THE UNIVERSITY of EDINBURGH

Decarbonising heating from the individual to the district

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Decarbonising UK domestic heating: Disruptive approaches
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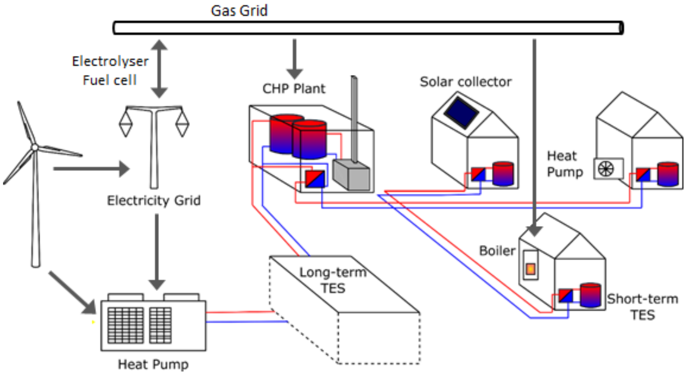
Heat decarbonisation options and opportunities



- Large scale and distributed nature of the heat demand
- Potential for integration with renewables
- Efficient and affordable thermal energy storage (TES)

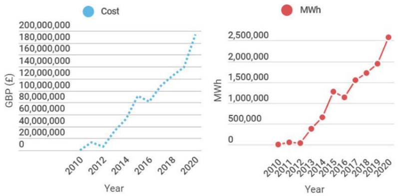
Current domestic heating

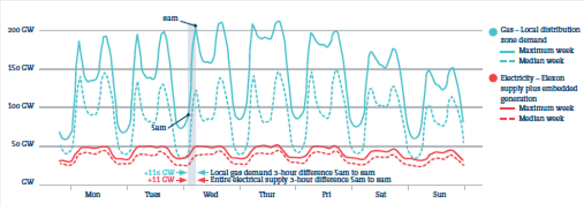
- User control and on-demand
- Gas is relatively cheap
- Gas boilers are robust, flexible and familiar
- Hot water tanks are removed
- Poor insulation

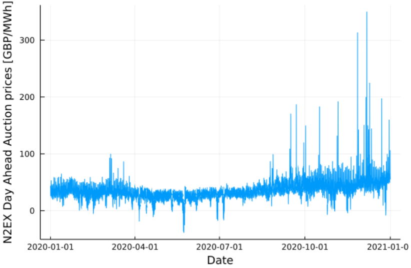
Challenges

- Complete decarbonisation
- Affects all customers

System flexibility and wind curtailment



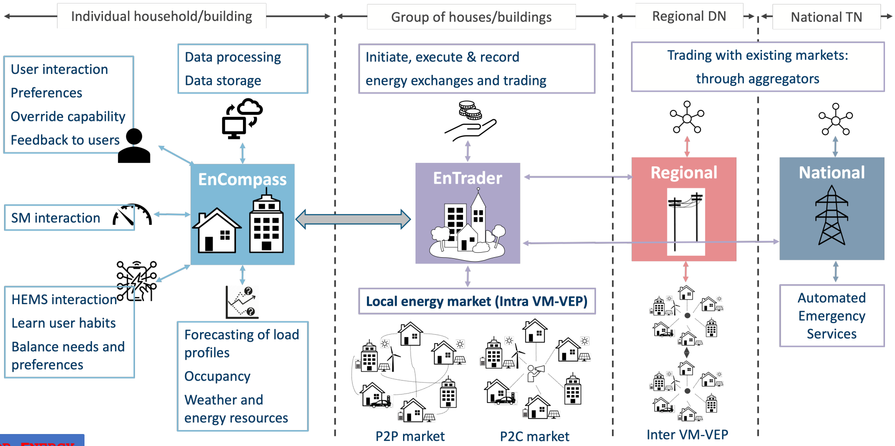




- Daily linepack in the gas grid of up to 690 GWh
- Peak daily and hourly gas demand up to four times the electricity demand
- 1 hour difference in demand over 7 times larger for gas compared to electricity
- Wind energy curtailment is increasing and predicted to reach costs of £1B

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

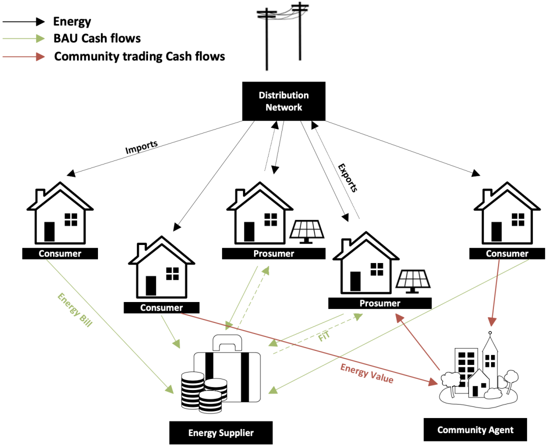
Bottom-up approach (Scalable VM-VEP): Four aggregation levels



MULTI-VECTOR ENERGY DISPATCH NET-ZERØ TRANSITION

- Lead by Prof Sasa Djokic with partners at Heriot-Watt University and University of Glasgow as well as industrial and public sector partners

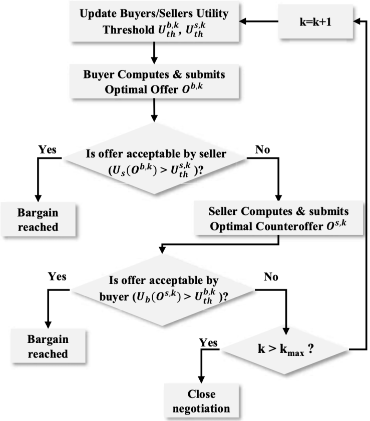
Local energy markets

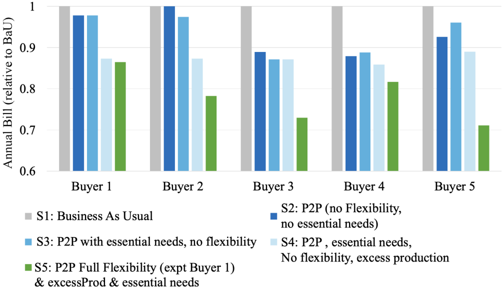


- Coordinate demand for locally generated renewable energy
- Enables special pricing when trading with vulnerable households facing energy poverty
- Prosumers benefit the Most
- Prosumers benefit a bit less if fuel poor households get a lower price

Andoni et al.: Local Energy Markets in Energy Communities and Their Impact on Energy Poverty, 2024 International Conference on Renewable Energies and Smart Technologies (REST), 2024

Automated negotiations

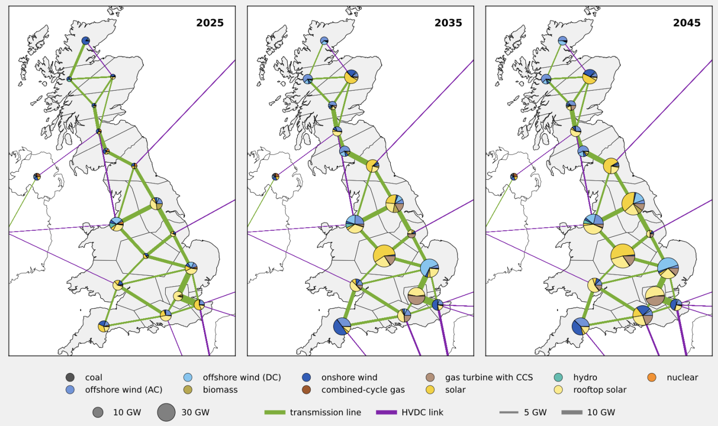




- Peer-2-peer trading with some flexibility could significantly reduce costs
- Incorporating also essential energy needs can reduce savings for others prosumers

Courand et al.: Enhancing Access to Affordable Energy Through Peer-to-Peer Automated Negotiations, 2024 International Conference on Renewable Energies and Smart Technologies (REST), 2024

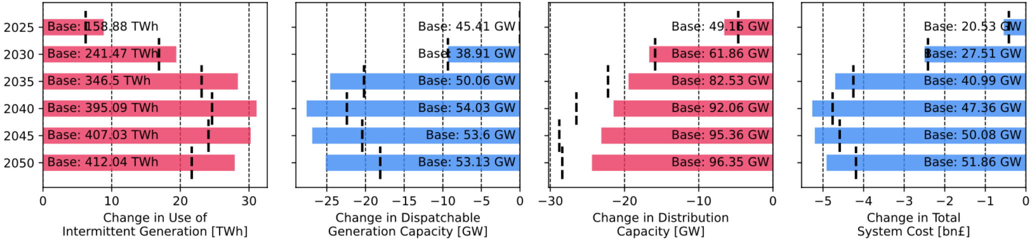
Design of the future energy system



- Generation capacities in the Leading the Way scenario for 2025, 2035 and 2045

Lyden, Sun, Struthers, Franken, Hudson, Wang, Friedrich: PyPSA-GB: An open-source model of Great Britain's power system for simulating future energy scenarios, Energy Strategy Reviews, 53, 2024
Franken, Hackett, Lizana, Riepin, Jenkinson, Lyden, Yu, Friedrich: Power system benefits of simultaneous domestic transport and heating demand flexibility in Great Britain's energy transition, Applied Energy, 2025

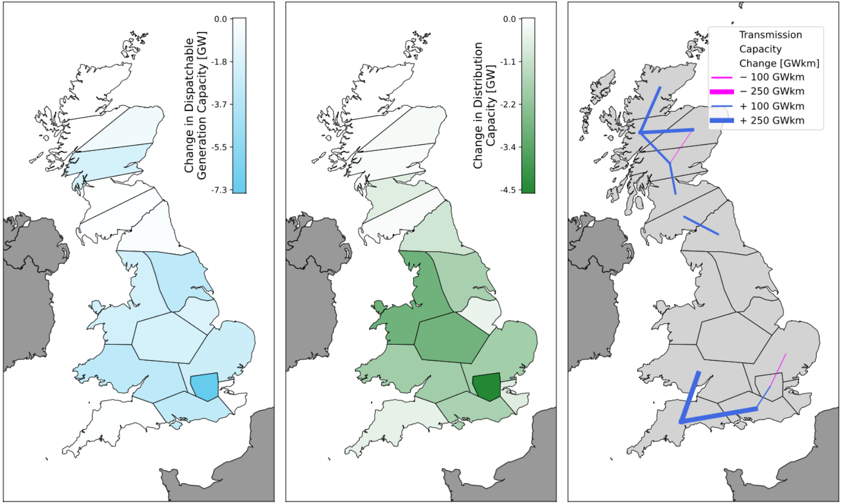
Benefits of simultaneous domestic transport and heating flexibility



- Total system changes for different years assuming FES Leading the Way scenario
- Flexible EV charging and heating can provide significant energy system benefits
- The model also shows where these benefits and changes occur

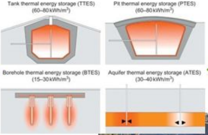
Franken, Hackett, Lizana, Riepin, Jenkinson, Lyden, Yu, Friedrich: Power system benefits of simultaneous domestic transport and heating demand flexibility in Great Britain's energy transition, Applied Energy, 2025
Lyden, Sun, Struthers, Franken, Hudson, Wang, Friedrich: PyPSA-GB: An open-source model of Great Britain's power system for simulating future energy scenarios, Energy Strategy Reviews, 53, 2024

Location of changes due to EV and heat flexibility



Franken, Hackett, Lizana, Riepin, Jenkinson, Lyden, Yu, Friedrich: Power system benefits of simultaneous domestic transport and heating demand flexibility in Great Britain's energy transition, Applied Energy, 2025

INTEGRATE and Heat Balance projects



- Charge large thermal storage with otherwise curtailed wind energy
  - Improves utilisation of limited renewable resource
  - Reduces need for grid reinforcement
  - Reduces electricity demand for heating in winter
  - Provides system resilience
- In conjunction with heat production units, large-scale thermal storage can provide electricity network services support such as frequency response and balancing

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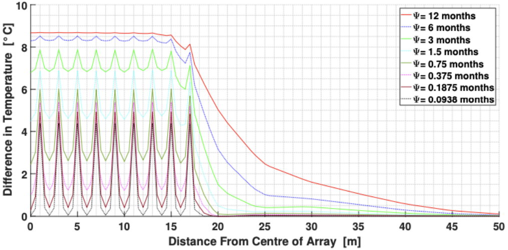
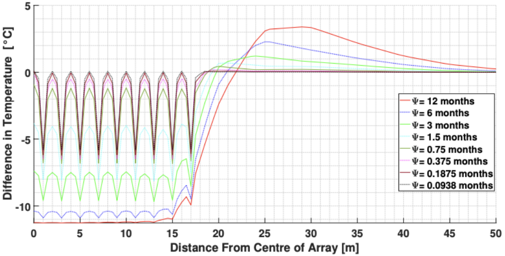
Temperature profiles for short-cycle BTES



(a) End of first charge cycle



(b) End of first discharge cycle

- Charge and discharge rates increase with decreasing cycle lengths
- Reducing the cycle length increases energy recovery and energy density, and therefore overall efficiency and storage capacity
- Good agreement between TRNSYS and OpenGeoSys (OGS)
  - OGS work by Prof Gioia Falcone and team at Uni Glasgow

Desguers, Brown, Kolo, Banks, Falcone, Friedrich: Short-cycle Borehole Thermal Energy Storage: Impact of Thermal Cycle Duration on Overall Performance, Applied Thermal Engineering, 2025

Key takeaways

1. Thermal energy can provide flexibility and benefits to the wider system and should be a vital part to provide an affordable, sustainable and reliable energy system
2. Thermal energy storage can provide reliable thermal energy for district heating at reduced running costs and with lower emissions while, at the same time, providing a large percentage of that energy from otherwise curtailed wind energy
3. Commercial and regulatory barriers need to be overcome to make this a reality

Questions?

Thank you for your attention!

Acknowledgements

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