Energy, climate change and people
An academic perspective

Prof. Gioia Falcone, Rankine Chair of Energy Engineering

APSE Energy Summit - Glasgow

22-23 October 2024

Summary

- Glasgow as a Living Lab Accelerating Novel Transformation (GALLANT)
- Community-scale energy
- Sustainable low-carbon energy
- Using Geographic Information Systems (GIS) to draw a coherent portrait of Glasgow's energy present and future
- Applying lessons learn on 'energy citizenship' from H2020 ENCLUDE

University of Glasgow

CENTRE FOR SUSTAINABLE SOLUTIONS

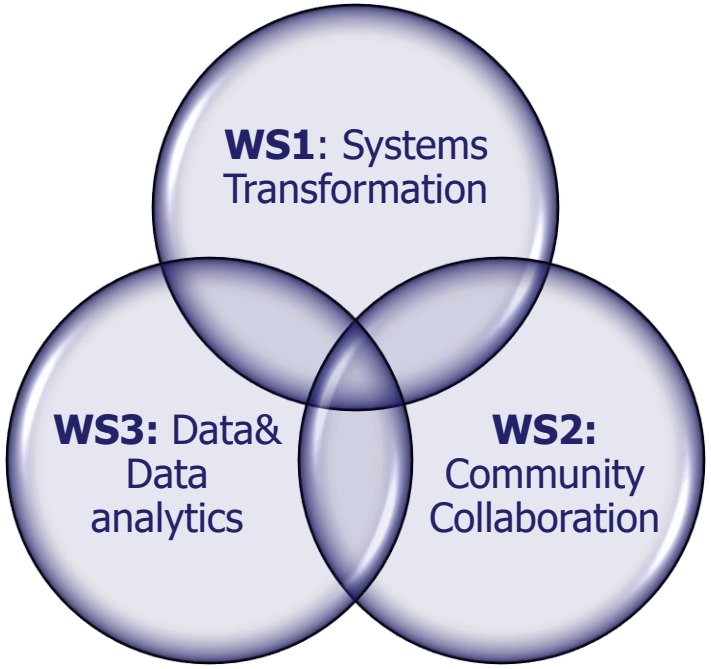
GALLANT

Glasgow as a Living Lab Accelerating Novel Transformation

Delivering a Climate Resilient City through City-University Partnership

£10.2m, NERC Changing the Environment, Jan 22 - Jan 27

***Leader of WP5**: Sustainable Low-Carbon Energy at Community Scale*
Executive Board Member



WP1 Climate Resilient Urban Riverscapes

WP2 Social Benefits of Urban Biodiversity

WP3 Regenerating VDL via C-sequestration

WP4 Benefits of active travel & urban mobility

WP5 Sustainable Low-Carbon Energy at Community Scale

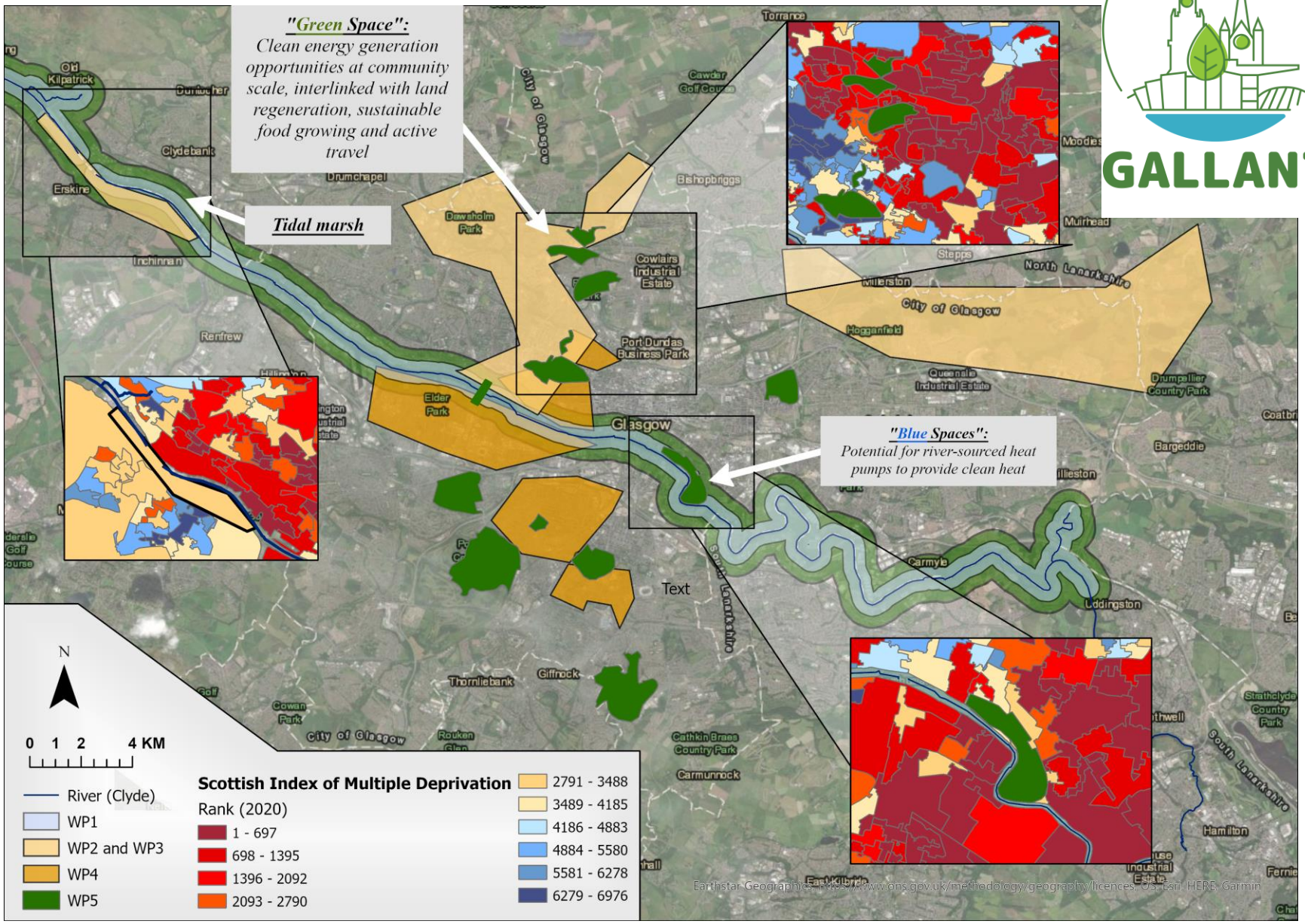


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Figure 1. GALLANT's work in the context of the safe and just space between social and ecological boundaries (Doughnut Economics Action Lab, 2020)

Energy: *sustainable, low carbon energy at community-scale, harnessing green-blue-grey spaces, empowering active Energy Citizens, reducing fuel poverty*

WP1, WP3, WP5

Air Pollution: *creating habitable space, reducing emissions, eliminate fossil fuel use*

WP2, WP4, WP5

Networks: *highly connected green and blue corridors for biodiversity, ecosystem services, inclusive active travel*

WP2, WP4

Biodiversity Loss: *connecting green-blue corridors, ecosystem services, Nature-based Solutions, regeneration of VDL*

WP1, WP2, WP3

Social Equity: *connecting people and place through regenerated urban space, tackling inequality via community collaboration and creating opportunities*

WP1, WP2, WP3, WP4, WP5

Land Conversion: *greening grey infrastructure, connecting habitats, regenerating VDL, connecting active travel routes to promote 1.5℃ lifestyles*

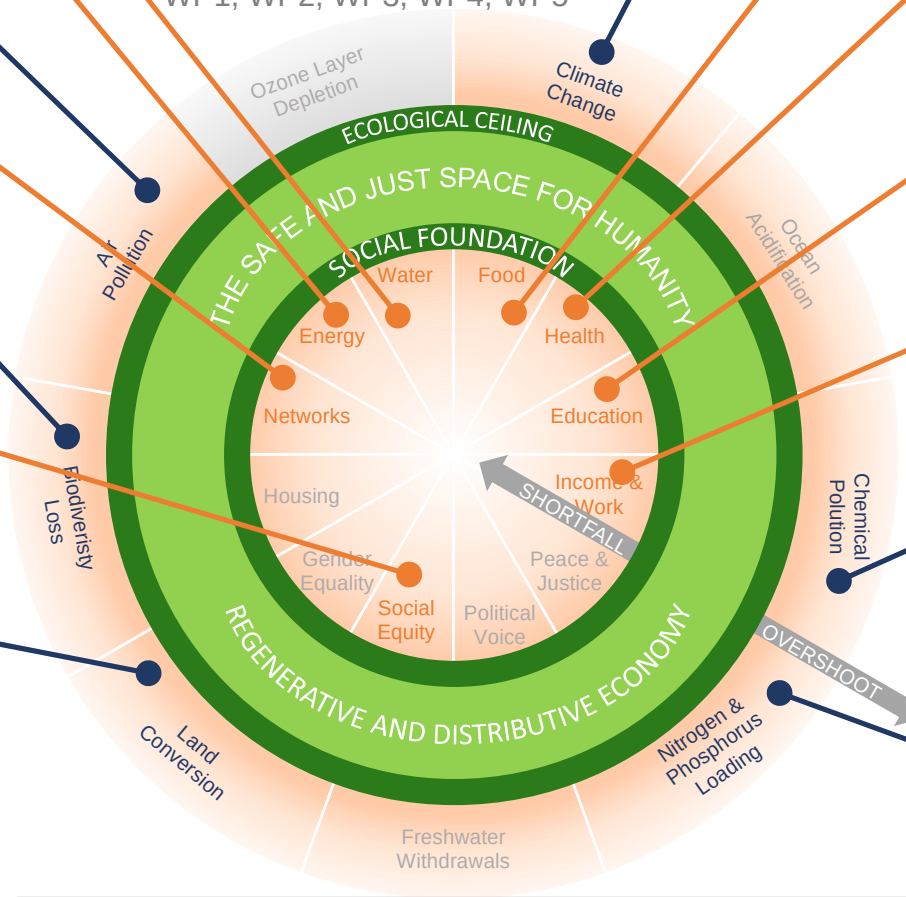
WP1, WP2, WP3, WP4

Water: *re-valuing urban riverscapes as ecological services, assets, energy sources - connecting people and places*

WP1, WP2, WP3, WP4, WP5

Climate Change: *mainstreaming 1.5℃ lifestyles, empowering individuals, novel nature-based solutions, benefitting planetary & human health*

WP1, WP2, WP3, WP4, WP5



Food: *remediating legacy pollutants, regenerating VDL for community needs, harnessing green spaces (parks) - powering greenhouses for community food production*

WP1, WP3, WP5

Health: *co-benefitting ecological and human health, connected green-blue spaces for wellbeing, enhanced biodiversity, inclusive active travel, reducing fuel poverty*

WP1, WP2, WP3, WP4, WP5

Education: *multi-directional knowledge exchange, empowering local people as stewards of place, ecopedagogical approach*

WP1, WP2, WP3, WP4, WP5

Income & Work: inclusive *net zero solutions, identifying talent & skills gap, skills development for low carbon energy futures*

WP3, WP4, WP5

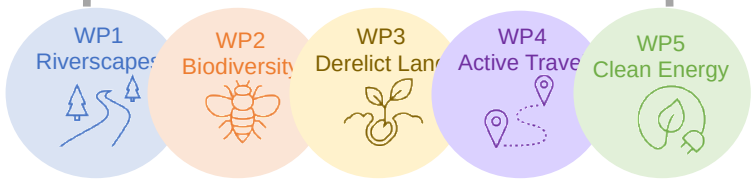
Chemical Pollution: *habitat suitability, ecosystem tolerance, remediating heavy metal & organic pollutants, reduced car use, improved air quality*

WP2, WP3, WP4

N & P Loading: *characterizing urban soils, ecology from plant to landscape scale, flood mobilization of nutrients, land-use and development at the river edge*

WP1, WP2, WP3

Work packages (WP) designed to prevent social shortfalls and ecological overshoots



Embedded Workstreams: Systems, Communities, Data: System mapping, stakeholder & community co-designed value-based indicators for inclusive growth, data accessibility via a Virtual Data Hub. Multi-disciplinary expertise informing and accelerating meaningful, evidence-based decision-making and transformation.

Sustainable Low-Carbon Energy at Community Scale

Sustainable low-carbon energy solutions at community scale in urban **green** (parks), **grey** (VDL, cyclist/pedestrian bridges) and **blue** (Clyde) spaces.

…what is ‘Community-Scale’ Energy?

…what is ‘Sustainable Low-Carbon Energy’?

What is ‘Community-Scale’ Energy?

Community-scale Energy:
Energy systems located in the same community. Ranges from a single neighbourhood with tens of buildings, to entire cities with hundreds of thousands of buildings. *(Flores et al., 2023)*

- ❑ Scale vs. Ownership/Source of Funding
- ❑ Use (residential, commercial, mixed)
- ❑ Urban vs. Rural
- ❑ On-/Off-Grid
- ❑ Council Remit vs. Beyond (emissions see no borders!)

Legal definitions of ‘Energy Communities’ at the EU level:

> Citizen Energy Community (CEC) Governance & Members

A legal entity that is based on voluntary and open participation, effectively controlled by shareholders or members who are natural persons, local authorities, including municipalities, or small enterprises, and micro-enterprises.

(EC, 2023)

> Renewable Energy Community (REC) Governance & Members

A legal entity that, in accordance with the applicable national law, is based on open and voluntary participation, autonomous, effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed by that legal entity; the shareholders or members of which are natural persons, SMEs or local authorities, including municipalities.

What is ‘Sustainable Low-Carbon Energy’?

Country- and regional-scale indicators of sustainable energy

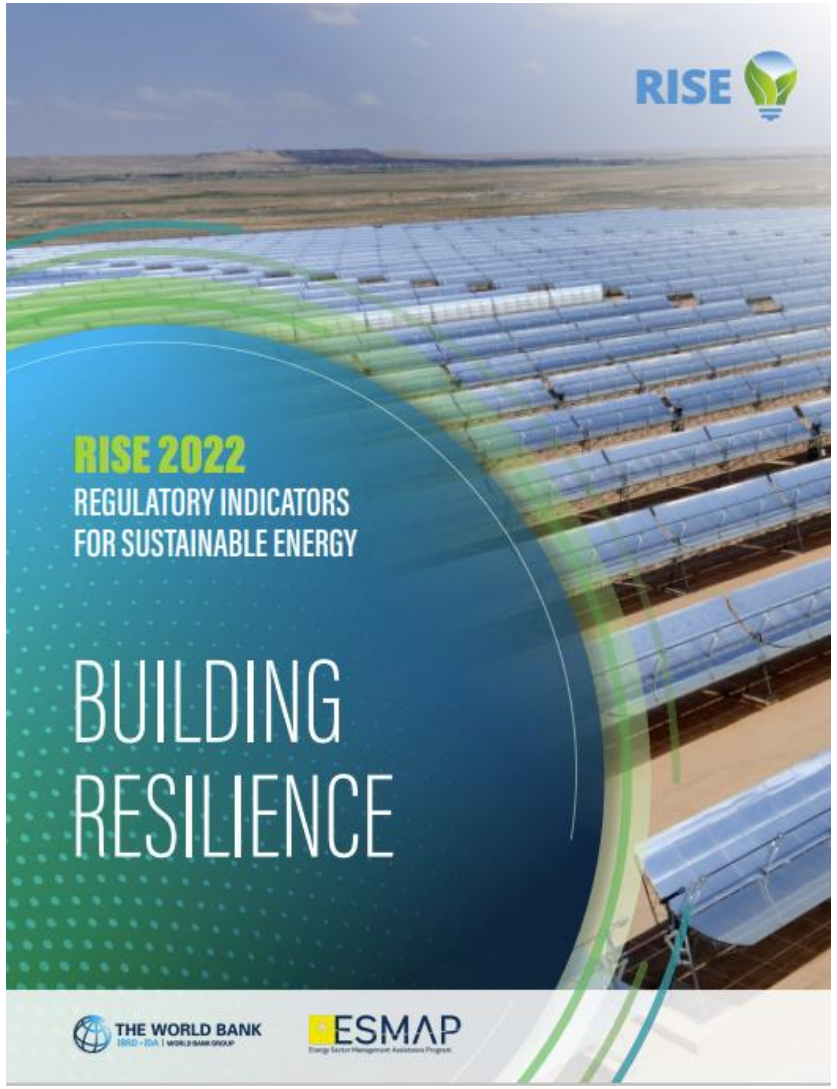


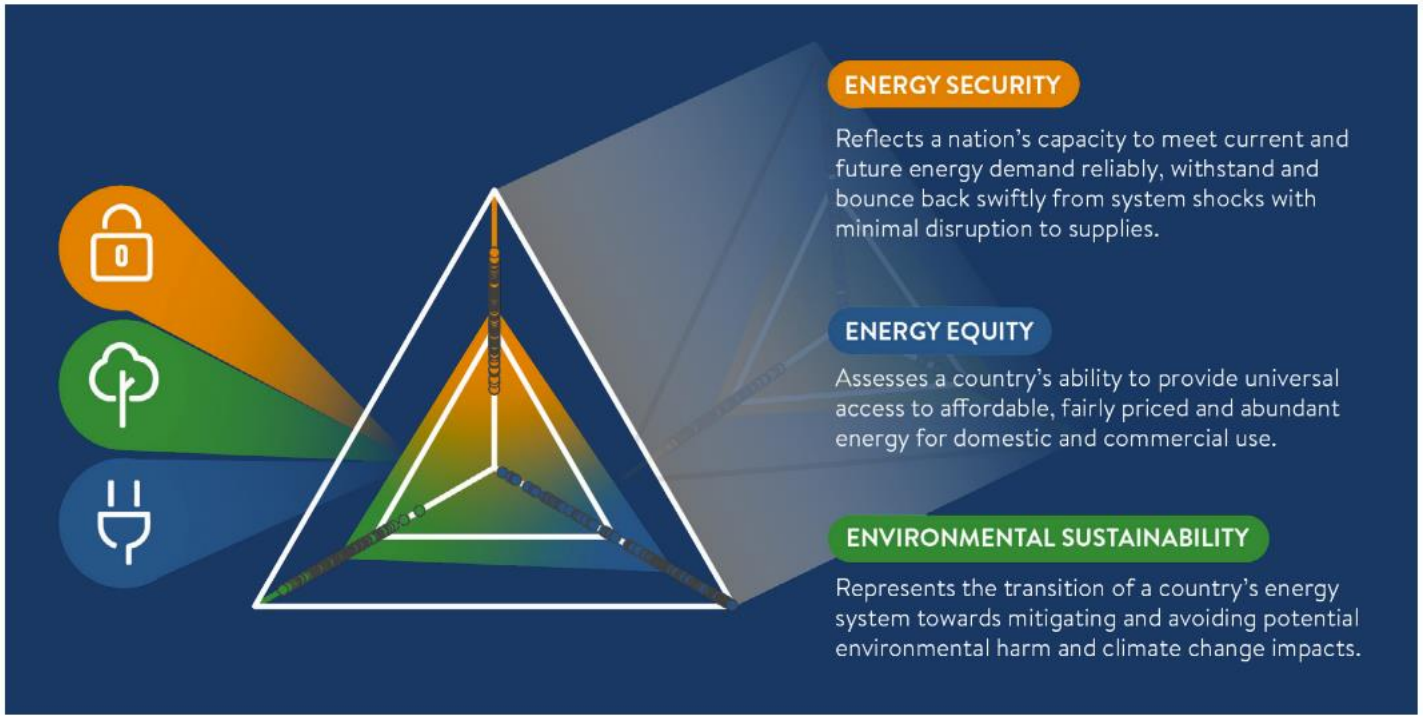
FIGURE 1. THE RISE FRAMEWORK: RISE'S SUSTAINABLE ENERGY PILLARS AND CORRESPONDING INDICATORS

Pillar	Indicators			
POLICIES AND REGULATIONS				
ELECTRICITY ACCESS	• Electrification planning	• Grid electrification framework	• Framework for off-grid systems	• Utility transparency and monitoring
	• Scope of the electrification plan	• Framework for minigrids	• Consumer affordability of electricity	• Utility creditworthiness
CLEAN COOKING	• Clean cooking planning		• Standards and labelling	
	• Scope of planning		• Financial lincentives for clean cooking solutions	
RENEWABLE ENERGY	• Legal framework for renewable energy	• Incentives and regulatory support for renewable energy	• Network connection and use	• Carbon pricing and monitoring
	• Planning for renewable energy expansion	• Attributes of financial and regulatory incentives	• Counterparty risk	
ENERGY EFFICIENCY	• National energy efficiency planning	• Incentives and mandates: Public sector	• Minimum energy performance standards	• Transport sector energy efficiency
	• Energy efficiency entities	• Incentives and mandates: Energy utility programs	• Energy labeling system	• Carbon pricing and monitoring
	• Incentives and mandates: Industrial and commercial end users	• Financing mechanisms for energy efficiency	• Building energy codes	

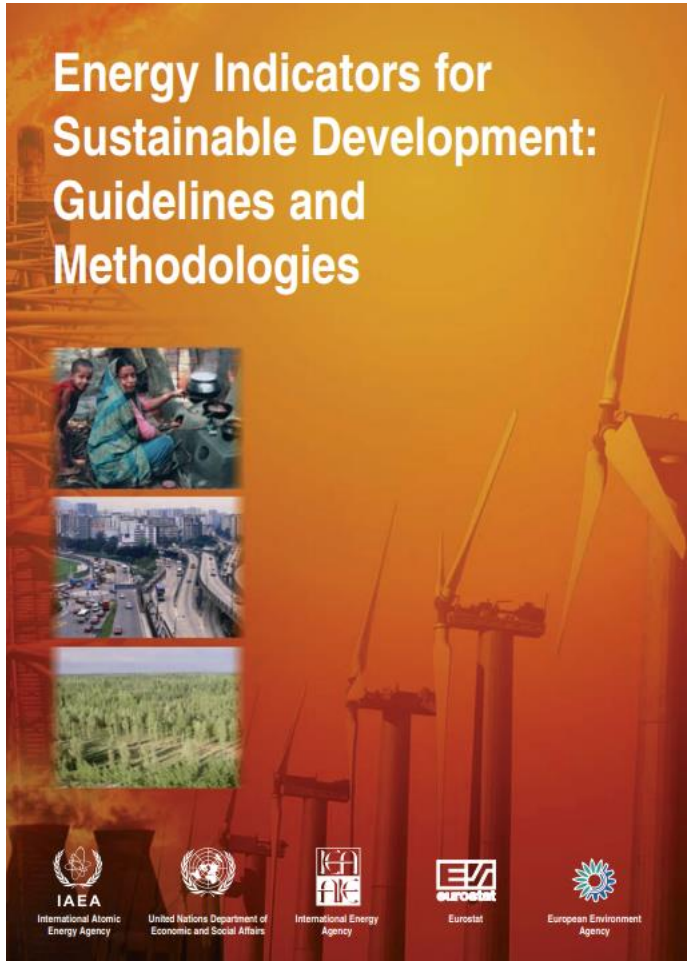
Source: World Bank, RISE 2022.
Note: Indicators that were updated for the RISE 2022 survey are highlighted in red

What is ‘Sustainable Low-Carbon Energy’?

Country- and regional-scale indicators of sustainable energy



(WEC, 2023)



(IAEA, 2005)

What is 'Sustainable Low-Carbon Energy'?

Project- and urban-scale indicators of sustainable energy

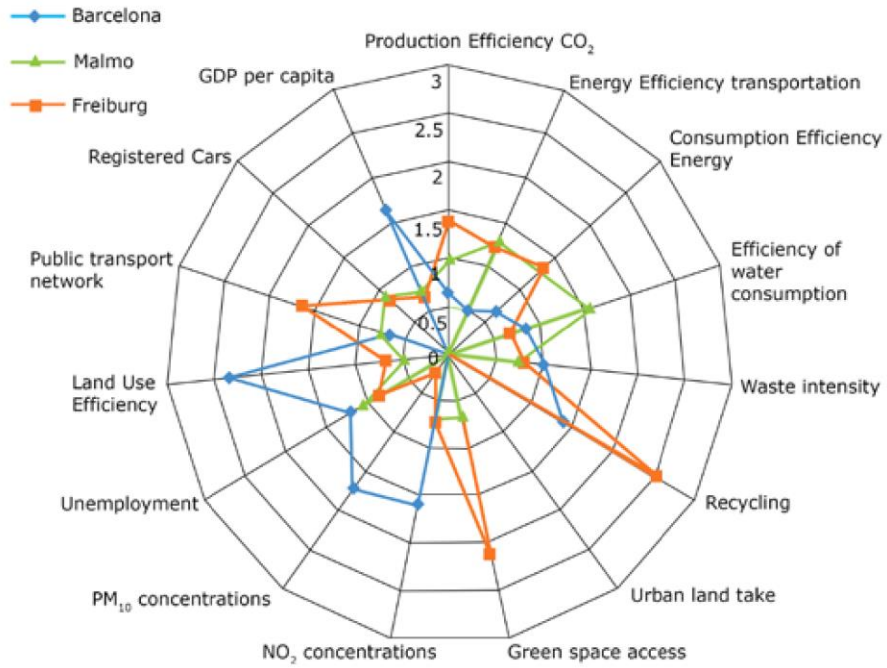
$$JC = \frac{\sum_{i=1}^{I}(JC_i \cdot t_i)}{P_{tot}}$$

where,JC represents the number of jobs created over the lifecycle of the project (jobs-y/Wh or jobs-y/J), JC_i is the number of jobs created during the life cycle stage i (years), t_i is the duration of employment in stage i(years), P_{tot} is the total energy generated over the asset life of the plant and I is the total number of lifecycle phases.

The impact of land use (ILU expressed in $\frac{m^2 \cdot y}{(J \text{ or } Wh)}$) of a plant is calculated as follows:

$$ILU = LA \cdot t_{LA}$$

where, $LA(\frac{m^2}{(J \text{ or } Wh)})$ is the total land area required for the construction and operation of the project per unit of energy produced and t_{LA} is the amount of time that the land area is occupied by the project (y).



(EC, 2015)

(Colla et al., 2019)

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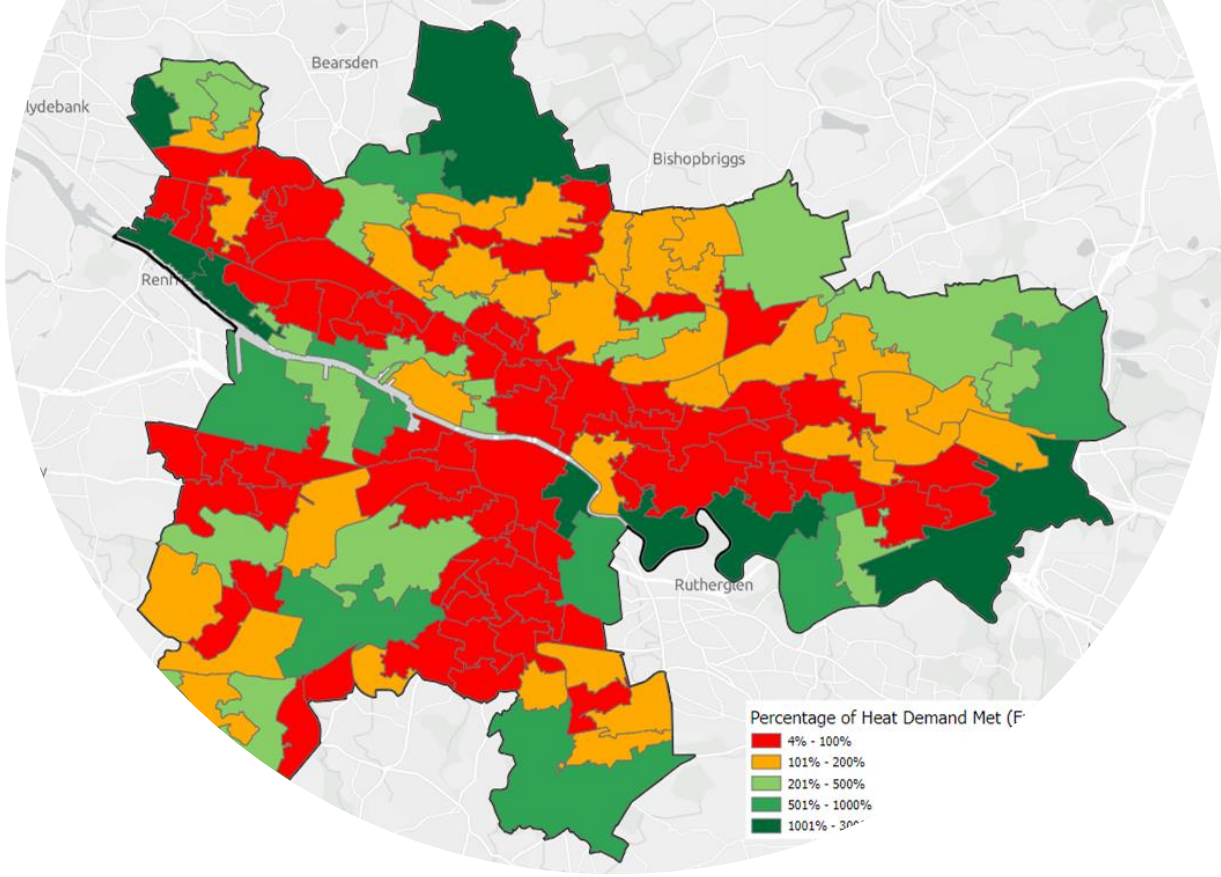
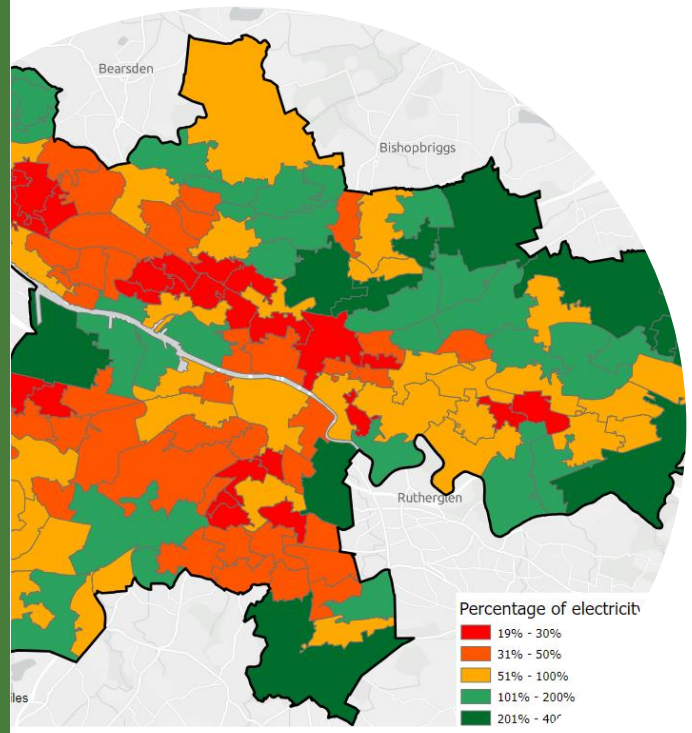
Can Glasgow survive on renewables?



(Tait & Falcone, 2024 – under review)



(Tait & Falcone, 2024 – under review)

Nicola Tait

GALLANT PhD student

Supervised by:
GALLANT Co-Investigators Gioia Falcone and Siming You,
Principal Investigator Jaime Toney, and
Research Associate Graeme Hunt

University of Glasgow Centre for Sustainable Solutions
Glasgow City Council

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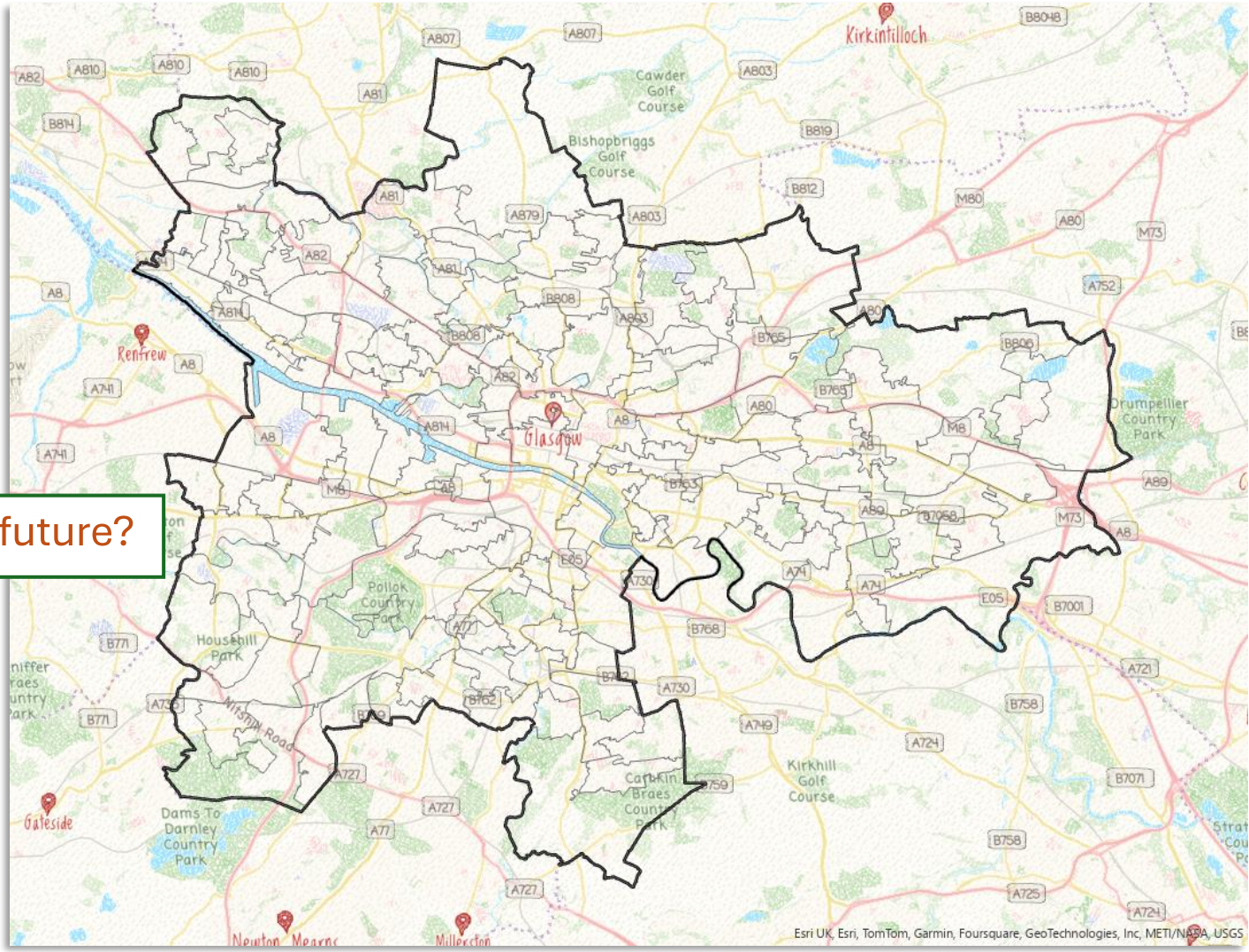
Glasgow consumes around 2.4 TWh of electricity, 4.7 TWh of gas, 245 ktoe of road transport fuel, and 37 ktoe in other residual fuels each year.

How could this look like in a net zero future?

What resources do we have in Glasgow?



University of Glasgow Centre for Sustainable Solutions

Glasgow City Council

Alternative electricity generation in Glasgow

Over 9,000 solar PV installations

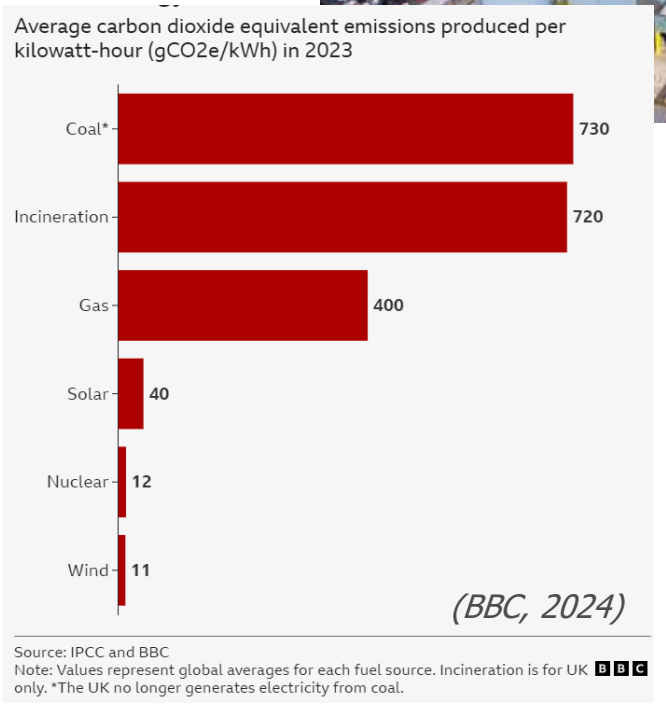
https://www.evoenergy.co.uk/case-study/bbc-glasgow/ Energy

3 small wind turbines

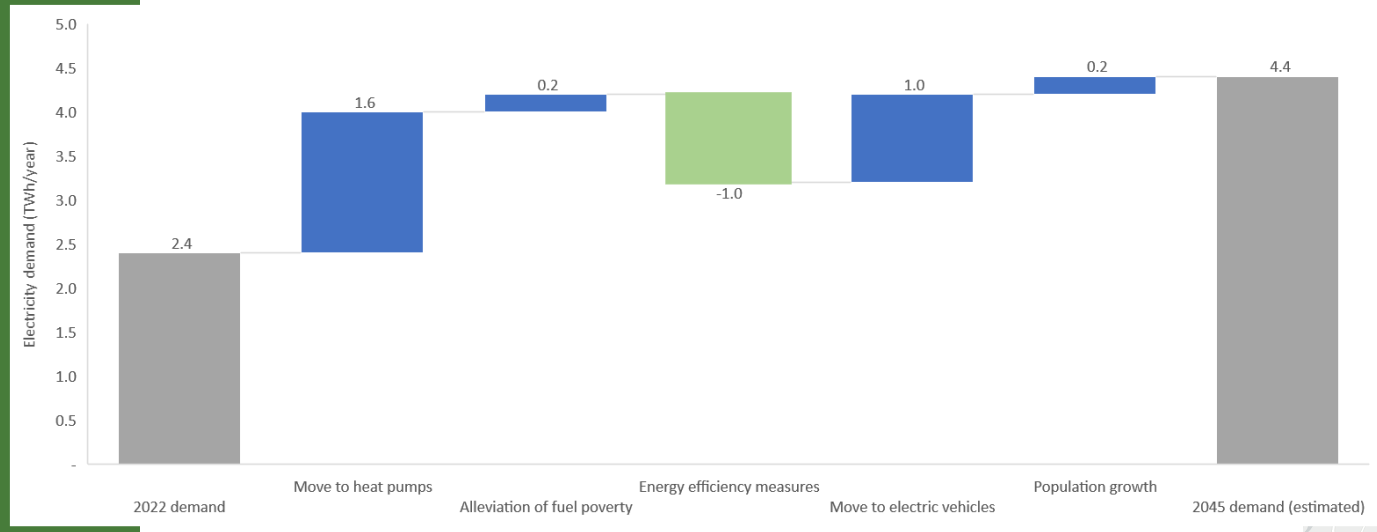
Installations insights source: The MCS Data Dashboard

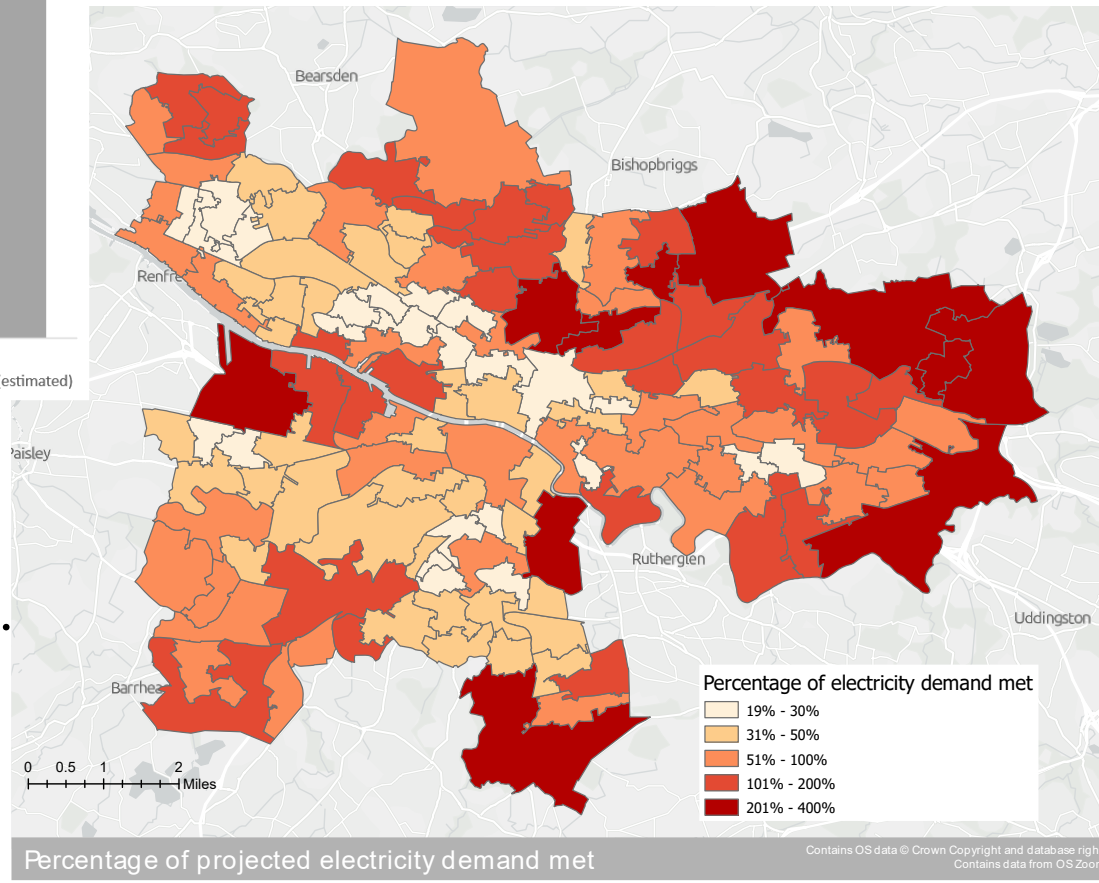
https://www.viridor.co.uk/energy/energy-recovery-facilities/glasgow-rrec/

Glasgow recycling and renewable energy centre



Meeting electricity demand now/in the future





Resources available to generate electricity fall short at city level but may be sufficient to power new demand only (i.e., from heat pumps and EVs).

(Tait & Falcone, 2024 – under review)

Alternative heat resources

Water source heat pumps (rivers, ponds, wastewater network)

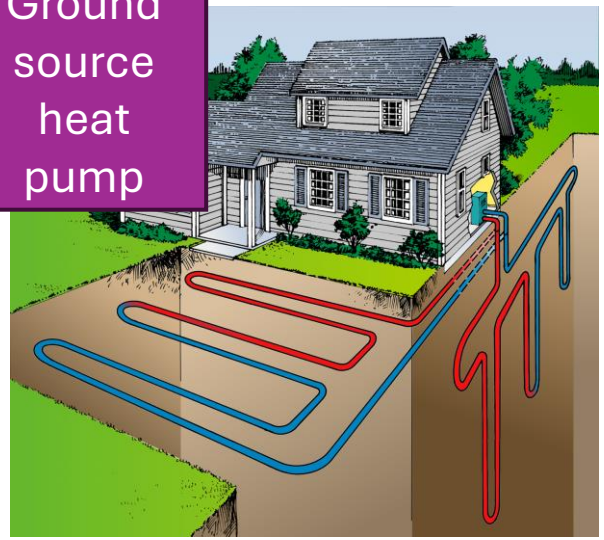
https://www.houseplanninghelp.com/

https://www.acrjournal.uk/heat-pumps/

Solar thermal

https://www.sunmaxxsolar.com/

Ground source heat pump

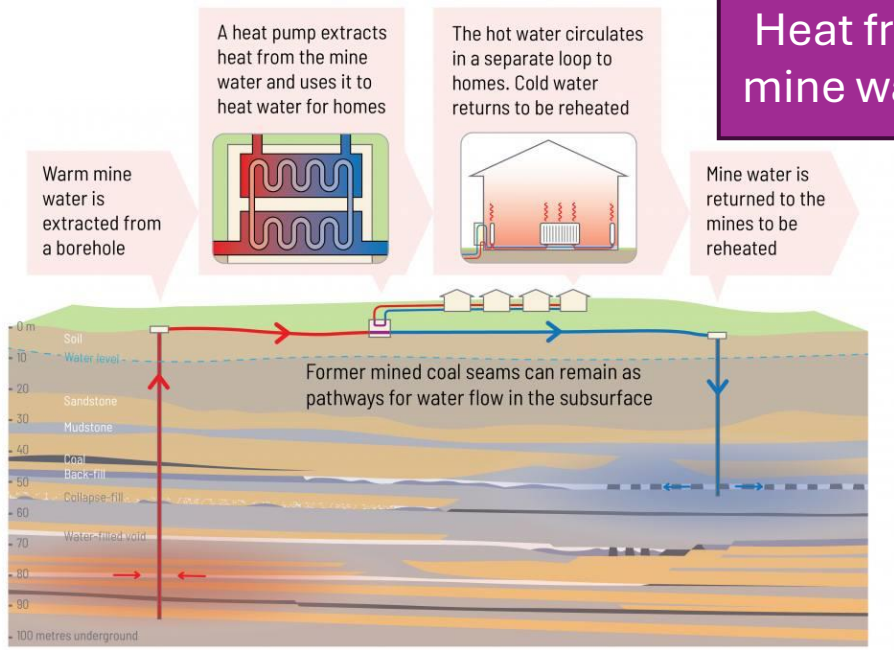


https://queenstownplumbing.co.nz/

Air source heat pump

https://greenerenergygroup.co.uk/

Heat from mine water

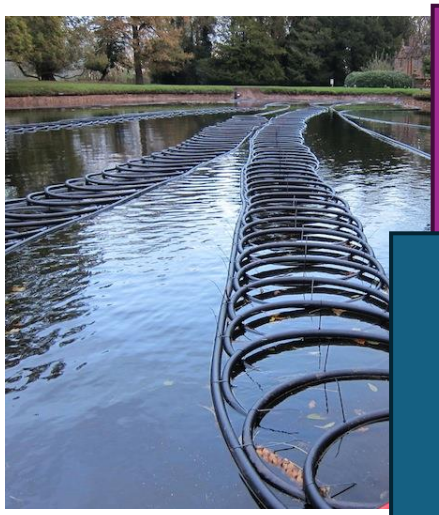


https://www.bgs.ac.uk/

Alternative heat resources

Solar thermal

Water source heat pumps (rivers, ponds, wastewater

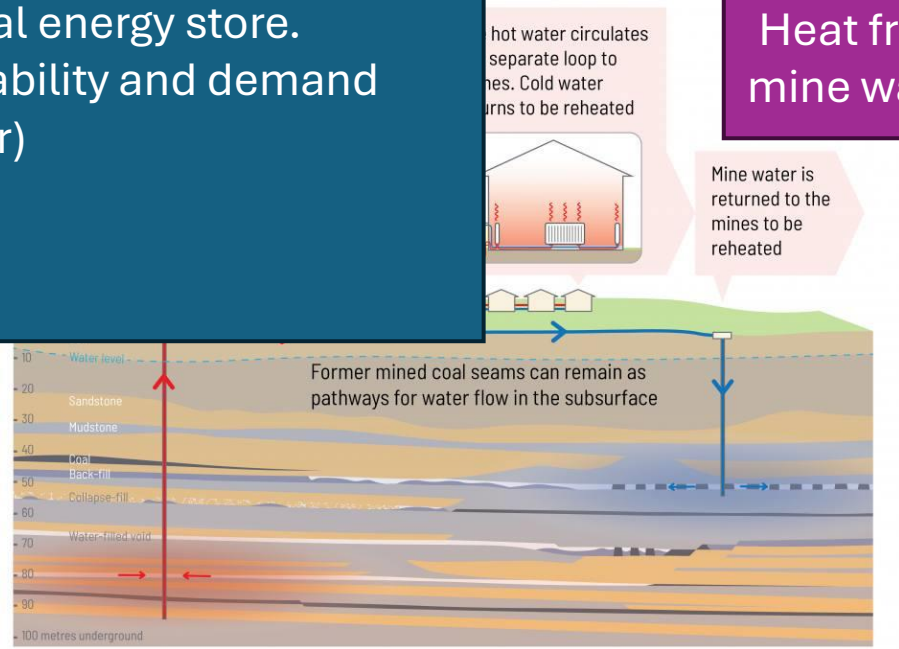


https://www.hou

Thermal energy storage

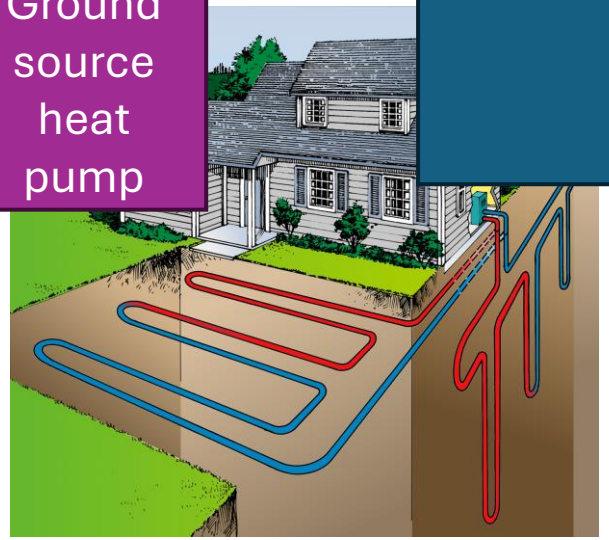
E.g., Mine water can be used as a thermal energy store.
Needed to help balance timing in heat availability and demand (day/night) (summer/winter)

Heat from mine water



https://www.bgs.ac.uk/

Ground source heat pump



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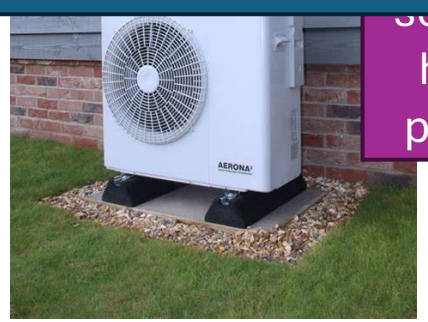
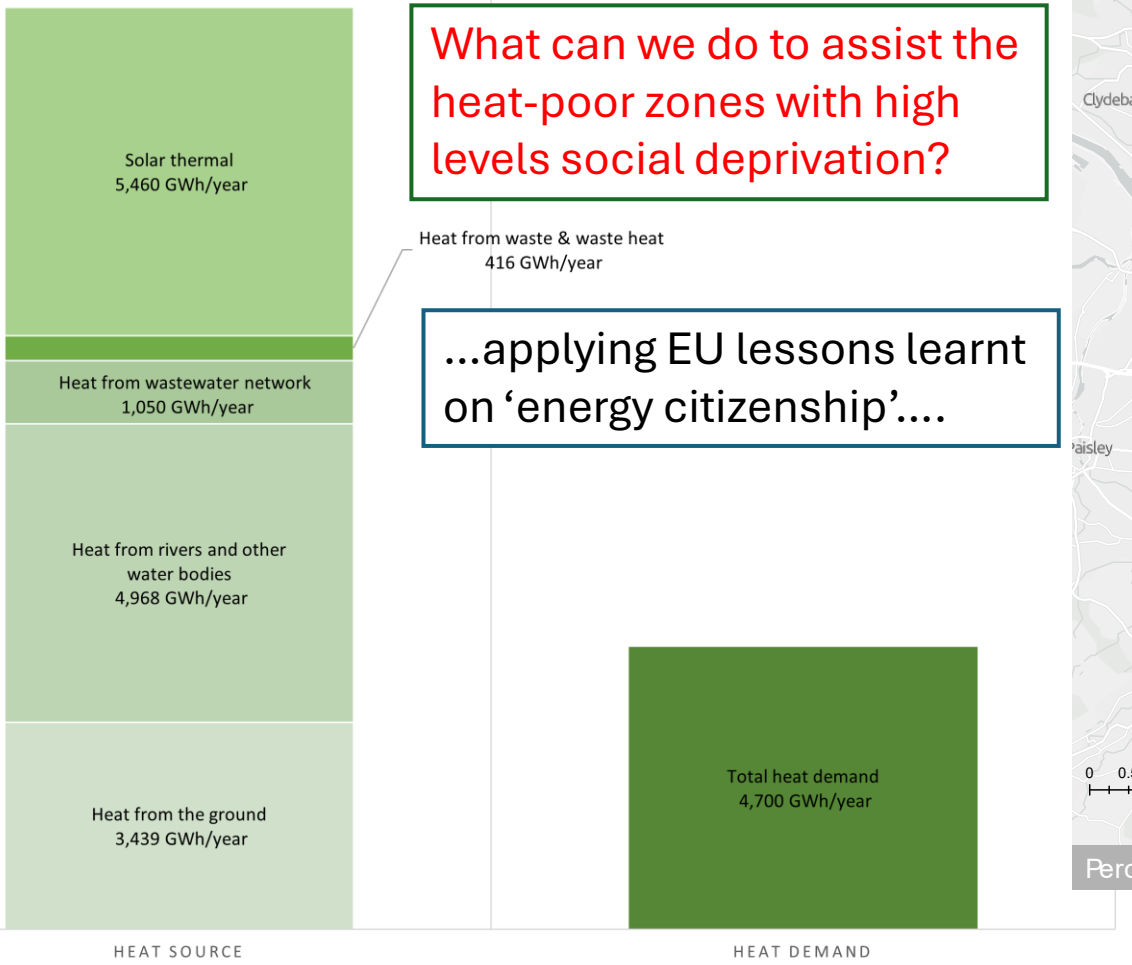
source heat pump



https://greenerenergygroup.co.uk/

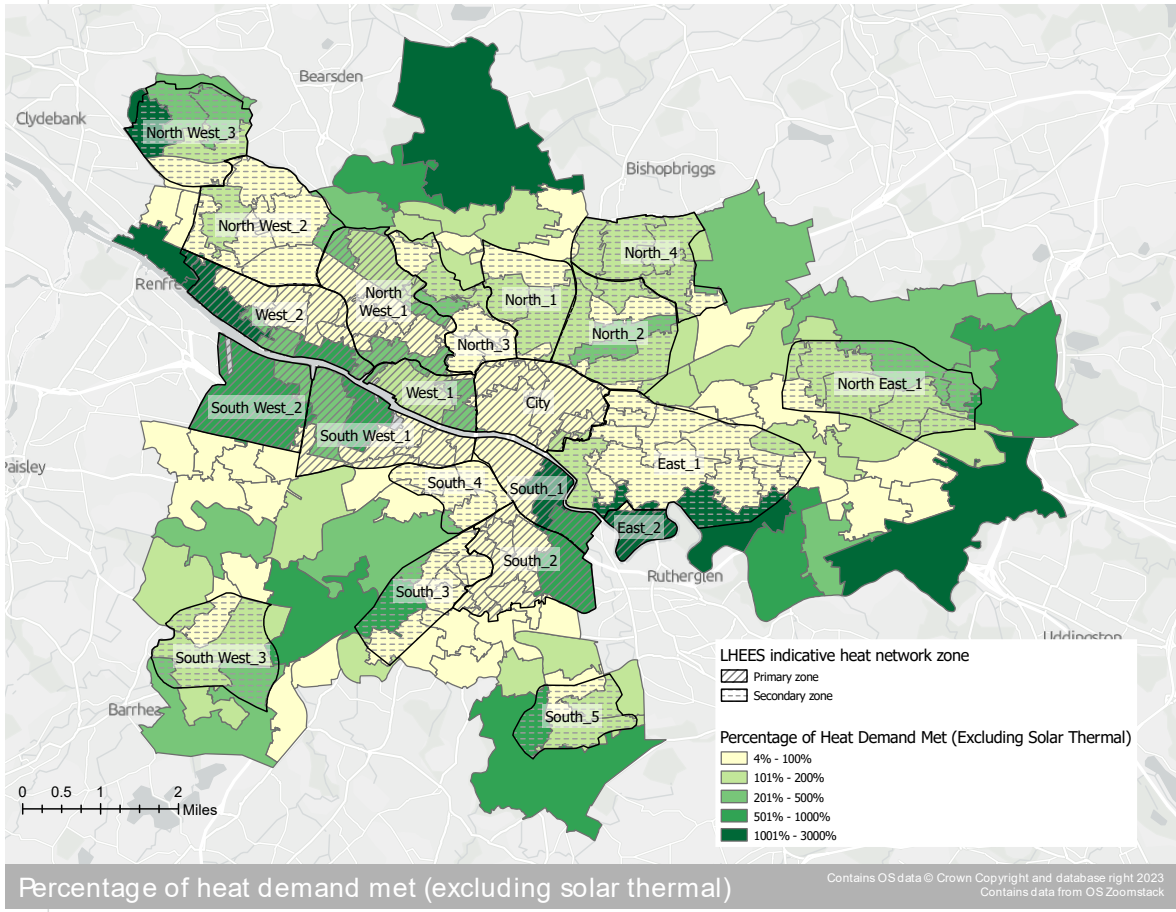
Meeting heat demand now/in the future

Some of the LHEES indicative heat network zones may struggle to find sufficient resources. Could neighbouring heat-rich zones be incorporated to help bridge the gap?



What can we do to assist the heat-poor zones with high levels social deprivation?

...applying EU lessons learnt on 'energy citizenship'....



Percentage of heat demand met (excluding solar thermal)

(Tait & Falcone, 2024 – under review)

ENCLUDE
Energy Citizens for Inclusive Decarbonization

To help the EU fulfil its promise of a **just** and **inclusive decarbonization pathway** through sharing and co-creating new knowledge and practices that **maximize the number and diversity of citizens** who are willing and able to contribute to the energy transition.

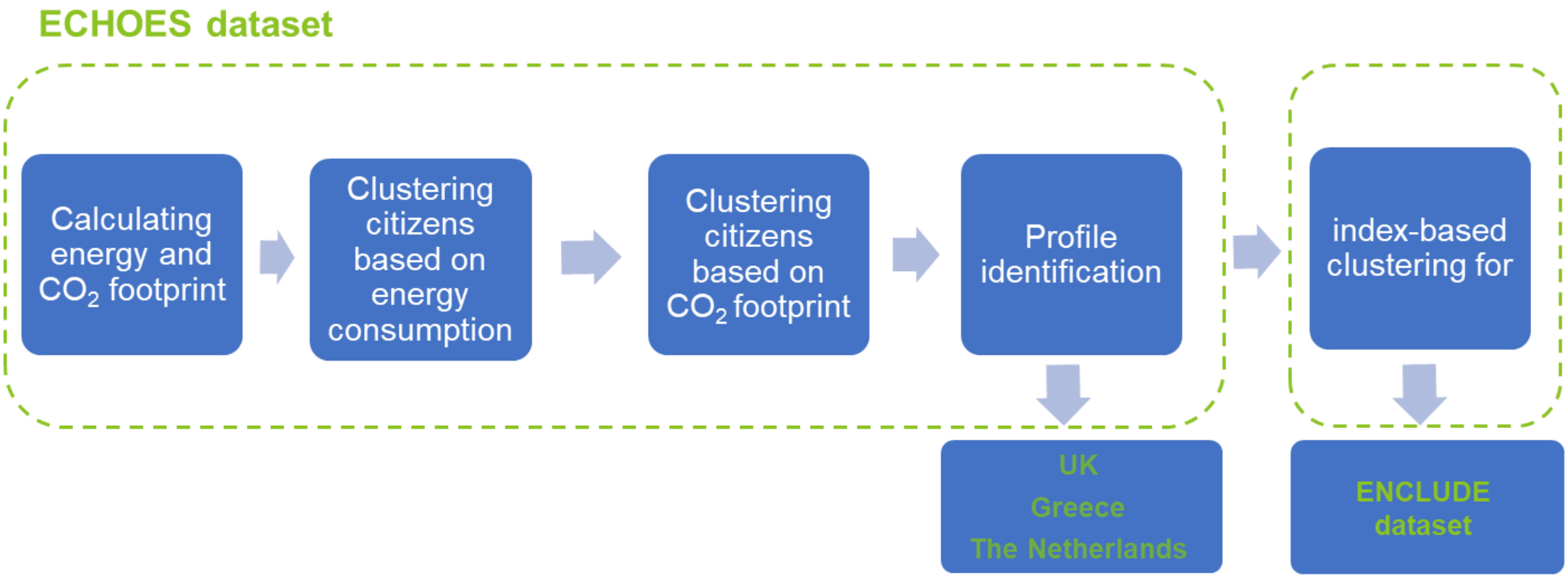
Horizon 2020, Jun 21 – Sep 24

***Leader of WP4**: Identification of citizen clusters for decarbonization*

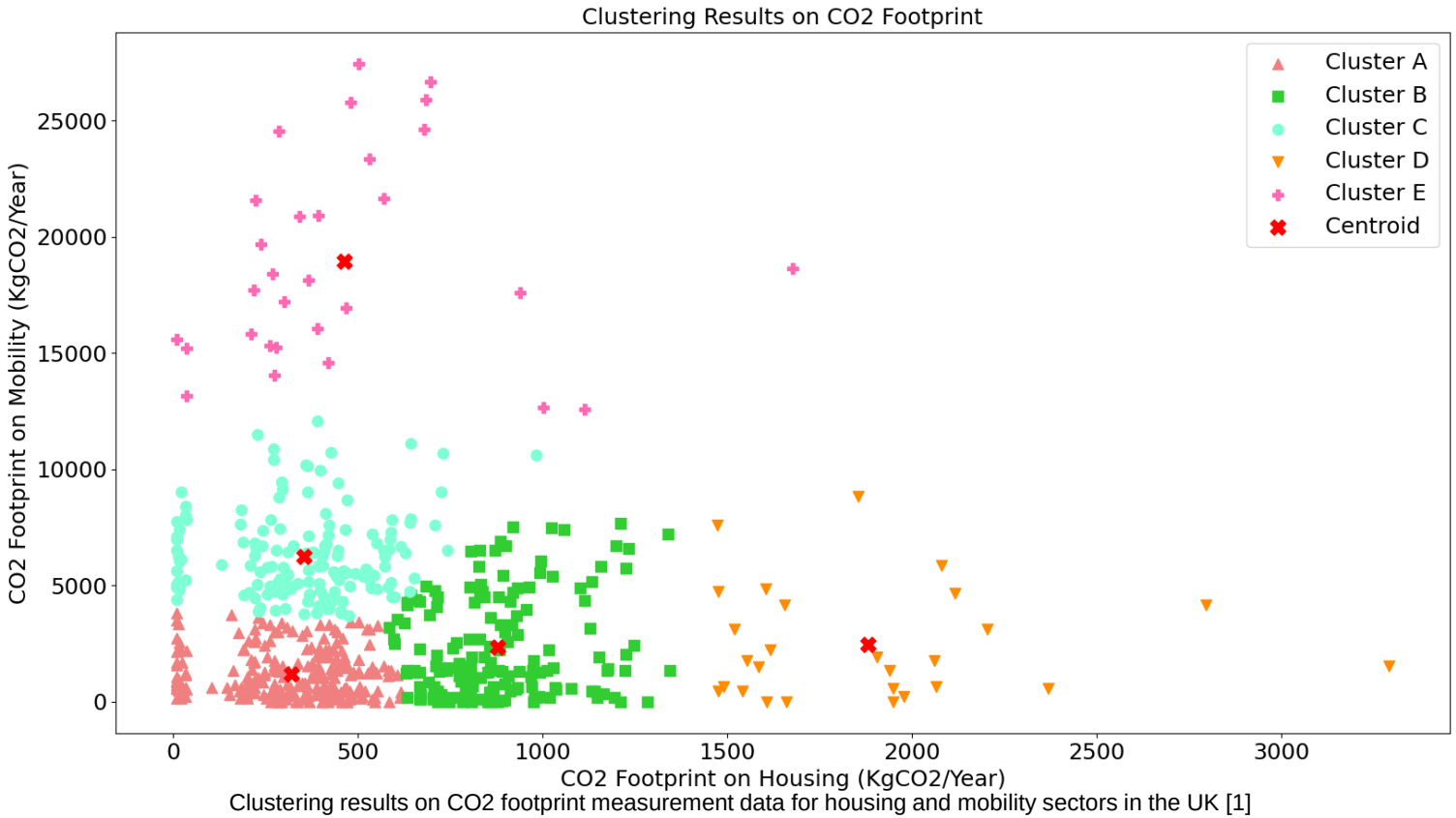
ETH zürich · TEESlab University of Piraeus Research Center · TU Delft · UCC University College Cork, Ireland Coláiste na hOllscoile Corcaigh · University of Glasgow

JOANNEUM RESEARCH LIFE · Th!nk E · Utrecht University · Green Partners environmental consulting · Eko-Svest · Missions Publiques Bringing citizens into policy · HOLISTIC · University of Victoria

ENCLUDE data framework for clustering citizens



K-means clustering method for clustering citizens based on carbon footprint – Results for ECHOES dataset – UK



Clustering results on CO2 footprint measurement data for housing and mobility sectors in the UK [1]

Clusters result for CO2 footprint measurement data for the housing and mobility sectors in the UK [1]

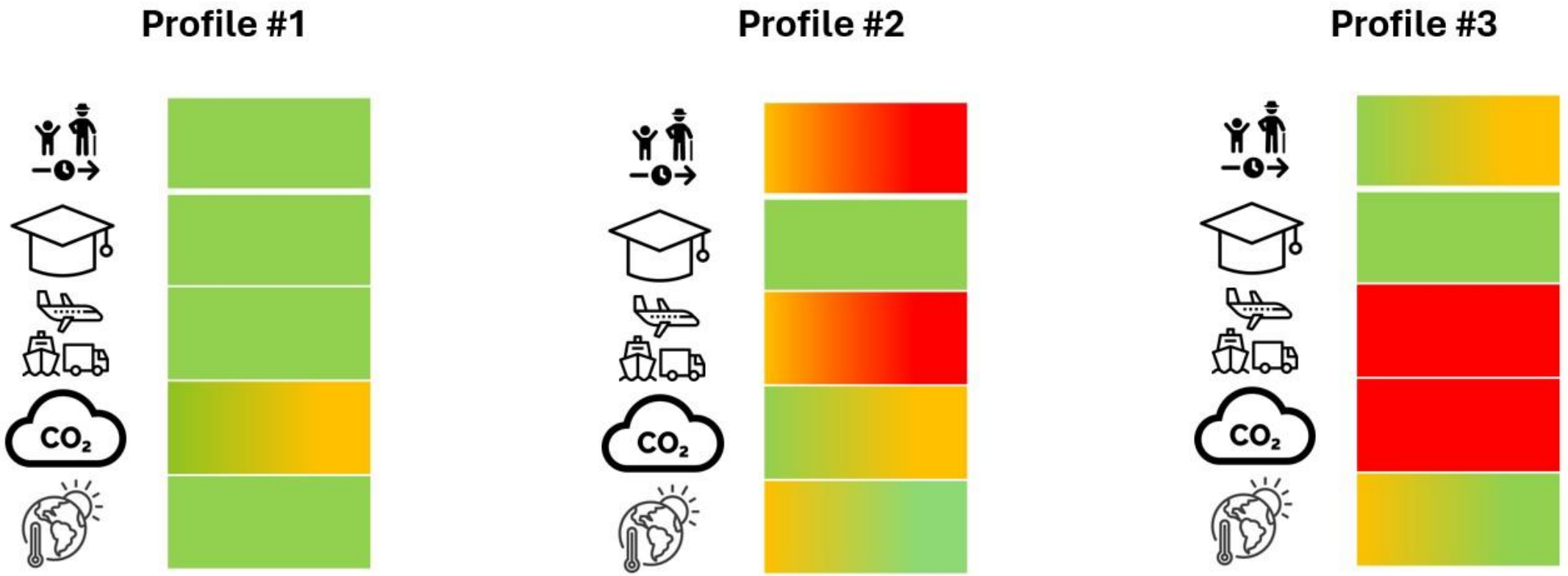
Cluster	Population	Centroid location on housing CO_2 footprint ($kgCO_2$/year)	Centroid location on mobility CO_2 footprint ($kgCO_2$/year)
A	247	320.63	1180.30
B	161	878.96	2343.67
C	157	352.97	6234.85
D	27	1881.56	2475.36
E	30	463.25	18935.05

Profile results for CO2 footprint clustering based on within-cluster statistics for the UK [2]

	Profile #1	Profile #2	Profile #3
Age range	19-34	>65	35-49
Education	College	College	College
Population %	64.95%	30.22%	4.82%
Energy on Mobility	Low	Low to medium	High
CO2 Emissions (housing and mobility)	Low	Medium to high	High
Climate Change Perception	positive	Neutral to positive	Neutral to positive

[1] Naderian, S., Ioannou, A. and Falcone, G., D4.2 – Report on the identification of citizens' clusters for decarbonization
[2] Naderian, S., Ioannou, A. and Falcone, G., D4.3 – Report on bridging clusters for decarbonization with energy models

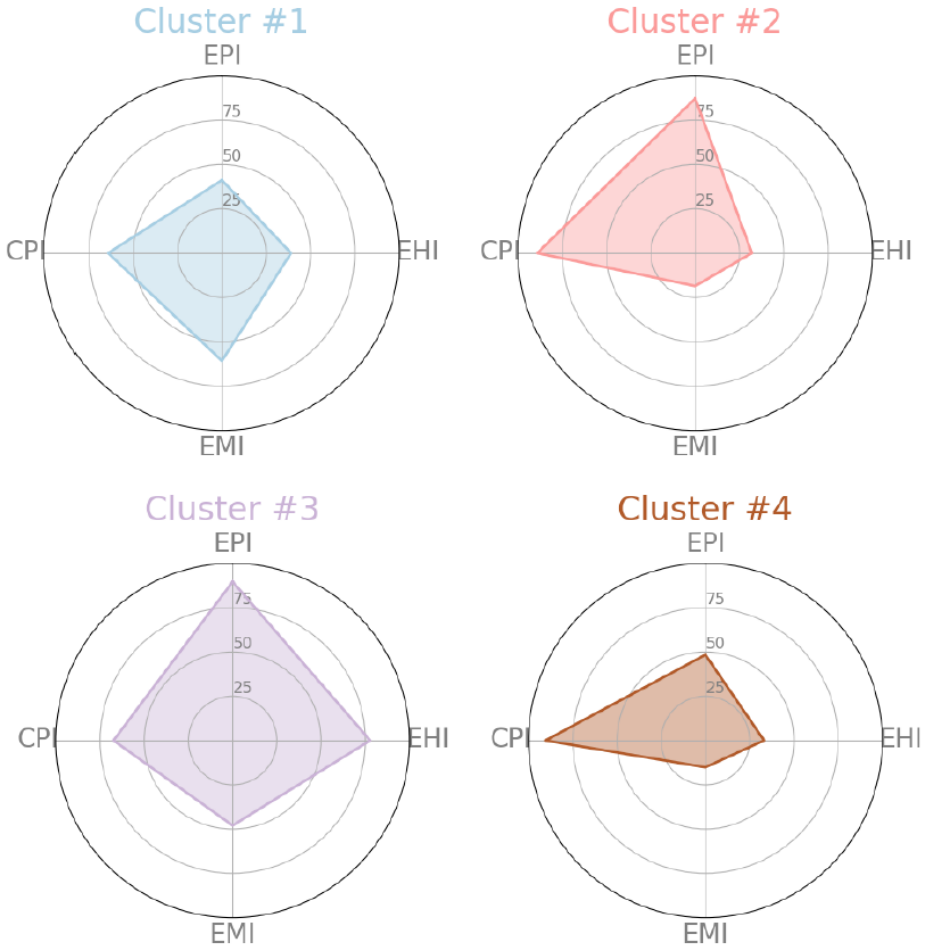
Profile development for citizens based on clustering results of CO2 emission for ECHOES dataset – UK



Energy citizens profiles based on clustering results and within-cluster statistics for the UK [1]

[1] Naderian, S., Ioannou, A. and Falcone, G., D4.3 – Report on bridging clusters for decarbonization with energy models

Clustering based on Energy poverty, Mobility, Housing, and Climate Change Perception Indices – ENCLUDE data (non-UK)



Spider plots of index-based clustering results for each of the four clusters [1]

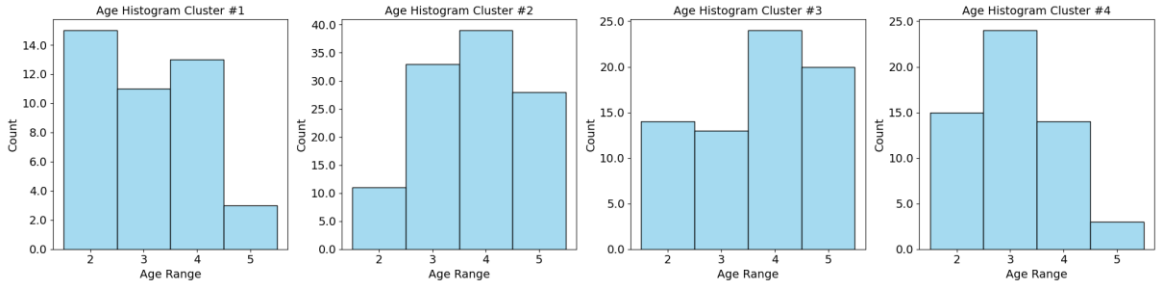
- Clustering ENCLUDE data via defined indices based on answers to questions in 4 categories: **Energy poverty, Mobility, Housing, and Climate Change Perception** [1].
- The aim is to calculate indices for each category using simple addition of answers which are mapped into meaningful numbers.
- 4 indices are defined (rescaled to 0-100) for each respondent based on relevant questions to each index [1].
- k-mean clustering method is applied to the full data set

Cluster	Population	Energy Poverty Index	Energy Housing Index	Energy Mobility Index	Climate Perception Index
1	111	41.12	39.08	60.80	64.28
2	76	87.22	31.98	18.57	89.18
3	54	89.62	77.81	47.99	67.37
4	42	48.37	33.18	15.10	90.47

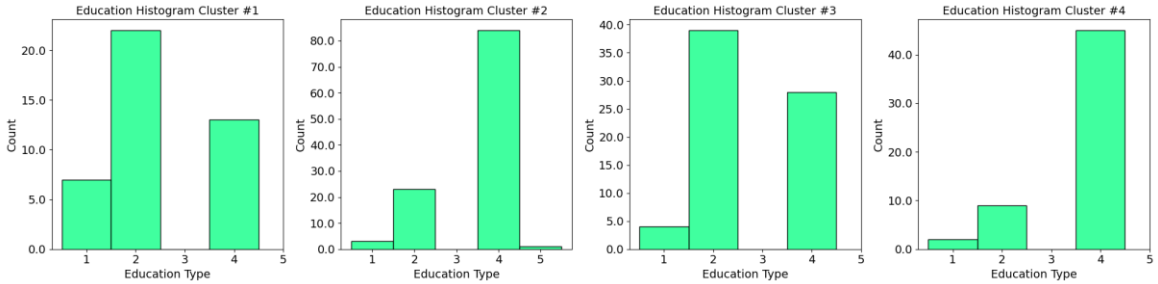
[1] Naderian, S., Ioannou, A. and Falcone, G., D4.3 – Report on bridging clusters for decarbonization with energy models

Within-cluster statistics

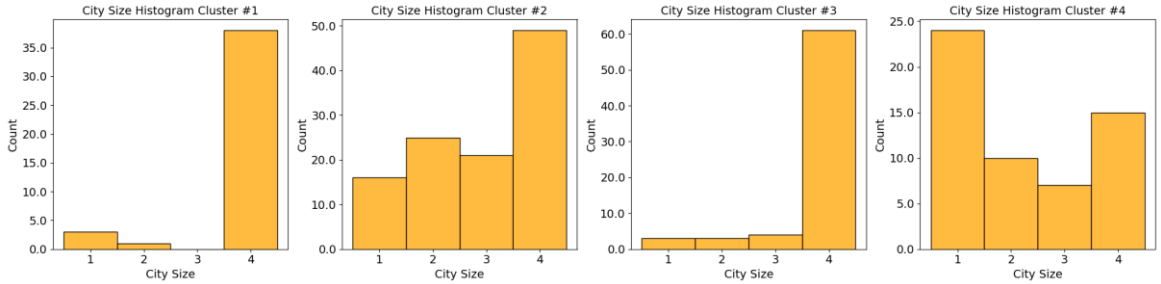
Age



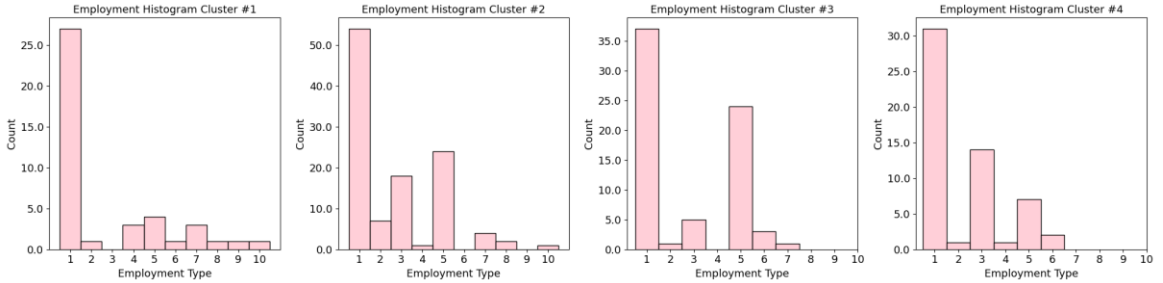
Education



City Size



Employment status



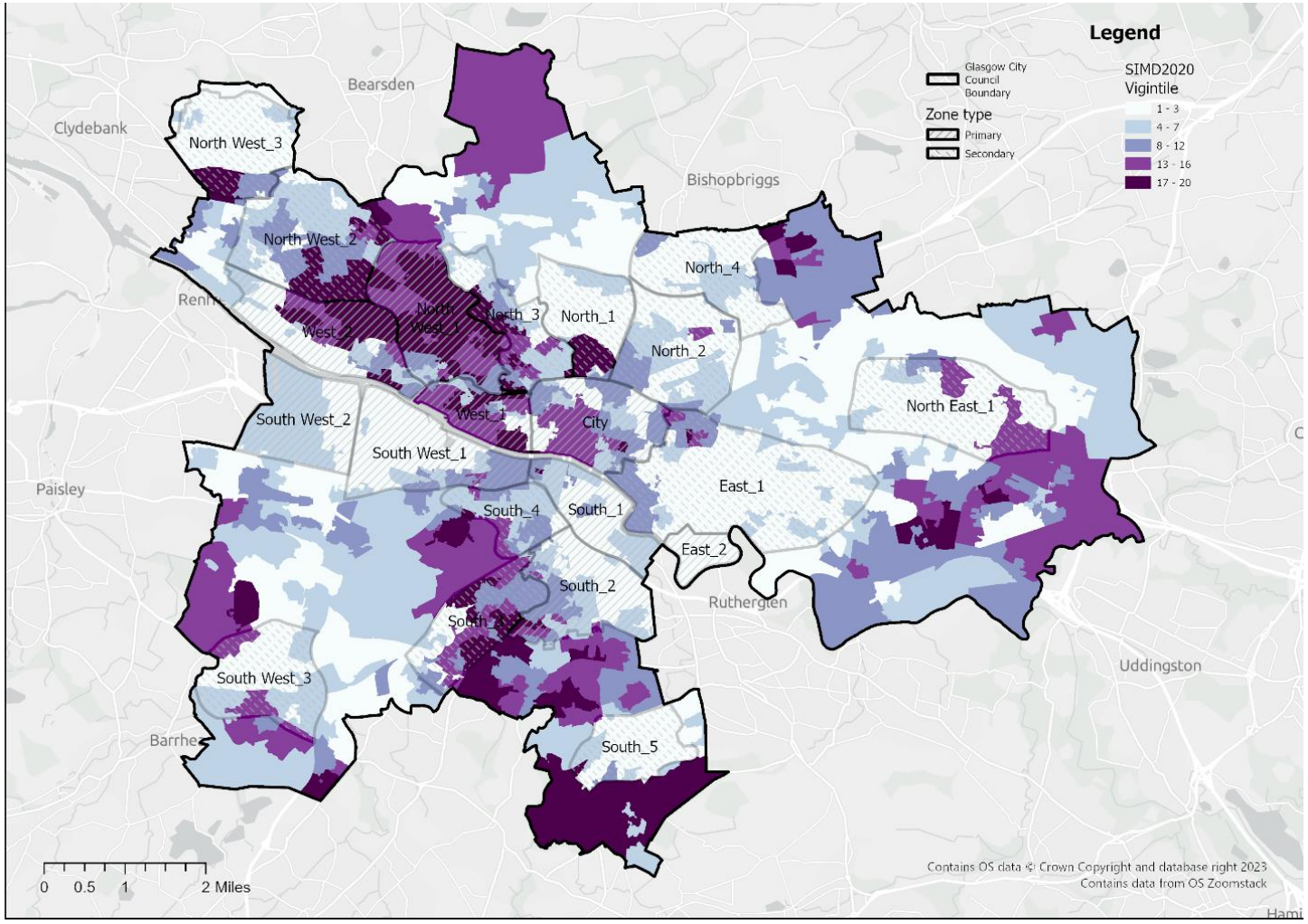
Applying clustering learnings to Glasgow

Vigintile distribution of overall SIMD 2020 rank for Glasgow showing the LHEES indicative heat network boundaries.

The most deprived areas are shown in lighter shades, with the least deprived areas represented by darker colours.

Extending the heat network zones further to capture a greater number of cluster 1-3 postcode areas would allow benefit to be more widespread.

Less than half of the cluster 5 postcodes fall within the indicative heat network zones, but properties in these areas are the greatest domestic users of energy and will therefore provide the greatest per household benefit to emissions reduction targets by going green.



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Thank you!

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