Decarbonisation of Heat/Cooling Supply Systems Using a Multi-Energy Approach

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Associate Editor of Applied Energy (Impact Factor: 8.426)

Jinan | 17th Sep 2019

CARDIFF, UK


Orkney Is.
Hebrides Is.
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HIGHLANDS
Inverness
GRAMPIAN MTS
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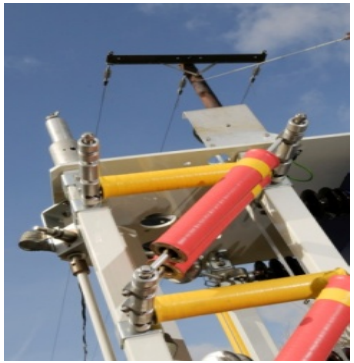
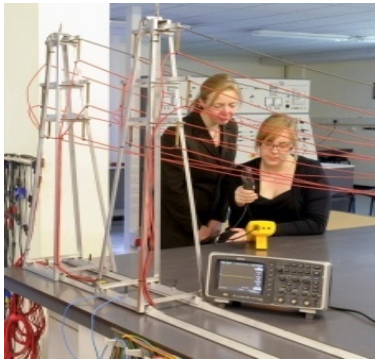
SCOTLAND
Edinburgh
Glasgow
Tweed
Clyde
North Channel
UNITED KINGDOM
Cheviot Hills
Londonderry
NORTHERN IRELAND
Belfast
CUMBRIAN MTS
PENNINE CHAIN
Isle of Man
Leeds
Lough Neagh
Liverpool
Manchester
Sheffield
IRELAND
Irish Sea
Dee
CAMBRIAN MTS
Birmingham
St. George's Channel
Severn
THE NETHERLA
ENGLAND
WALES
Cotswold Hills
LONDON
Strait of Dover
Cardiff
Thames
Celtic Sea
Plymouth
Isle of Wight
English Channel

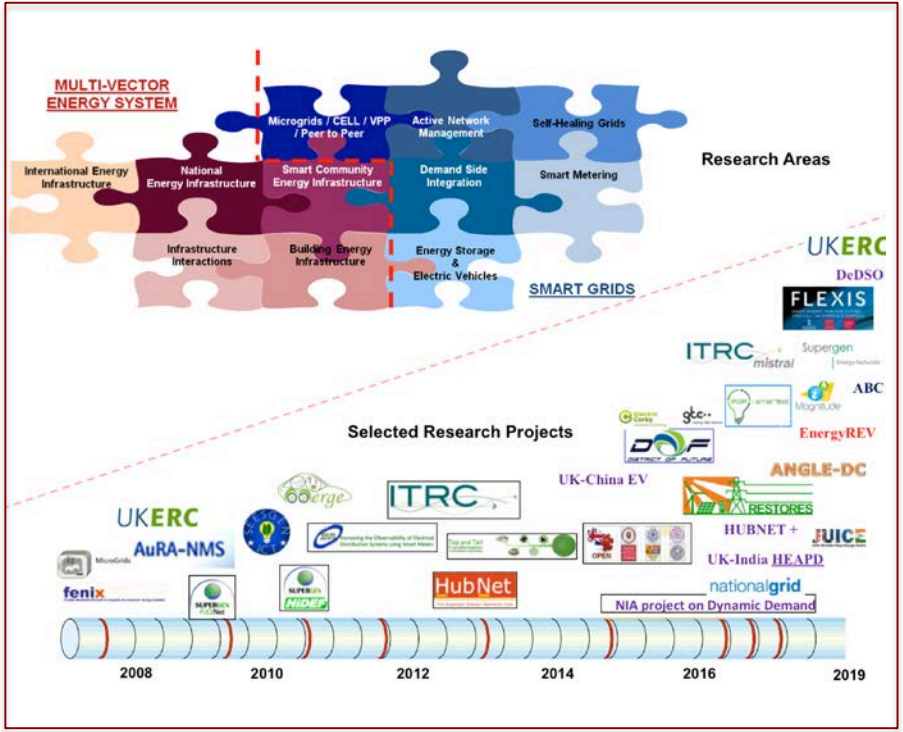
CARDIFF UNIVERSITY

- **Cardiff University is one of the Russell Group of universities which consists of 24 leading UK universities.**
- **The research of the School of Engineering was ranked TOP 7 amongst UK universities in the 2014 Research Excellence Framework.**
- **The School of Engineering is TOP in the UK for Research Impact in this 2014 REF.**

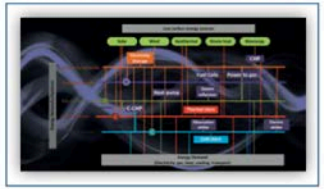




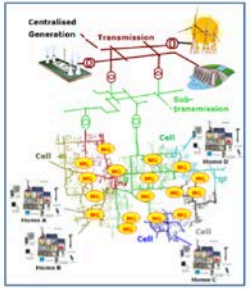
MY RESEARCH



Multi-vector Energy Systems



Peer-to-Peer Energy Trading



We are one of the initiators of these two research areas which are now global focuses in Energy R&D.

- Web of Science Essential Science Indicators (ESI) Highly Cited Papers:

  6 papers / 16 papers from ENGIN

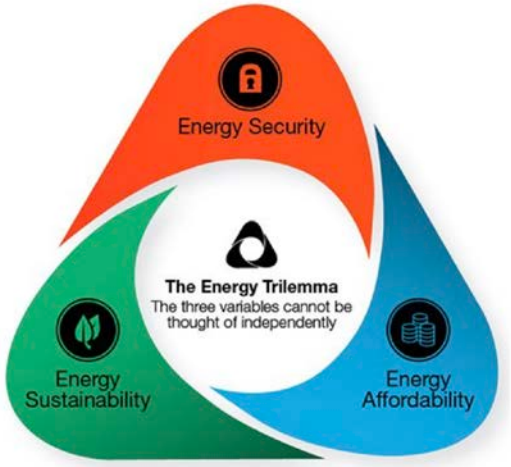
- Significant Research Engagement and Research Income

Supergen Energy Networks	£5.1m	JUICE	£5.1m
ITRC mistral	£5.3m	Magnitude	€4m
EnergyREV	£12m	ANGLE-DC	£15m
FLEXIS	£25m	UKERC	£18m
	£36m	Ongoing Projects	

OUTLINE

1. Energy Landscape
2. Decarbonisation of Heat/Cooling
3. Multi-energy Approach
4. Latest Research Development
5. Conclusions

ENERGY LANDSCAPE



Energy Trilemma

Environmental Sustainability

Encompasses the achievement of supply and demand-side energy efficiencies and the development of energy supply from renewable and other low-carbon sources.

Energy Equity

Accessibility and affordability of energy supply across the population.

Energy Security

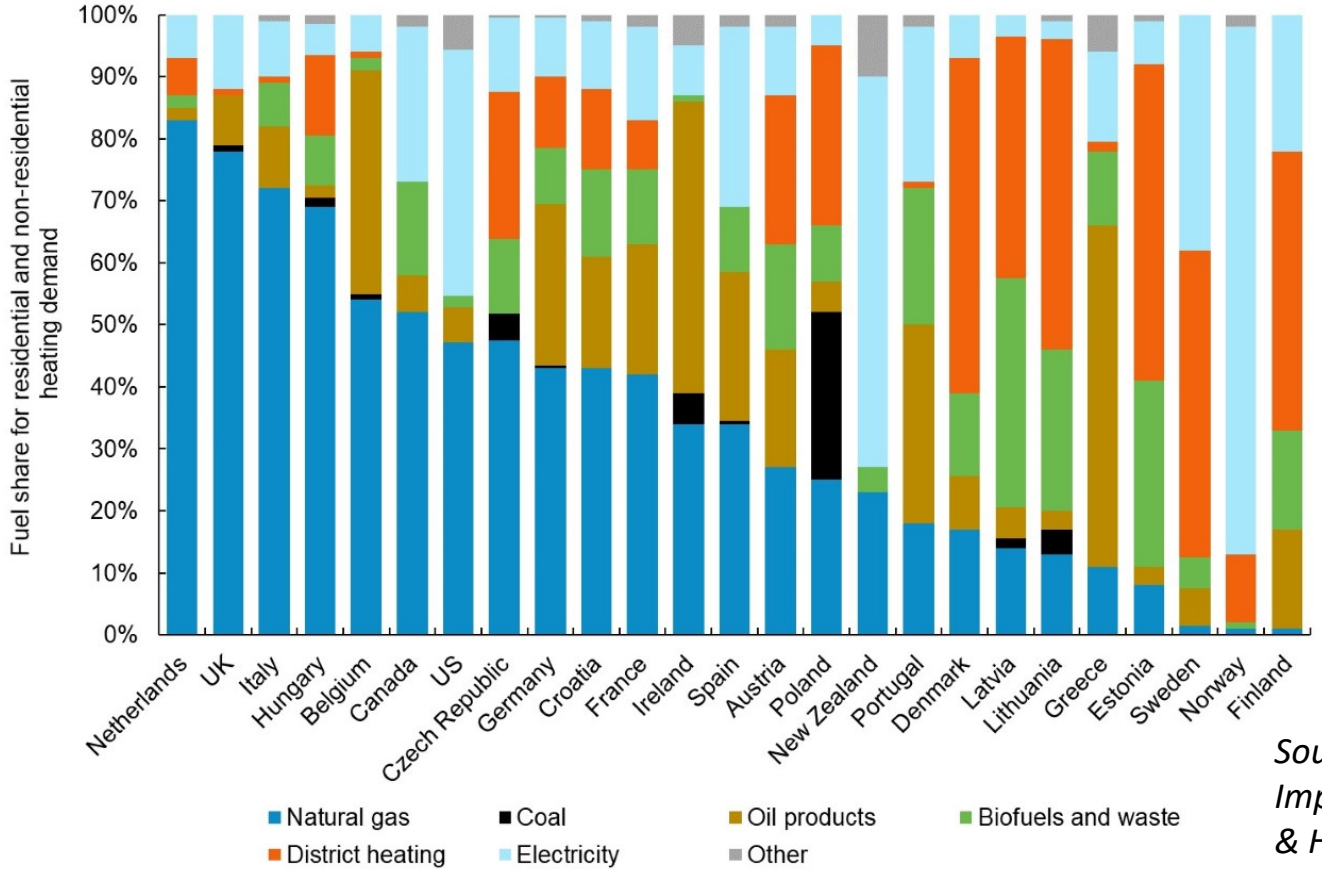
The effective management of primary energy supply from domestic and external sources, the reliability of energy infrastructure, and the ability of energy providers to meet current and future demand.

- **One of the most important infrastructures of the modern society.**
- **An unprecedented energy revolution is now ongoing globally.**
- **IEA predicted that smart energy market is around $2 trillion to be invested globally in energy infrastructure every year.**

ENERGY LANDSCAPE

- Heat is required to keep buildings warm, produce hot water, and to supply energy for industrial processes.
- In total, heating and cooling accounts for half of the EU's annual overall energy consumption and 59% of total EU gas consumption.
- Heat constitutes the single biggest use of energy in the UK.
  - Almost half (46%) of the final energy consumed is used to provide heat, of which around three quarters is used by households and in commercial and public buildings; the rest is used in industrial processes.
- A great deal of uncertainty regarding the deployment of low-carbon heat technology and the Net Zero target by 2050.

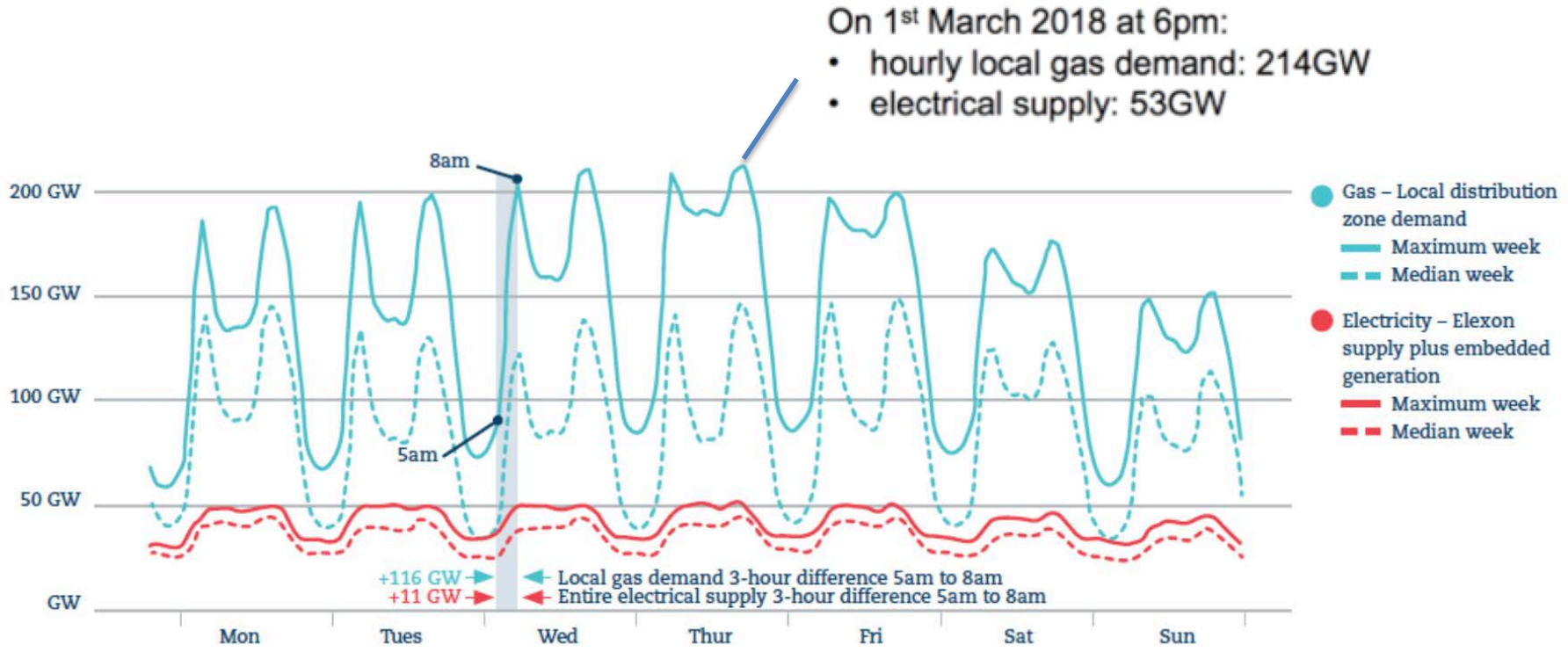
ENERGY LANDSCAPE



Fuel shares for residential and non-residential heating in selected countries

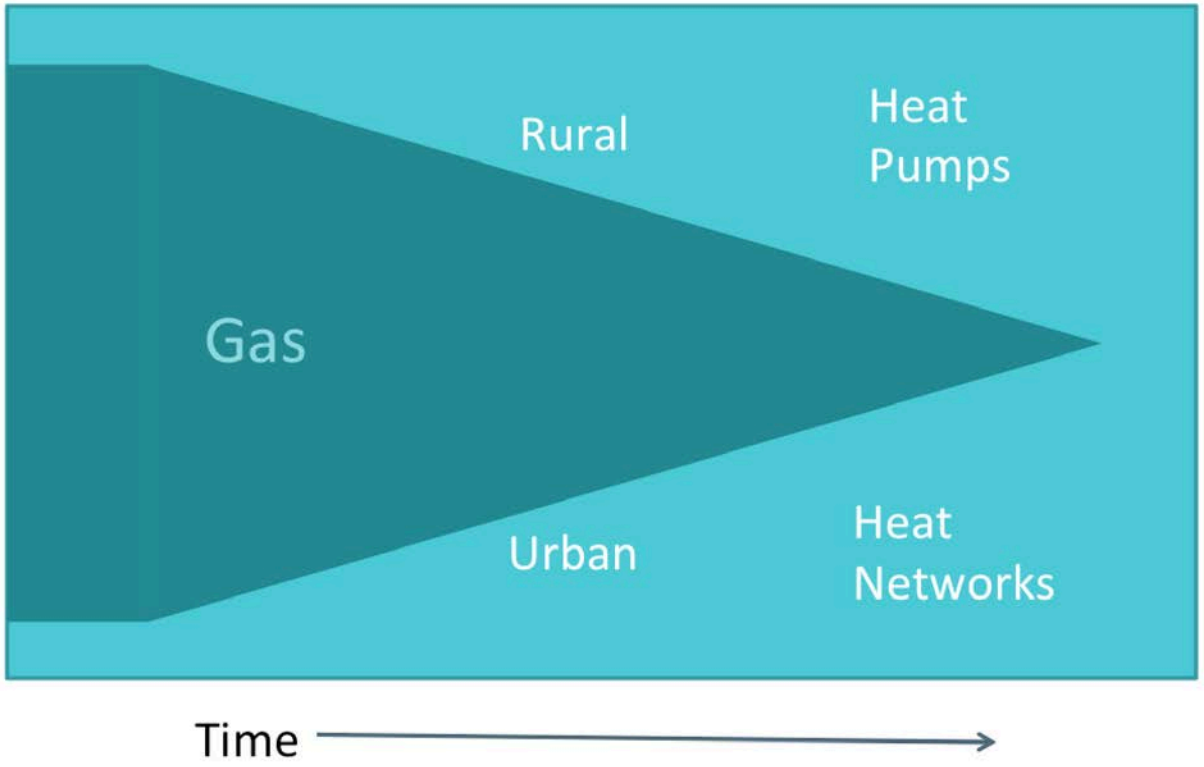
Sources: Vivid Economics & Imperial College (2018); Gross & Hanna (2019)

DECARBONISATION OF HEAT/COOLING - Challenges



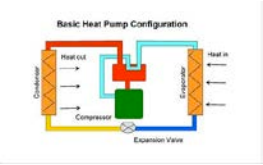
Grant Wilson, University of Birmingham
http://www.ukerc.ac.uk/publications/local-gas-demand-vs-electricity-supply.html

DECARBONISATION OF HEAT/COOLING - Pathways



DECC Heat Pathway – Feb 2015

DECARBONISATION OF HEAT/COOLING - Pathways



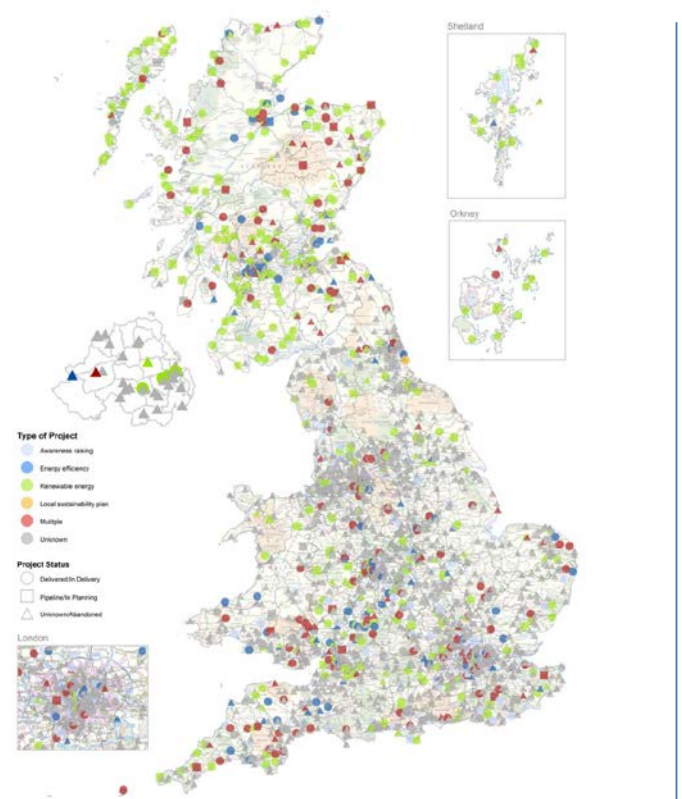
The Committee on Climate Change (CCC) in the UK has identified multiple decarbonisation pathways for low-carbon heating. Three central pathways have been identified:

- by 'greening' the gas supply by shifting to hydrogen;
- electrification of the heating sector supported by low-carbon power generation;
- by potential hybrid solutions, with the bulk of heat demand, met by electricity, and peak demands met by green gas.

Three alternative pathways were investigated in a report to CCC prepared by Imperial College:

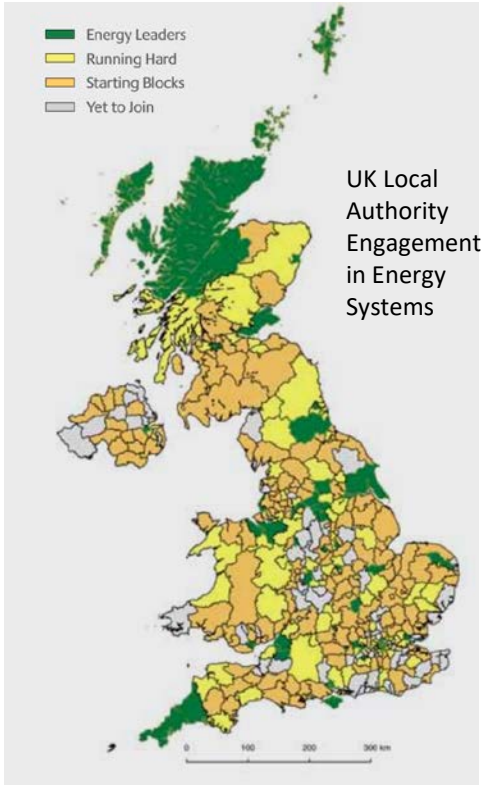
- regional decarbonisation (e.g. through cost minimisation);
- district heating;
- micro-CHP.

DECARBONISATION OF HEAT/COOLING - Coordination is Complex

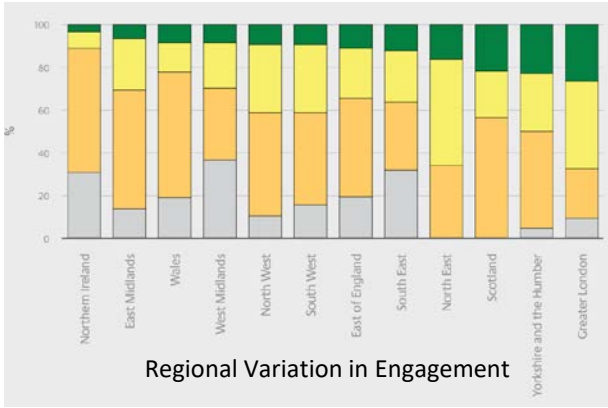


Map illustrating all community groups identified in this study that have been active in the UK community energy sector since 2008

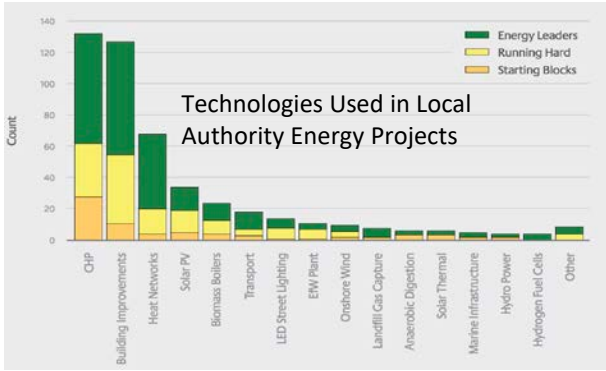
DECC 2014. Community Energy in the UK: Part 2



UK Local Authority Engagement in Energy Systems



Regional Variation in Engagement



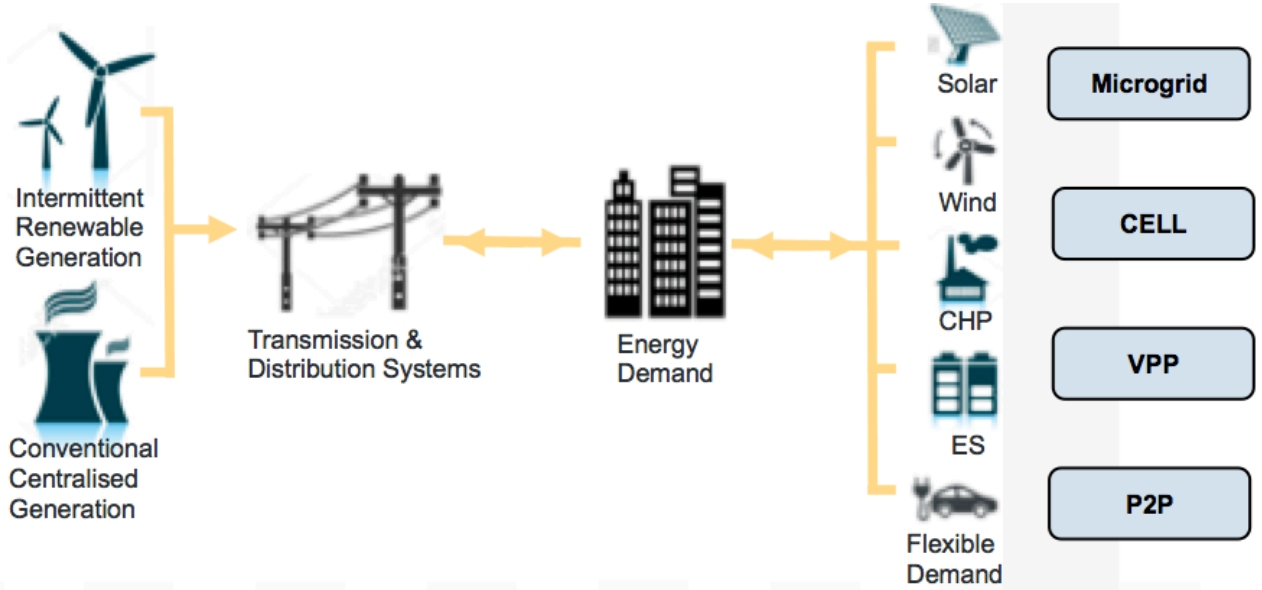
Technologies Used in Local Authority Energy Projects

Sources: Contains Ordnance Survey data 2012; 2013; National Statistics data 2013; NIRSA data 2013; NRS data 2013. Crown copyright and database right. Map created using QGIS (QGIS Development Team, 2016).

UKERC and ETI 2017. Local Authority Engagement in UK Energy Systems: Highlights from Early Findings.

DECARBONISATION OF HEAT/COOLING - Electrification

Development in Electricity Sector

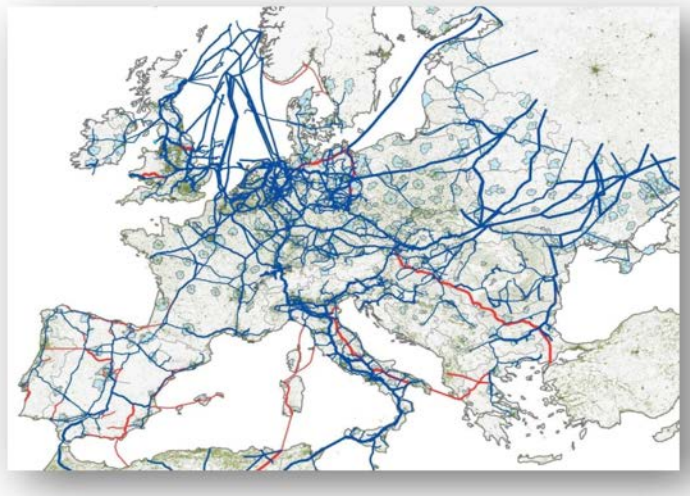


- A large penetration of intermittent renewable generation
- Distributed Energy Resources are dispersed in the system
- New technologies and novel business models are urgently needed to accommodate large heat demand

Development in Gas Sector

Gas Infrastructure Europe

- 2.2 million km transport and distribution grid in the EU
- 100 billion m³ storage capacities (≈ 1,000 TWh)
- 200 Million gas-based systems operated in household, industry, power plants, mobility in Europe



Transport

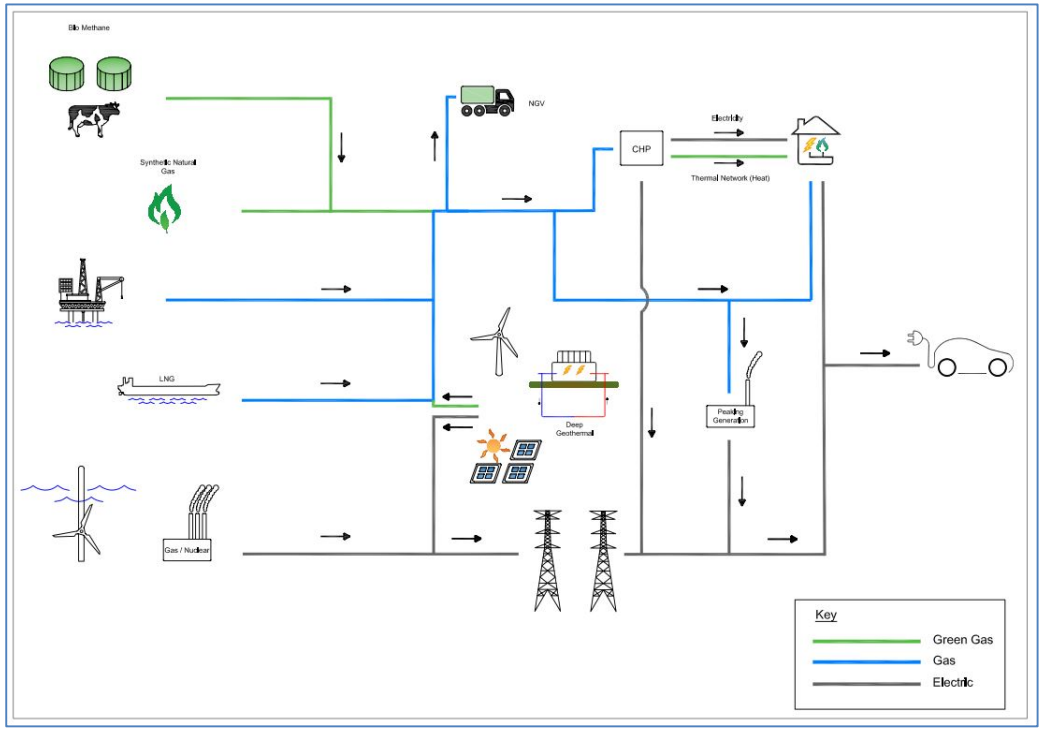
HVAC Grid

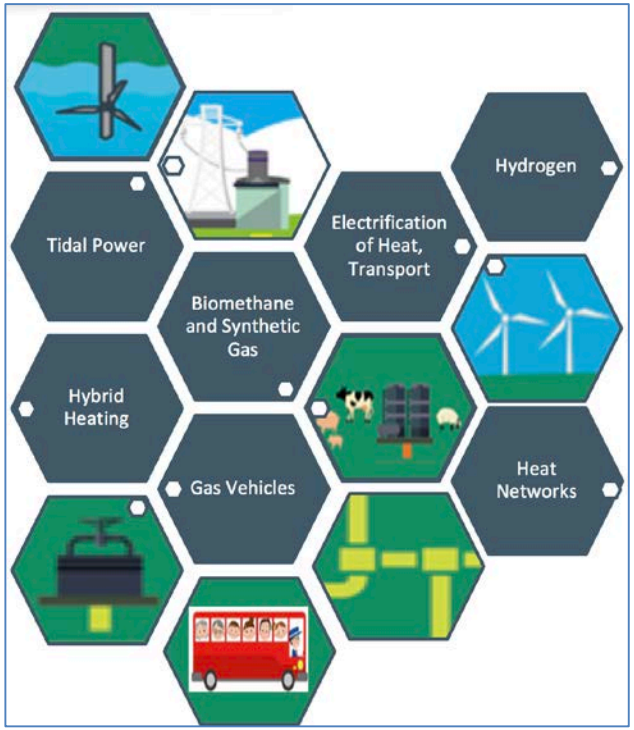
- 380 kV
- AC
- 2 * 1.8 GW_{elek}
- 5 % for 500 km

NG grid

- 80 bar
- 1200 mm
- 30 GW_{chem}
- 0.5 % for 500 km

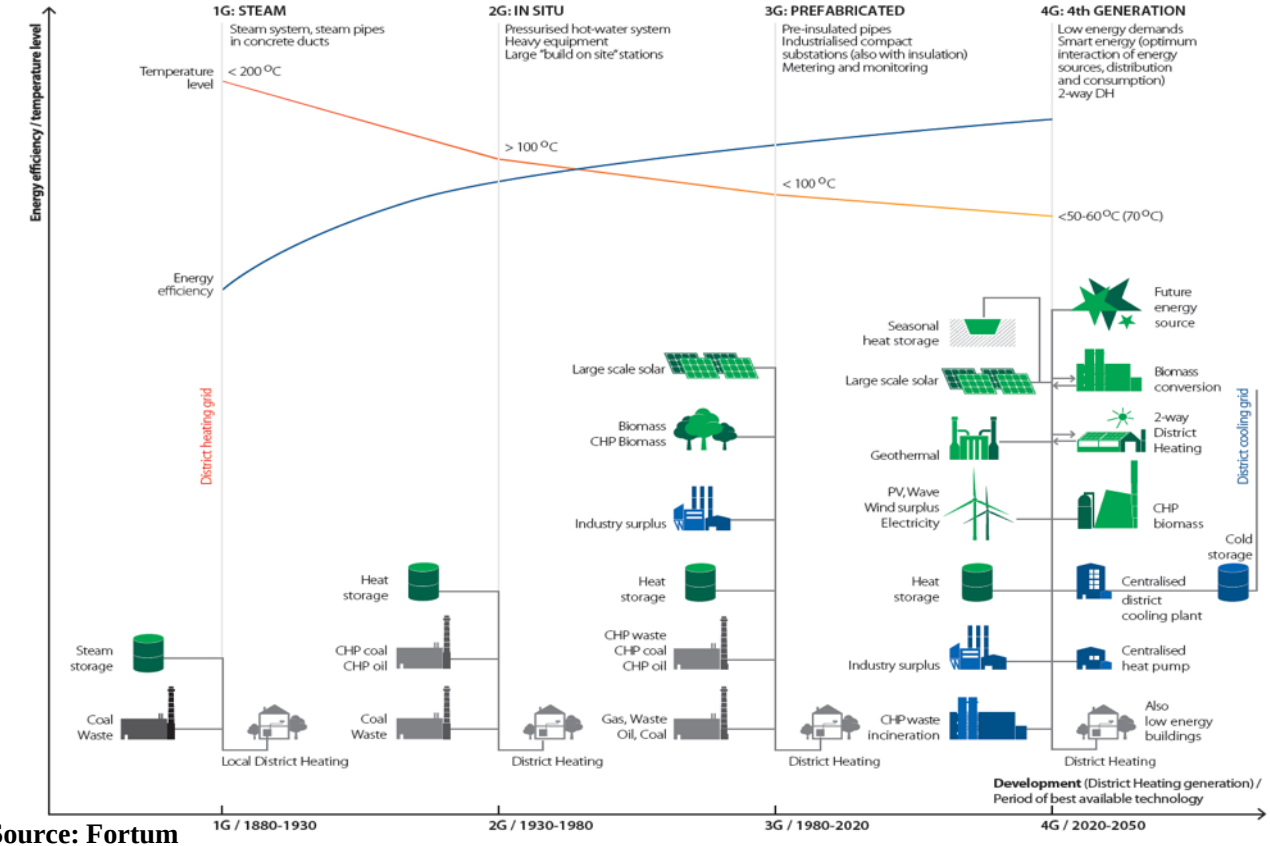
Development in Gas Sector





Source: WWU

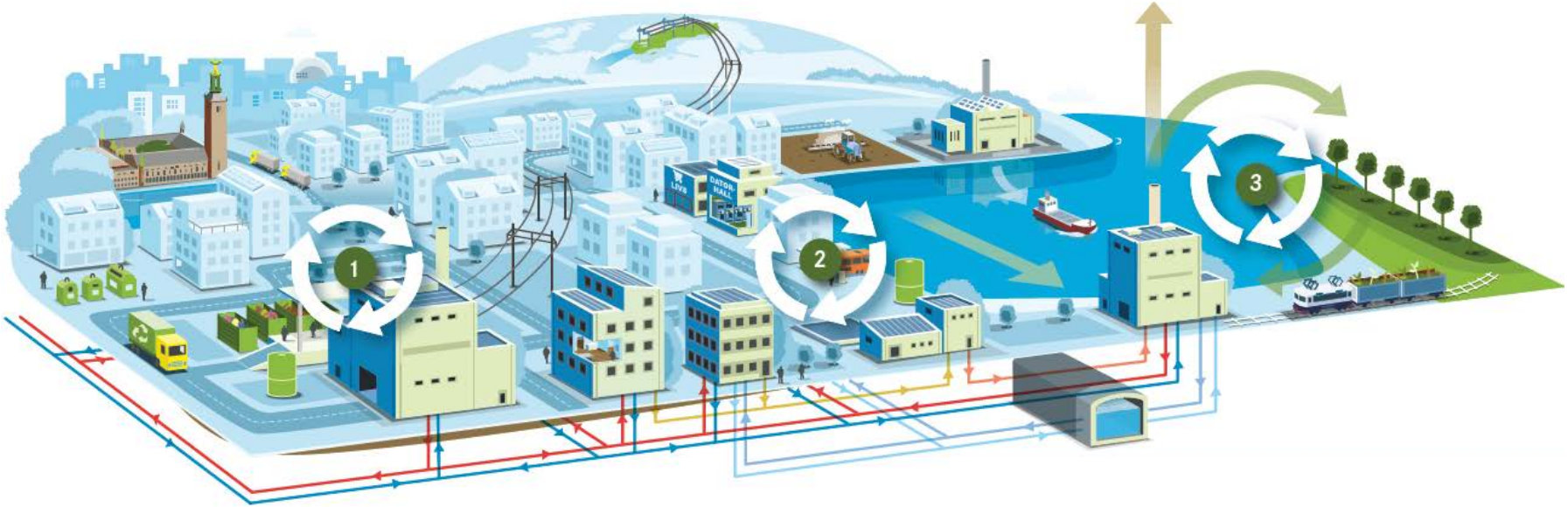
Development in Heat Sector



Source: Fortum

DECARBONISATION OF HEAT/COOLING – Swedish Vision

Towards 100% renewable and recycled fuels – Swedish Vision



1. Combined heat and power from waste incineration

2. Heat recovery: from sewage treatment plants, the district cooling network and data centers

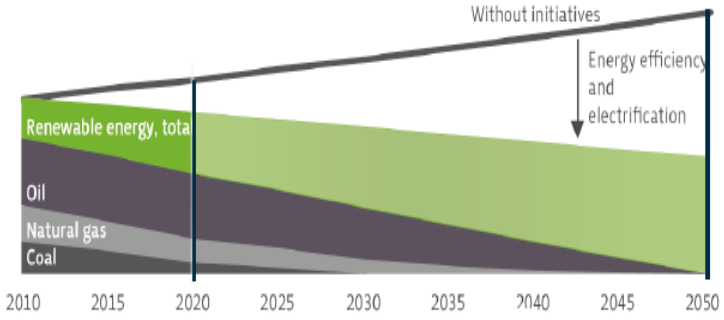
3. Renewables: Combined heat and power from forest residues. Sea water for ”free” cooling and heat pumps.

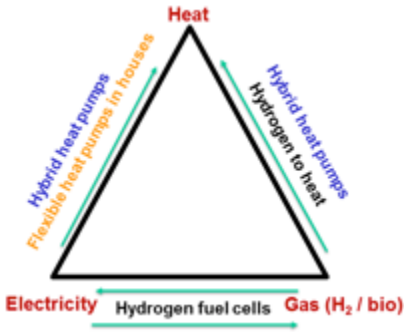
Source: Fortum

DECARBONISATION OF HEAT/COOLING – Danish Vision

Denmark's Energy Strategy

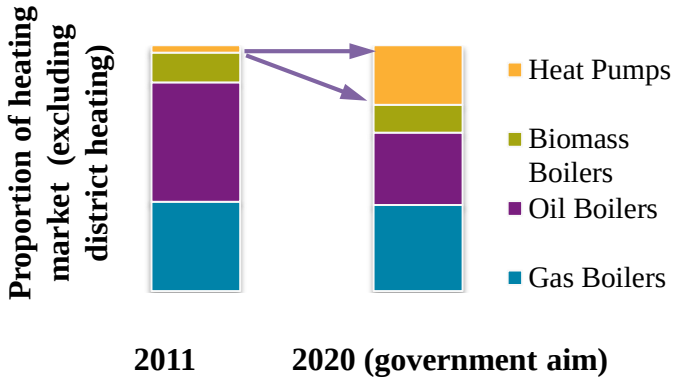
- 100% renewable energy by 2050
- Wind producing 50% of electricity by 2020



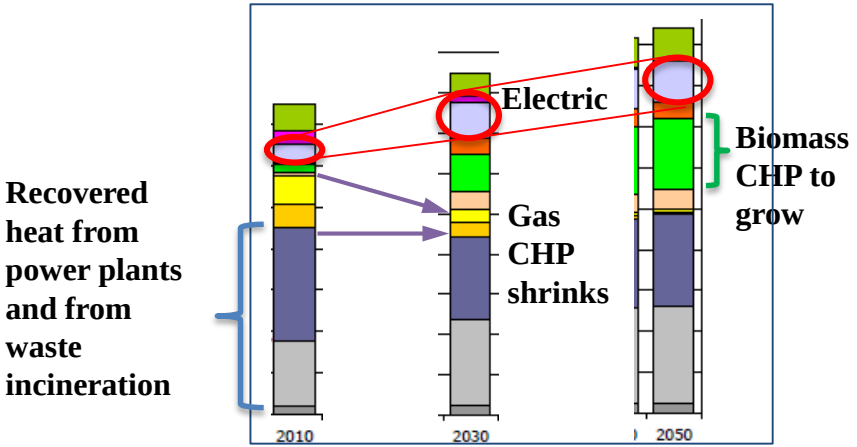


Source from DELTA Energy & Environment

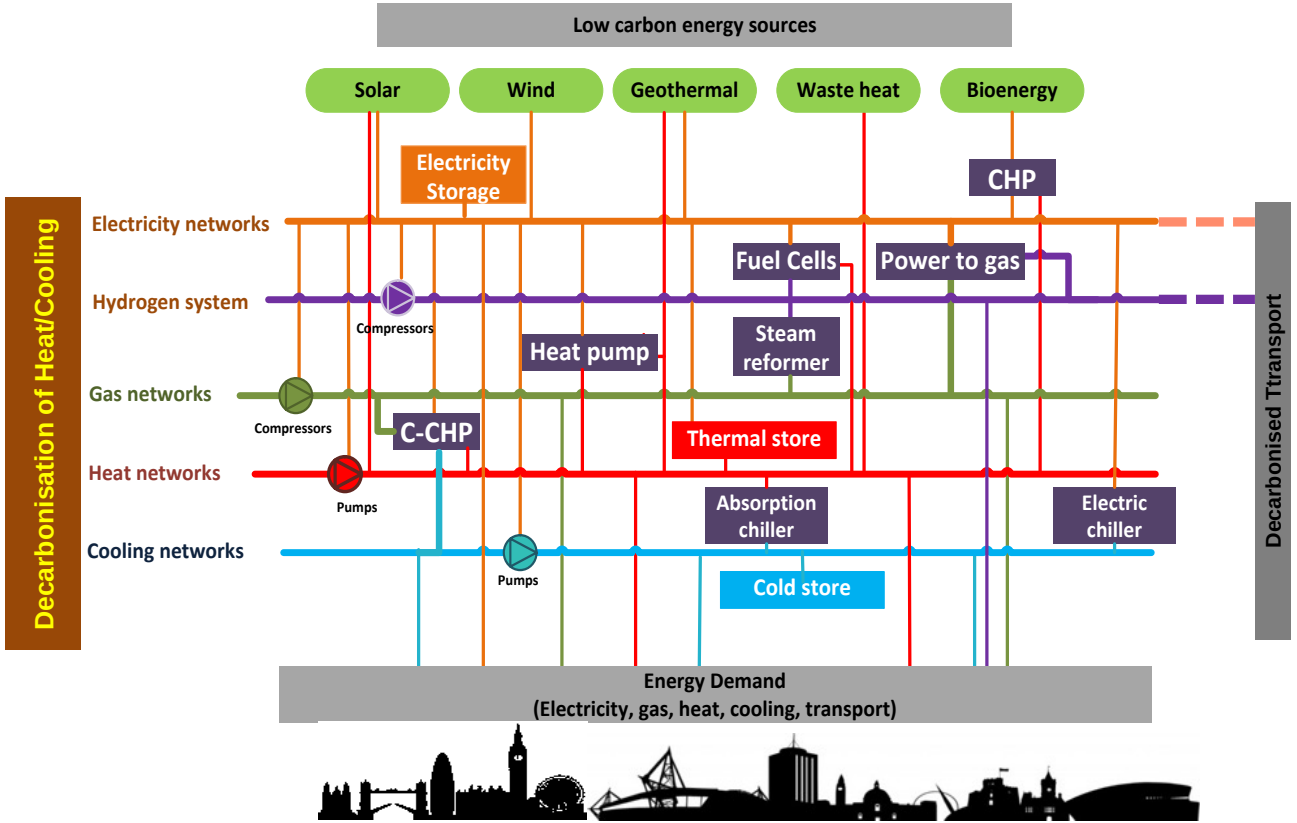
Individual systems



District heating (vision of Danish DH Assoc.)



MULTI-ENERGY APPROACH



MULTI-ENERGY APPROACH

MULTI-ENERGY APPROACH

Characteristics of Integrated Multi-Vector Energy Systems

Complementary advantages of various energy vectors for system design and operation

Exploring and facilitating the integration of local sustainable and renewable energy resources and new energy demand

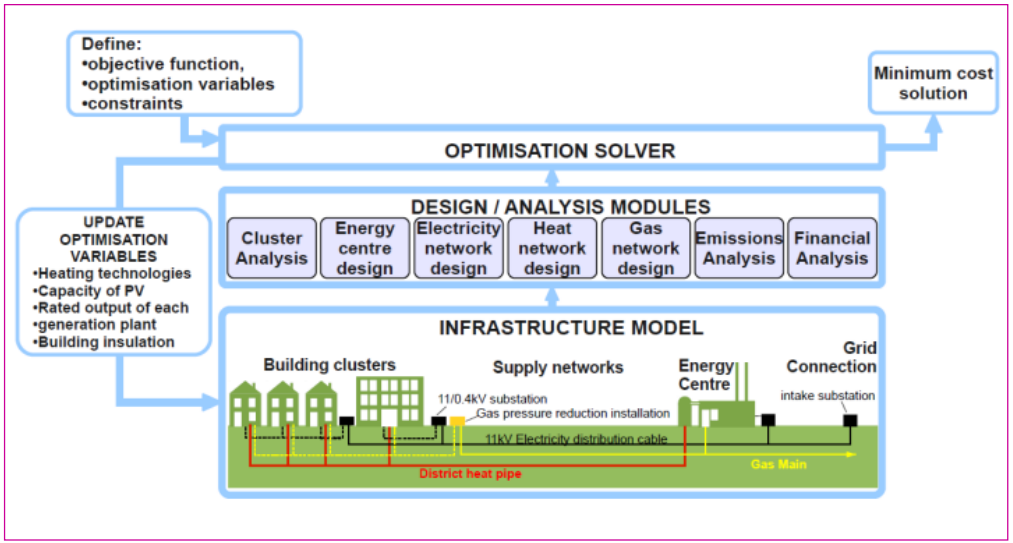
Increasing system reliability and resilience

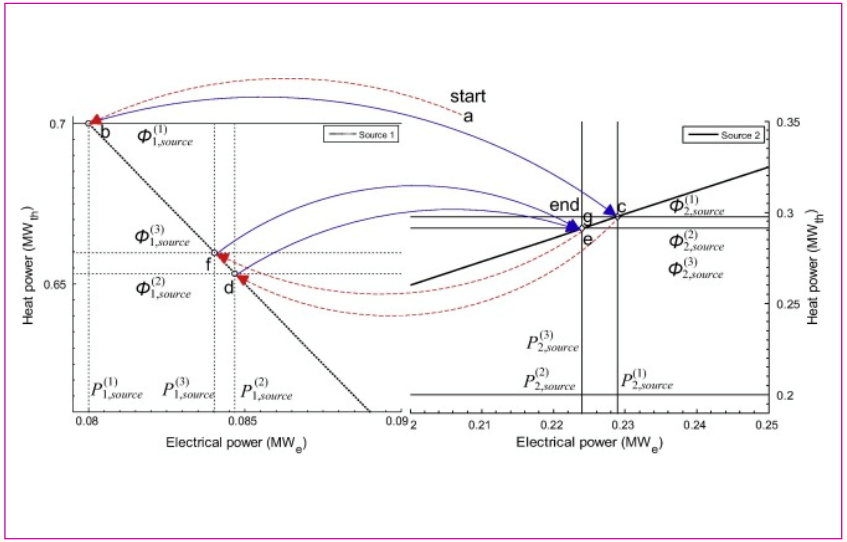
Helping combat rural fuel poverty

Improving energy efficiency and reducing energy cost

Increasing the risk of cascading faults, if not managed properly

MULTI-ENERGY APPROACH – Analysis Methods

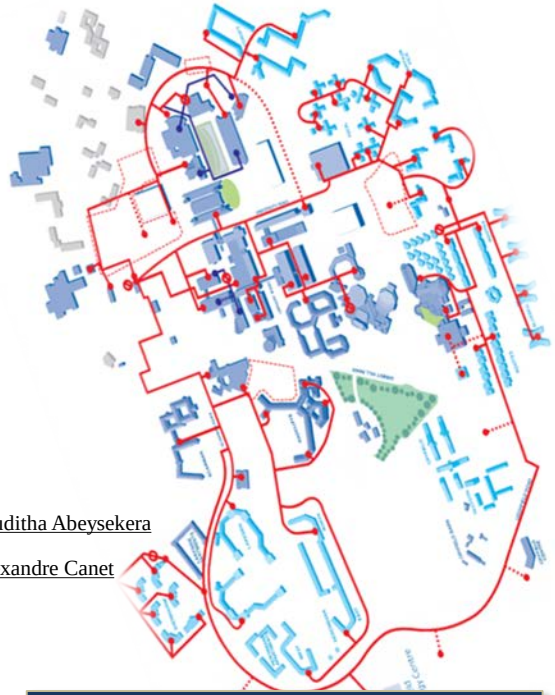




Liu X, Wu J, Jenkins N, Bagdanavicius A, Combined Analysis of Electricity and Heat Networks, Applied Energy, 162, 1238-1250, Jan 2016 (ESI Highly Cited Paper)

Pirouti M, Bagdanavicius A, Wu J, Jenkins N, and Ekanayake J, Minimisation of the capital costs and energy usage in a district heating network, Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, (2014)

A real example of multi-vector energy systems



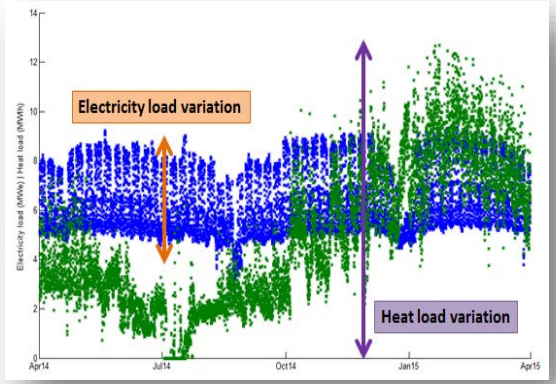
Author: Muditha Abeysekera

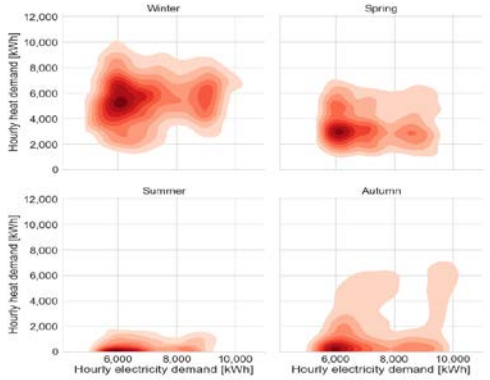
Alexandre Canet

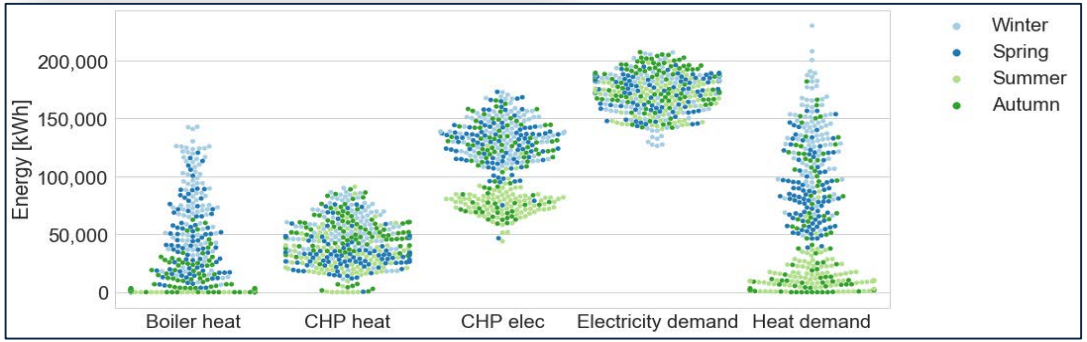
Energy loads

Electricity demand ~ 10MW$_{e\ (peak)}$

Heat demand ~ 15MW$_{th(peak)}$



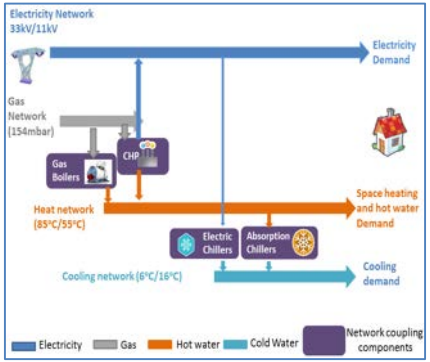




Case study of a University campus

MULTI-ENERGY APPROACH - Optimal Design and Operation

A real example of multi-vector energy systems



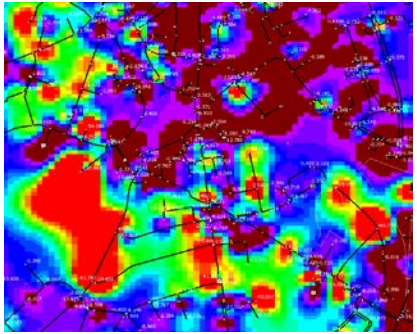
CHP

Electric Chiller

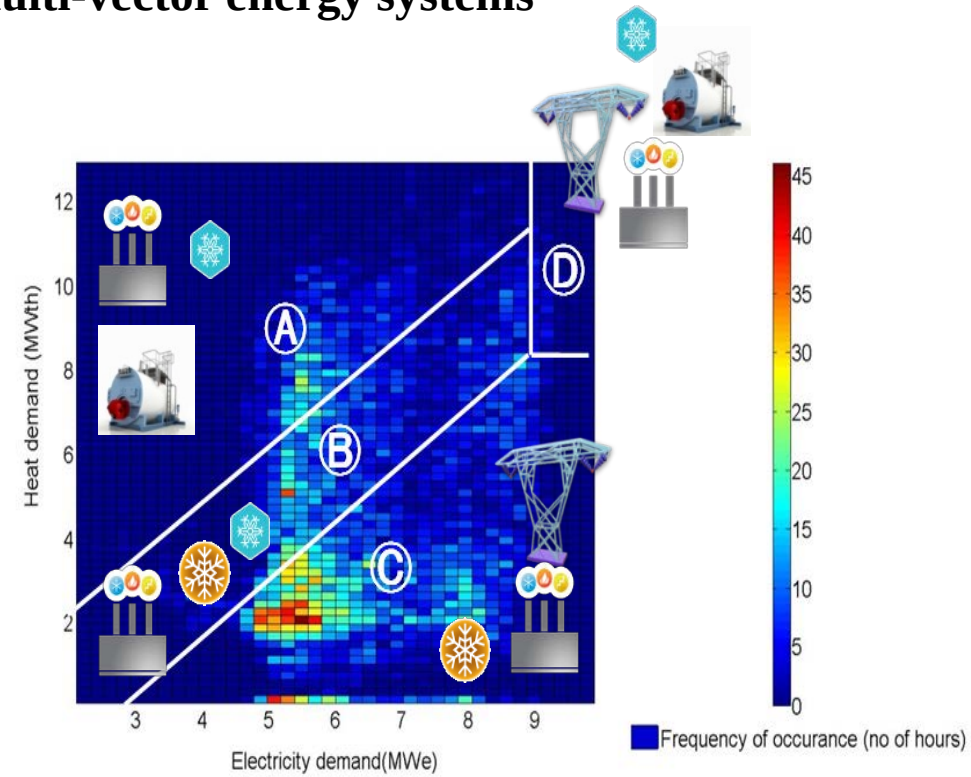
Gas Boiler

Electricity import

Absorption chiller



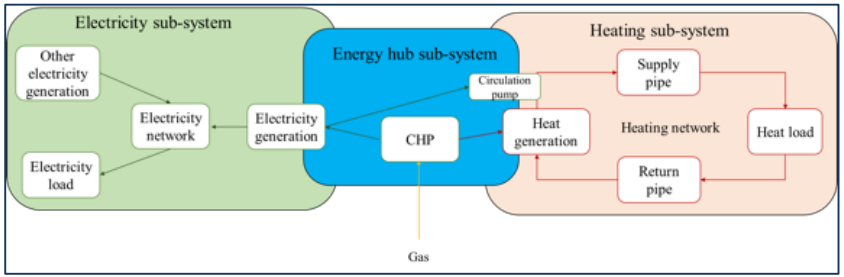
Example of geographical distribution of heat demand (Source: WWU)



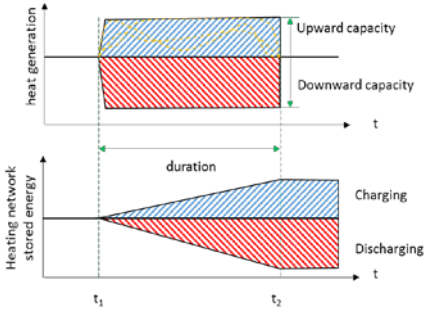
Optimal Operational Strategies of the Multi-Vector Energy System

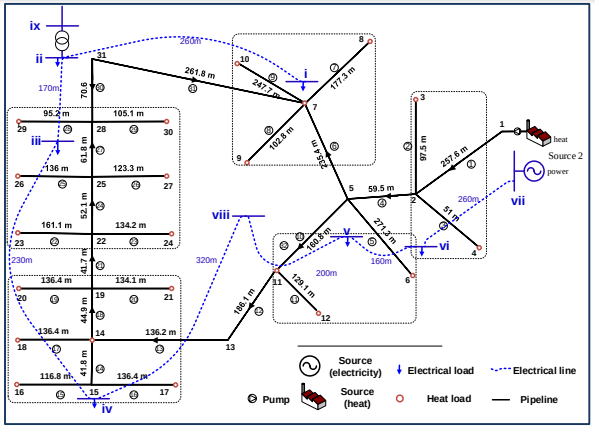
Author: Muditha Abeysekera

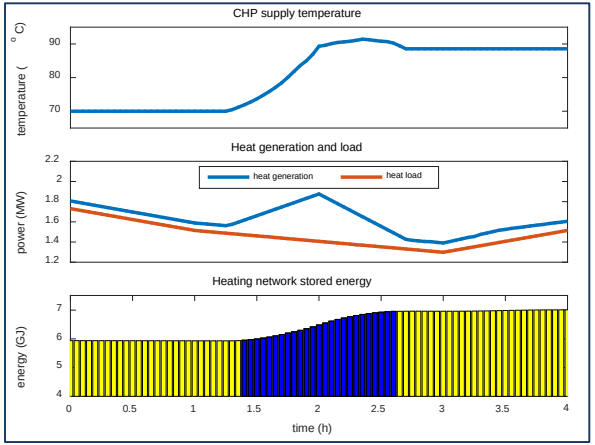
MULTI-ENERGY APPROACH - Flexibility Provision



System	Electricity network	CHP	Heating network	
			hydraulic	thermal
Velocity	3×10^8m/s	-	≈km/s	≈m/s
Time scale	nanoseconds ~milliseconds	milliseconds ~minutes	~seconds	~minutes

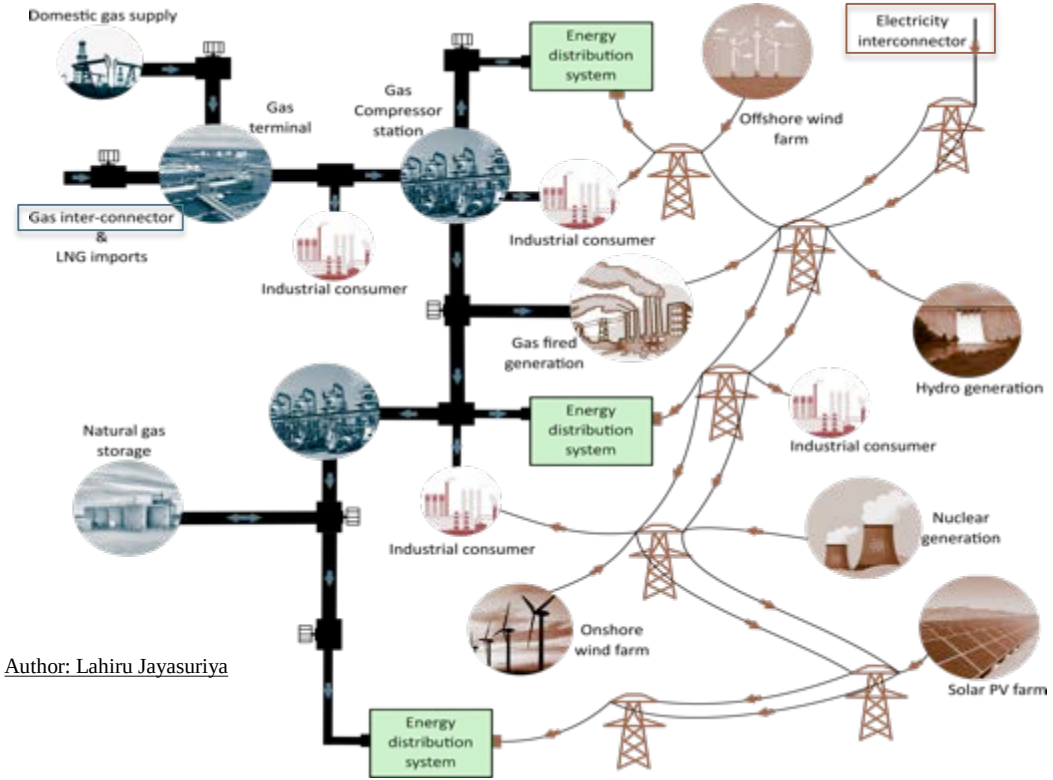






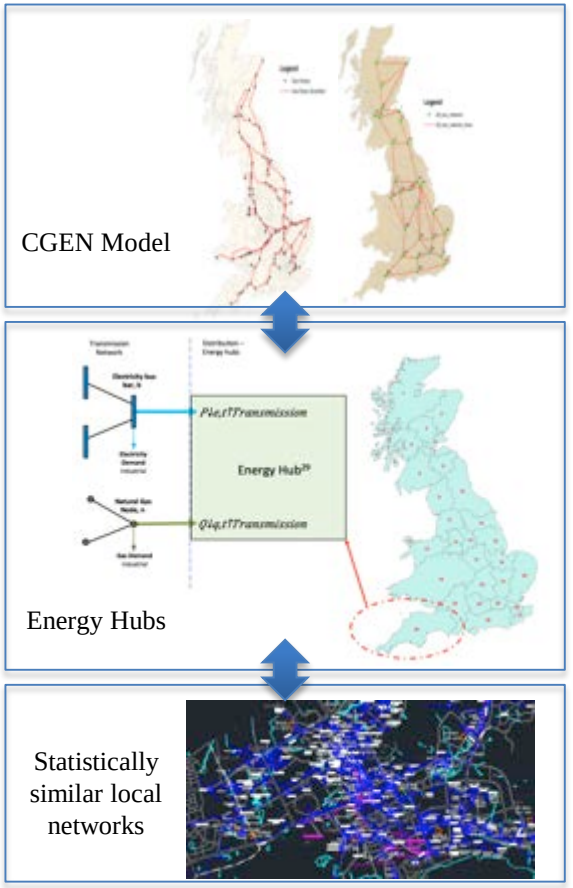
Ref: Pan Z. Wu J., et al., Quantification of operational flexibility from a heating network. *Applied Energy Symposium of REM*, 2017

MULTI-ENERGY APPROACH - Whole-Systems Approach



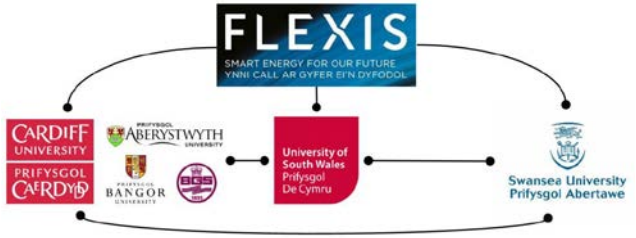
Author: Lahiru Jayasuriya

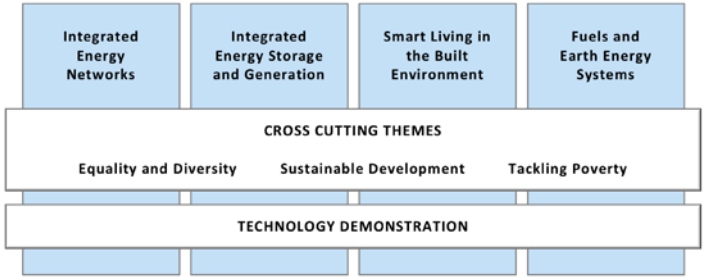
Whole-systems modeling



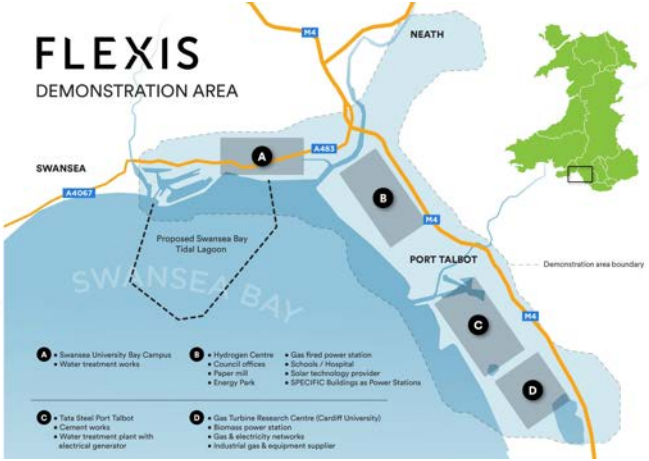
LATEST RESEARCH DEVELOPMENT

£24.5m WEFO funded research project
Flexible Integrated Energy Systems



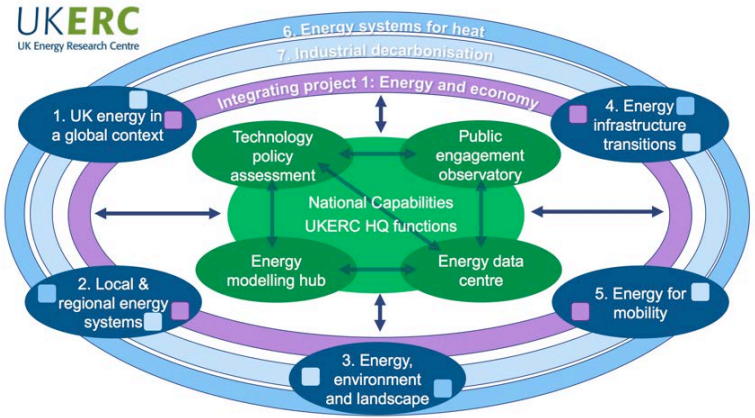


- Amongst UK's most polluted cities
- 8th most populous local authority in Wales
- 17 areas within the top 10% most deprived in Wales

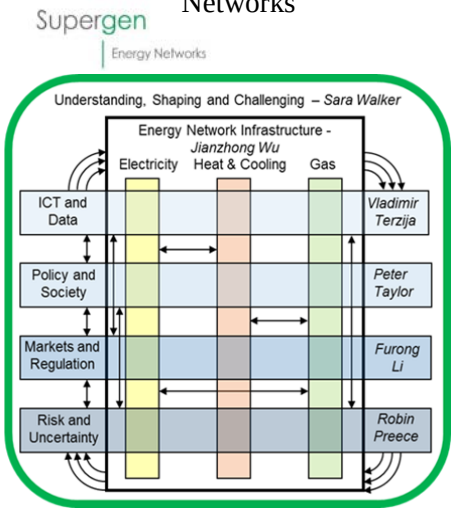


LATEST RESEARCH DEVELOPMENT

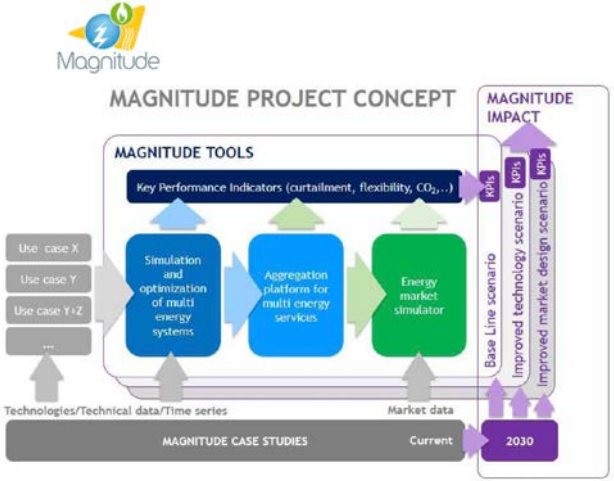
£18m UK Energy Research Centre
Phase 4 starting from 1st April 2019 for 5 years



£5m Supergen Hub on Energy Networks



€4m H2020 MAGNITUDE project
Including 7 real case study systems



£12m ISCF investment on Energy Revolution Research Consortium (ERRC)
EnergyREV

£36m Active Building Centre

CONCLUSIONS

- **No single solution can solve all energy problems.**
- **Integrated multi-vector energy system is an important option for cost effective transition to a more secure, reliable, sustainable, and affordable heat/cooling supply.**
- **Significant opportunities from new advancements in technology and from integrating multiple energy conversion, distribution and utilisation across energy vectors and across scales.**
- **Setting out appropriate policy, regulation and markets will be crucial.**

THANK YOU

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