Who Is Left Cold in a "Green" Island System?

Mapping household heating risk in Orkney for fair and resilient energy planning

Engineering and Physical Sciences Research Council

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Research motivation

Conventional resilience assessment usually asks whether the network can keep operating. This research asks a more basic question:

Can people keep warm and safe when the system is under strain?

Using detailed housing energy performance data, postcode-level income and deprivation indicators, and a energy poverty lens, this work identifies where household heating risk concentrates across Orkney and shows how those patterns should change resilience planning.

Low EPC share
Poor fabric means higher thermal exposure.

Costly heating
Legacy electric and oil systems amplify burden.

Deprivation exposure
Risk clusters are social as well as technical.

Low incomes
Affordability pressure reduces shock absorption.

Research question & contribution

Can a technically high-performing island energy system still leave households exposed to cold, damp and unaffordable heating?

This work makes social and health risk visible in the same way technical risk is already mapped, then translates that evidence into a fair-governance lens for resilience planning.

"Demand reduction" can hide harm

Demand reduction is not neutral

Equal kWh reduction ≠ equal welfare impact

A measured **drop in demand** can be:

- **Benign** — Efficiency-driven reduction.
- **Harm** — Deprivation-driven suppression.

Governance must distinguish participation vs. shielding

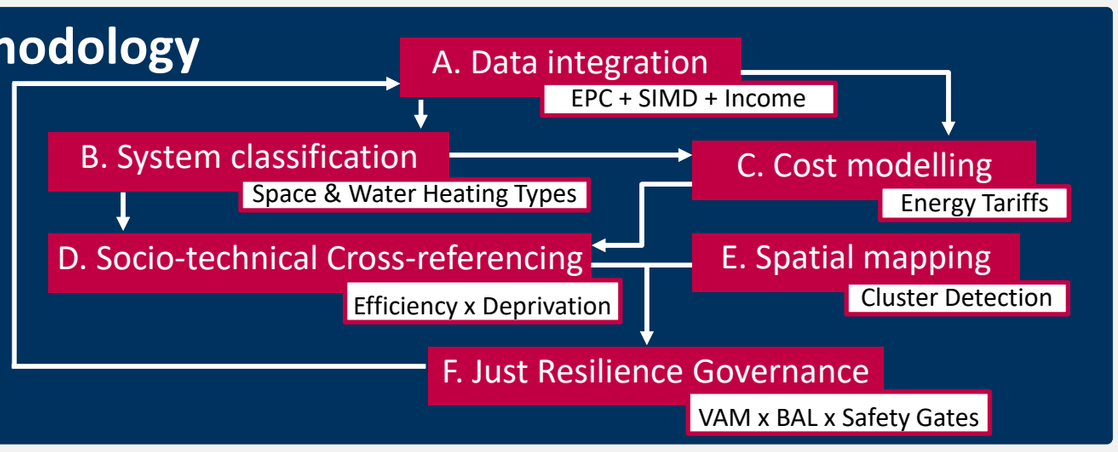
Why Orkney?

Orkney is often presented as an energy-transition success story:
a renewable-rich island region with generation potential that can exceed local electricity demand, and a well-known testbed for innovative grid and smart energy solutions.

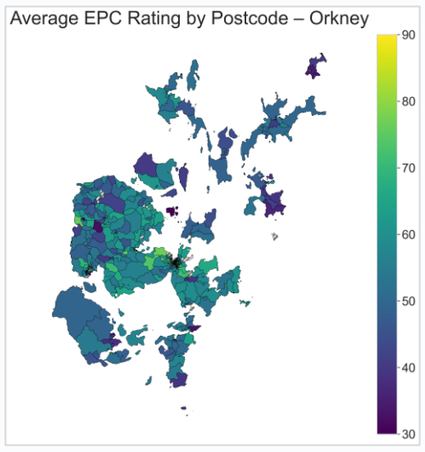
Yet many households still live in cold, damp, hard-to-heat homes exposed to volatile heating costs and extreme weather.

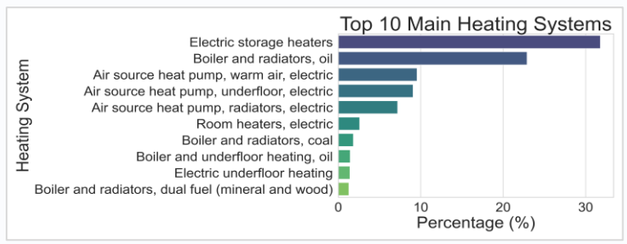
Orkney also reveals **how policy delivery is constrained by local barriers** such as high costs, limited contractors, weak retrofit trust, and poor fit between standard assessments and island conditions.

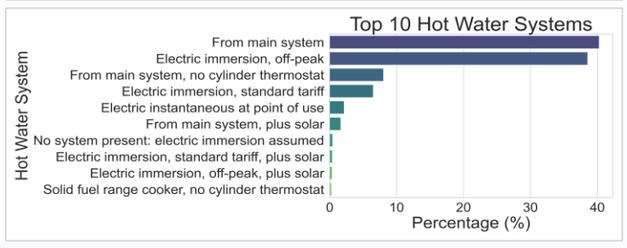
Methodology

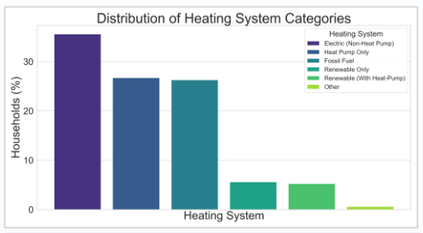


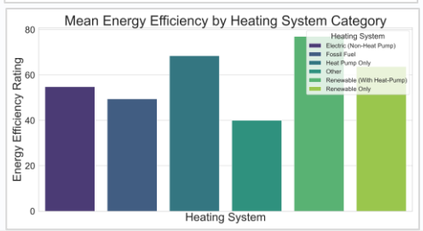
Evidence 1 – Low energy efficiency, legacy heating systems











Heat pumps and renewable systems have the lowest modelled demand on average.

Electric non-heat pump systems dominate the stock.

Electric storage heaters and boilers dominate.

Low-carbon options, including heat pumps, remains limited.

Most postcodes have mid-range average EPC ratings.

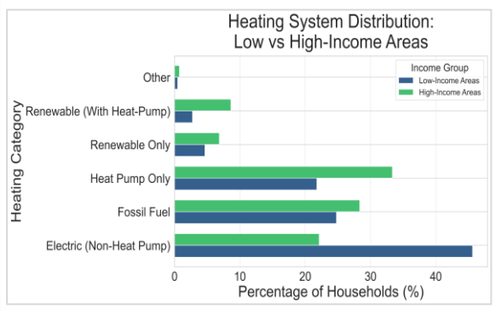
Several clusters perform low.

Evidence 2 - Heating systems are socially uneven

Sharp divide

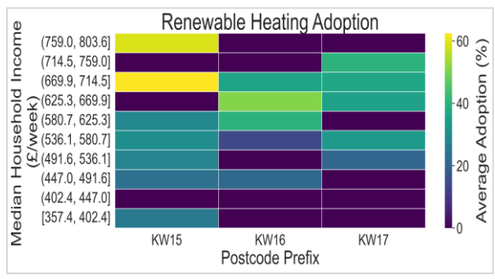
Low-income areas rely heavily on electric (non-heat-pump) and fossil-fuel systems.

High-income areas show greater diversity and higher uptake of heat pumps and renewables.



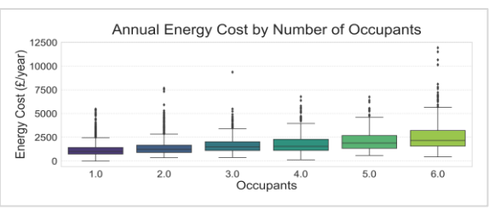
KW15, the more affluent postcode area, leads renewable uptake among mid-to-upper income groups.

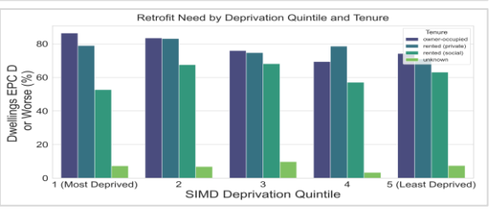
Renewable systems are almost absent in low-income zones.



Costs rise with household size, and inefficient systems such as immersion heaters can compound the strain when heating/hot water is needed outside cheaper night-time periods and extreme events.

Evidence 3 - Cost burden rises with occupancy





Retrofitting need is highest in dwellings built before 1965.

EPC D-G shares exceeding 90% across most tenures.

Social housing performs best.

≈ £1,250
Median annual electricity cost for **single-person dwellings**

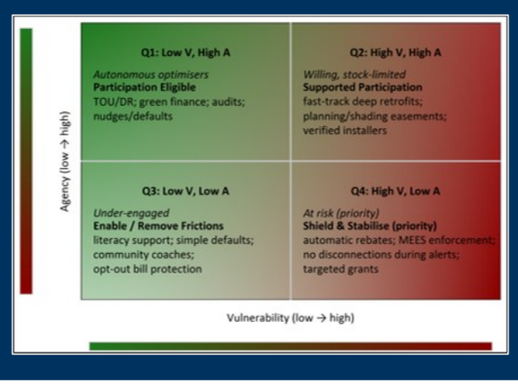
Dual tariff
Off-peak rules can penalise larger households

From evidence to fair resilience governance

Vulnerability Energy Matrix (VAM)

Vulnerability
exposure + sensitivity

Agency
capacity to act



Behavioural Adaptation Ladder (BAL)

2 rungs with representative levers

Step 1 — Micro-behaviours (Low effort – "do now")	Step 2 — Operational & low cost aids (Programmatic – quick installs)	Step 3 — Structural/Strategic (Higher effort – survey/consent)
• Set-point trim (0.5-1°C)	• Heating schedule optimisation	• Insulation package (loft/cavity/solid/floor)
• Room/zone discipline	• Off-peak DHW timers/smart plugs	• High performance glazing
• Blinds/curtains timing	• Programmable stats/smart plugs	• Major fabric retrofit
• Moisture-control ventilation by rule	• Draught-proofing kits	• MVHR installation
• Off-peak DHW habits	• Thermal/blackout curtains	• Heating system redesign
• Vulnerable household checks		• Heat pump

Safety Gate

Household Condition/Extreme Event + VAM Segment + BAL Action

Input: event type + VAM segment + candidate action

Risk Checks — **IAQ/humidity/mould**

Thermal safety: over/underheating exposure | **Financial:** arrears/self-disconnection

Outcome

Eligible | **Eligible only with protections** | **Not Eligible**

Decision log fields

event • segment • action • risk flags • rationale

Take-away messages

1. **A renewable region is not automatically a resilient one.**
2. **Demand reduction is not neutral – suppression must be visible.**
3. **Resilience planning must protect households, not only infrastructure.**

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