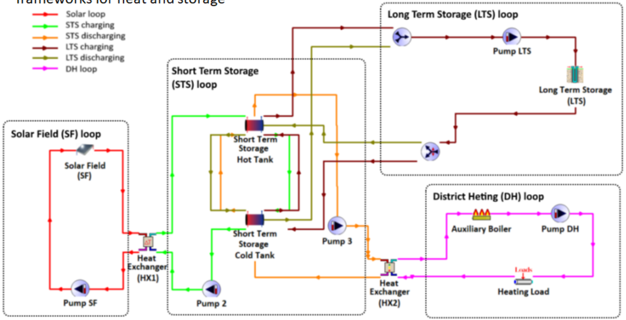
- Quantity and grade of potential sources of waste heat
- Distribution (charge/discharge) and capacity (sizing for demand)



University of Glasgow

- Steady-state and transient output of BTES & ATES
- Parameters based on geological settings

- Extend solar district heating models with variable electric heating and waste heat streams
- Use detailed Trnsys model to train and validate surrogate models which allow two-way communication with the wider system

Renaldi, Friedrich: Techno-economic analysis of a solar district heating system in the UK, Applied Energy, 236, 2019
Maximov, Mehmood, Friedrich: Multi-objective optimisation of a solar district heating network with seasonal storage for conditions in cities of southern Chile, Sustainable Cities and Society, accepted

Conclusion

- Heating and cooling decarbonisation presents significant challenges but also huge opportunities
- Seasonal thermal energy storage is one of the cheapest forms of storage
- Integration of different energy systems and vectors is key to balance the system and to increase the utilisation of the variable resource
- Lots of open questions on how to coordinate and regulate it

Acknowledgements

- Dr Renaldi: seasonal thermal energy storage model of DLSC
- Energy system work is performed in collaboration with Prof Harrison and Drs Harry van der Weijde and Wei Sun
- Serguey Maximov and Sajid Mehmood: Chilean energy system and seasonal thermal energy storage optimisation

Questions?

Thank you for your attention!

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Industrial and international partners

sse Enterprise

Perth & Kinross Council — Comhairle Pheairt is Cheann Rois

SP Energy Networks

natural power

Town Rock Energy

Drilcorp

Ramboll

Star Renewable Energy

energy technology partnership

Aalborg University Denmark

Natural Resources Canada — Ressources naturelles Canada

wsp

Messages from the partners

Running order

- Dave Gowans, Drilcorp
- Mark Richardson, Ristol Consulting for Perth& Kinross Council
- Steve Smith, Natural Power
- Lucio Mesquita, Natural Resources Canada
- Angelos Chatzidiakos, Ramboll
- Watson Peat, SP Energy Networks
- Charlie Drysdale, SSE Enterprise
- David Pearson, Star Renewables
- David Townsend, Town Rock Energy

Questions?

Thank you for your attention!

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