Adaptation and Resilience in Energy Systems (ARIES)

Professor Gareth Harrison

University of Edinburgh

Dr David Jenkins

Heriot Watt University

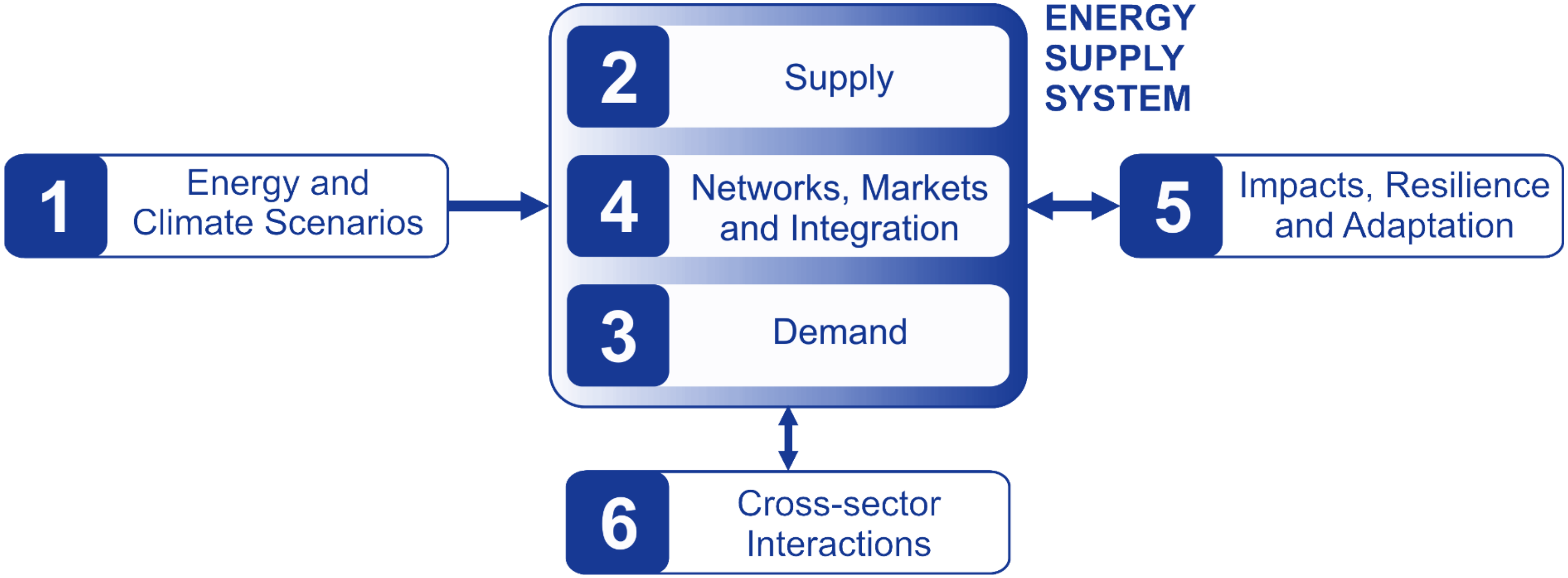
Aims and Objectives

- **ARIES aims for a comprehensive risk framework to assess UK energy system resilience to climate change**

- Examine physical and economic impacts of climate change on current and new **electricity generation technologies**
- Examine climate-driven changes in heat and electricity **demand** in (non-) domestic buildings as well as response to changes in building design, behaviour and micro-generation
- Examine regional and national **balance of supply and demand** for gas and electricity, its implications for a resilient energy system
- Deliver a **risk management framework** to appraise system adaptation

Approach

- Considers ***matching*** of renewable generation and demand incorporating long-term climate variability and change
- ***Bottom-up analysis*** identifies climate risks for individual supply and demand factors and system-level risks
- Tackles ***interdependence*** of renewable supply and demand creates analytical challenge at regional and national scales



Supply Side

Prof Gareth Harrison
Dr Venki Venugopal
Dr John Chick
Dr Richard Essery
Dr James Robertson
Dr Camilla Thomson

Dr Dougal Burnett
Dr Lucy Cradden
Dr Atul Agarwal
Dr Niall Duncan
Dr Ed Barbour
Dr Wei Sun

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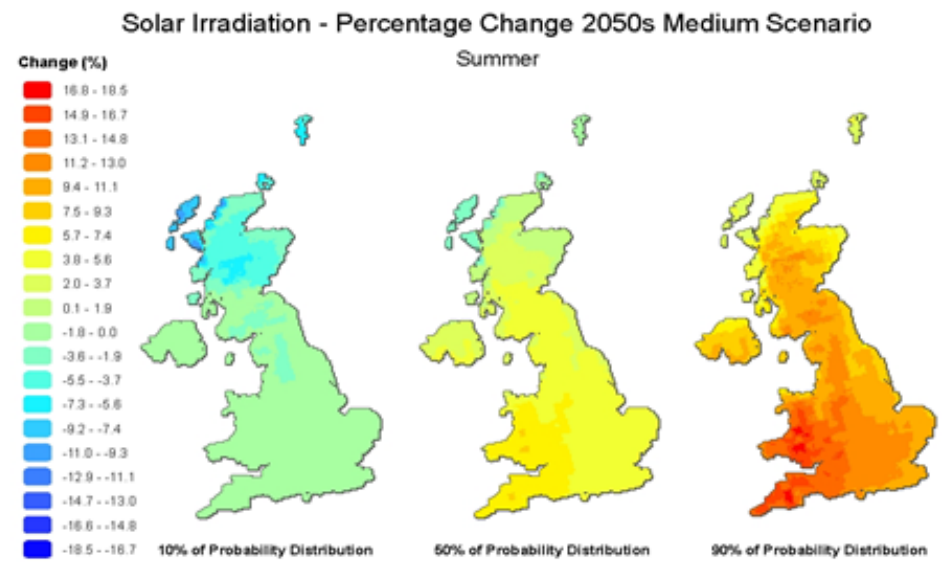
Supply

- Examination of physical and economic impacts of climate change on current and new **generation technologies**
- Made use of UKCP09 suite of weather generator, RCM and probabilistic output as well as other GCM data
- Applied models of technologies and geophysical processes

Technology	Qualitative Analysis	Production and Economic Analysis	Adaptation
On/offshore wind	Complete	Complete	Qualitative
Solar PV/thermal	Complete	Complete	Qualitative
Tidal	Complete	Access only	Qualitative
Wave	Complete	Complete	Qualitative
Hydropower	Complete	Complete	Completed
Thermal generation	Complete	Complete	Qualitative
Biomass	Complete	Not considered	Not considered

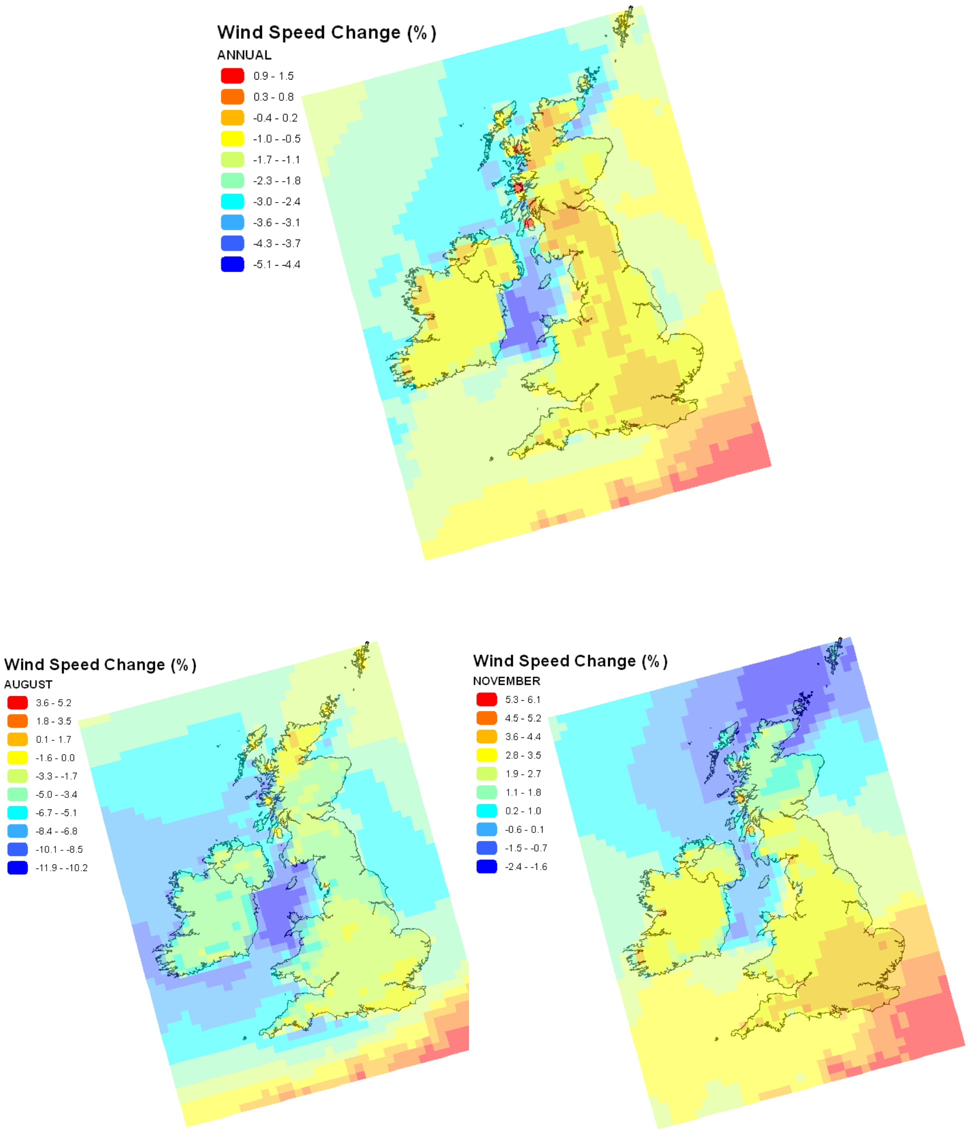
Solar Energy

- Applied UKCP probabilistic projections for 2050 to indicate change in insolation and PV output
- For medium emissions UK median annual change is an increase of 3.6% (range of –1 to 8.5%)
- Apparent regional / seasonal trends:
- Mid/N Scotland: ~3% decrease in winter and slight increase in summer
- S Scotland/N England: 1-2% decrease in winter and 2-3% summer increase
- Midlands/South: slight winter decrease and 7-8% summer increase
- Coincident temperature rise will offset PV production gains but is dependent on the PV technology



Wind Energy

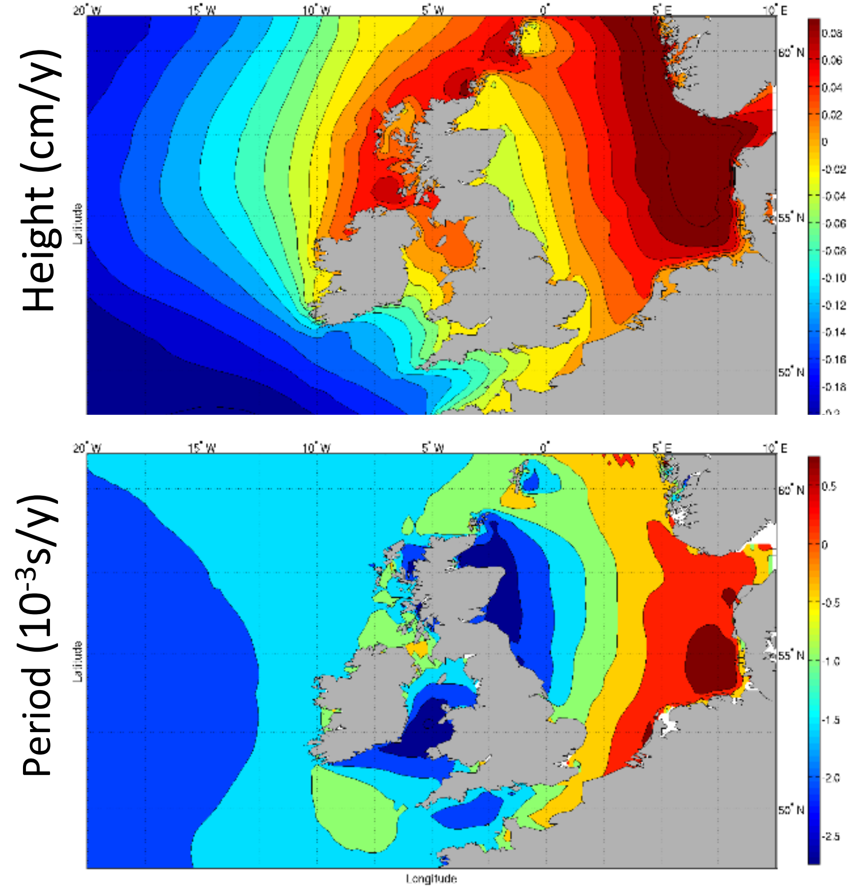
- Applied UKCP probabilistic projections for 2050 to indicate potential changes in wind speed and generation
- For medium emissions UK median annual changes is a small decrease everywhere with largest changes west of Scotland and Irish Sea
- Seasonally, August has largest reduction, particularly offshore, and November sees largest increases in south reducing to the north
- Impact on generation from 38 GW on/offshore fleet is a modest –1.4% (range of –6.6 to 3.2%)
- 5–10% reduction in summer and very slight increase in winter



Wind speed change (%) for 2050s medium emissions scenario with 50% probability

Wave Energy

- Published UKCP09 wave climate data not adequate to estimate wave energy – required simulation of long time series with Wavewatch III model
- Simulated historic wave climate identified clear change in mean height and period over 1921 and 2010: waves are larger, longer and more powerful
- Generated three future wave climates for high (A2), medium (1B) and low (A2) emissions using ECHAM5 data to test sensitivity to GHG levels
- Trend modest in all cases and ANOVA test showed no statistically significant differences suggesting it is unlikely that the wave climate will be influenced by climate change forcing



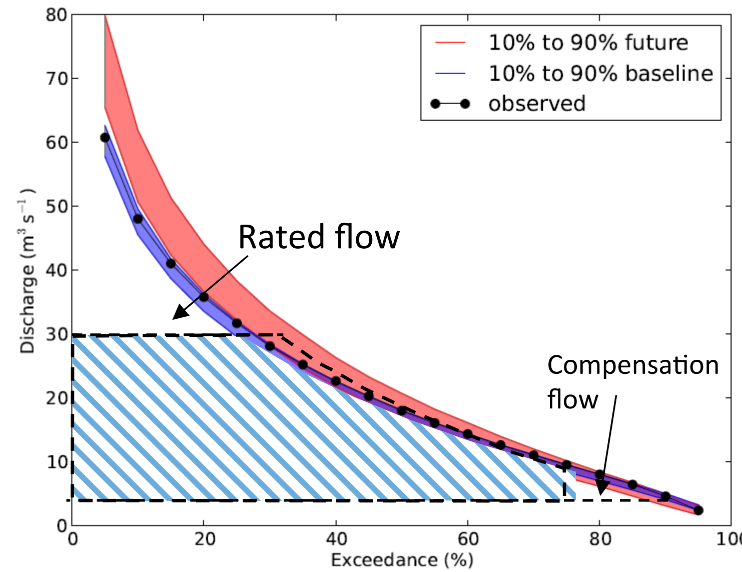
Annual trend in wave height and period between 2001 and 2100 for A2 scenario

Hydropower

- Applied UKCP09 weather generator and hydrological model of Scotland to estimate future river flows and hydro production
- 2050 medium emissions results in higher winter and lower summer flows

- With median estimate of future flows a hypothetical run-of-river Ewe scheme experiences
  - ~1% increase in annual generation
  - ~6% increase in winter generation
  - ~15% *decrease* in summer generation
- As hydro schemes are site specific designs can existing or future schemes be *adapted* to changing conditions?

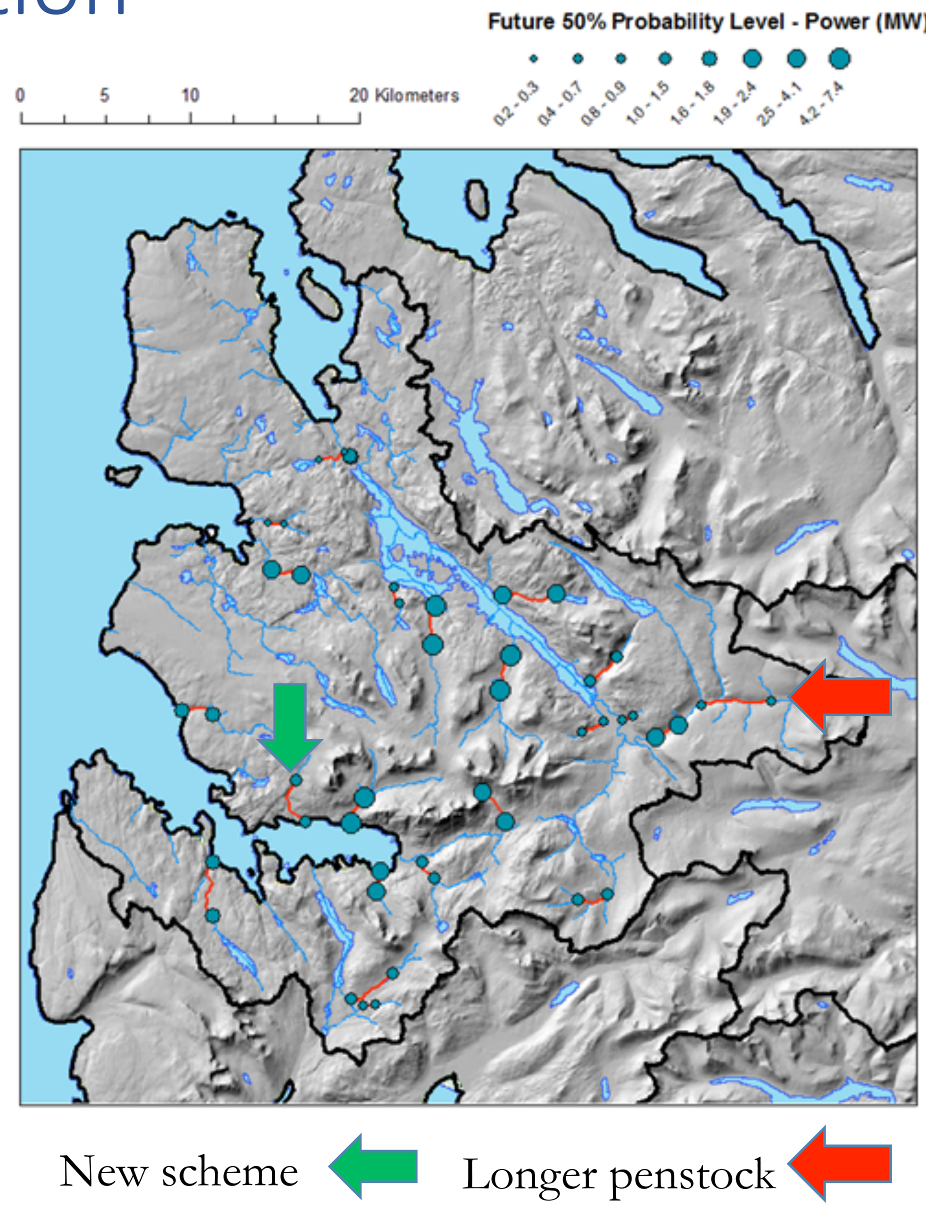
Flow duration curves for Ewe catchment at Poolewe: 1961-90 baseline and medium emissions scenario for 2050s



Blue hatched area: flow for baseline generation
Black dotted area: flow for future generation

Hydropower: Adaptation

- Applied a 'hydro search' algorithm to identify change in characteristics of viable schemes
- Compared to baseline, median future flow conditions result in:
  - Total capacity increases 25%
  - One additional scheme identified
  - Average turbine capacity 19% larger as design flow increases by 13%
  - Larger diameter/longer penstocks
  - Average capacity factor falls slightly
  - Average scheme cost increases 20%
- Over full 10%-90% flow range key indicators vary by ±10%



Supply: Summary of Impacts

- Most generating technologies are projected to have changes that are relatively modest with some resources increasing and some declining

- There is a tendency for existing seasonal and regional variations to be enhanced

- The range of potential outcomes projected is a challenge for effective adaptation but the period over which changes will occur should provide time for adaptation

- More recent GCM/RCM datasets at high Representative Concentration Pathways may indicate different outcomes

Demand Side

Dr David Jenkins
Sophie Simpson
Dr Sandhya Patidar
Prof Phil Banfill

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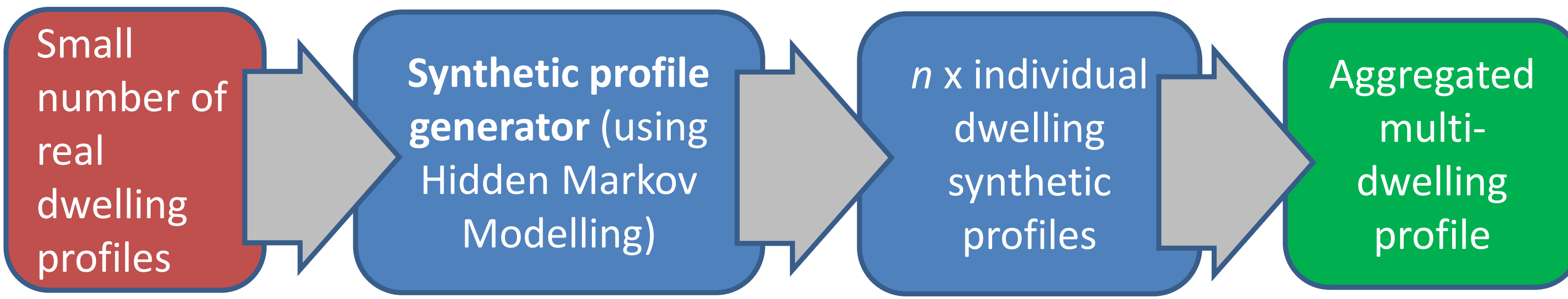
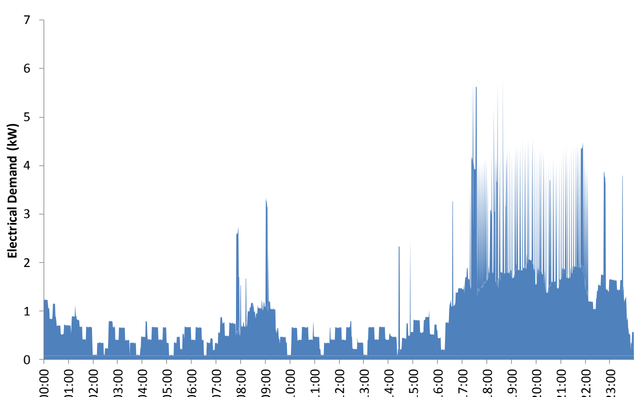
Demand

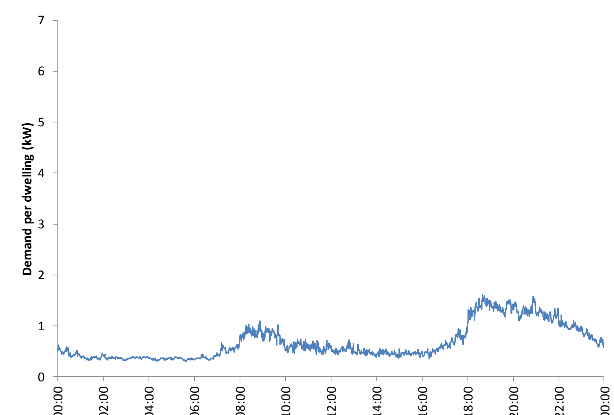
- Examine climate driven changes in heat and electricity demand particularly the effects of building design, behaviour, micro-generation
- Requirement to consider regional and national demand necessitating bridging the gap between individual building scale and aggregate levels
- Made use of UKCP09 weather generator as well as emulation tools developed as part of Low Carbon Futures project
- Developed new models of building stock and techniques to credibly aggregate information from individual buildings whilst handling probabilistic information

Aggregate Electrical Demand

- An upscaling approach was created to synthesise demand profiles from real measured data

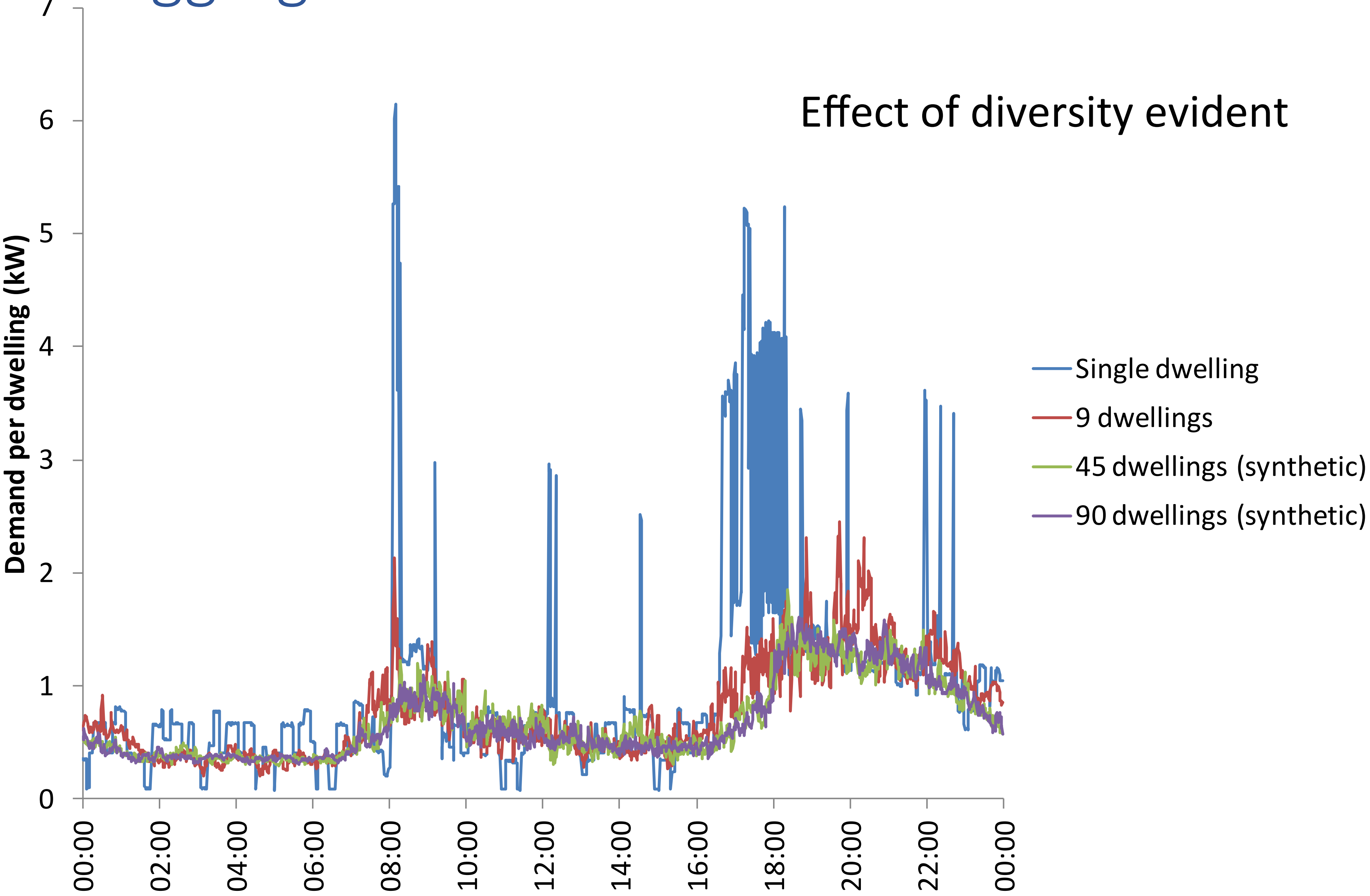






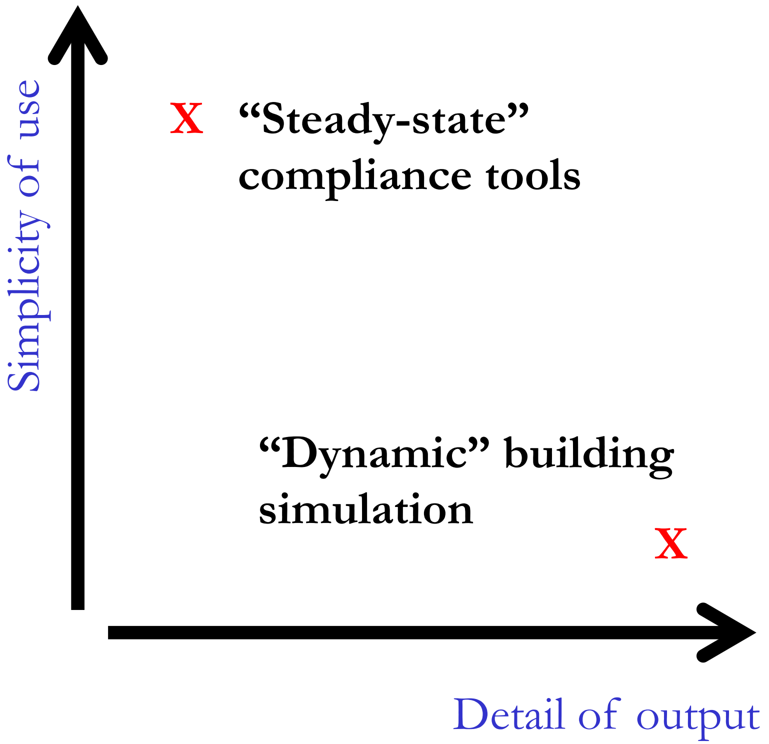
Jenkins, Patidar and Simpson, Synthesising electrical demand profiles for UK dwellings, Energy and Buildings 76, 2014

Aggregate Electrical Demand



Aggregate Heat Demand

- Construction of a Dynamic Local-Scale Stock model (DLSSM)
- Accounts for important aspects of building physics but in way that is suitable for extrapolation
- Can look at effect of e.g. large-scale changes in heating technology (in warmer climate)
- Developed a method for dynamically simulating large numbers of dwellings simultaneously (in IES-VE)



Dynamic Local-Scale Stock Model

National Stock Analysis

Multiple simulations

Archetypes

Thermal demand profiles

Physical Data
- Geometry
- Thermal

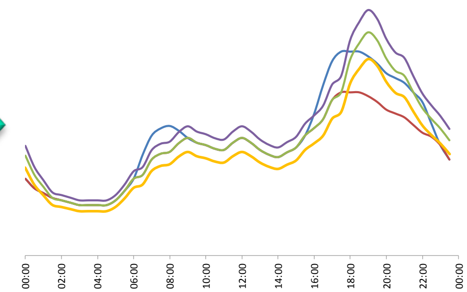
Operating Data
- Heating schedule
- Temperature set-point

Local Stock Analysis

Weighting factors

Stock review
- Building typology
- Socioeconomic data

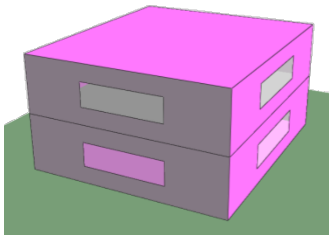
Aggregated Thermal demand profile



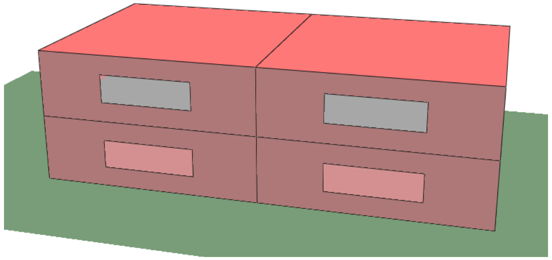
Additional Information Operational performance

Collaborate with other models

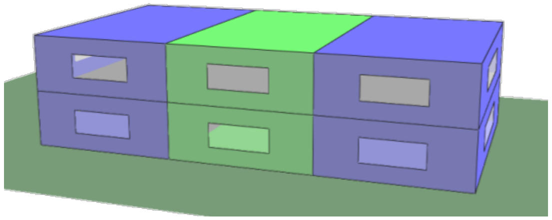
Thermal and Geometric Properties



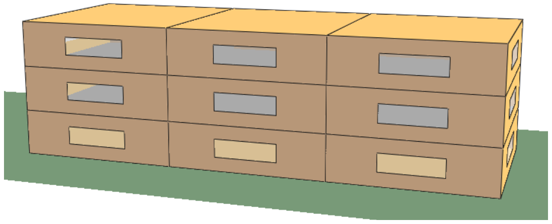
Detached



Semi-detached



End and mid-terrace

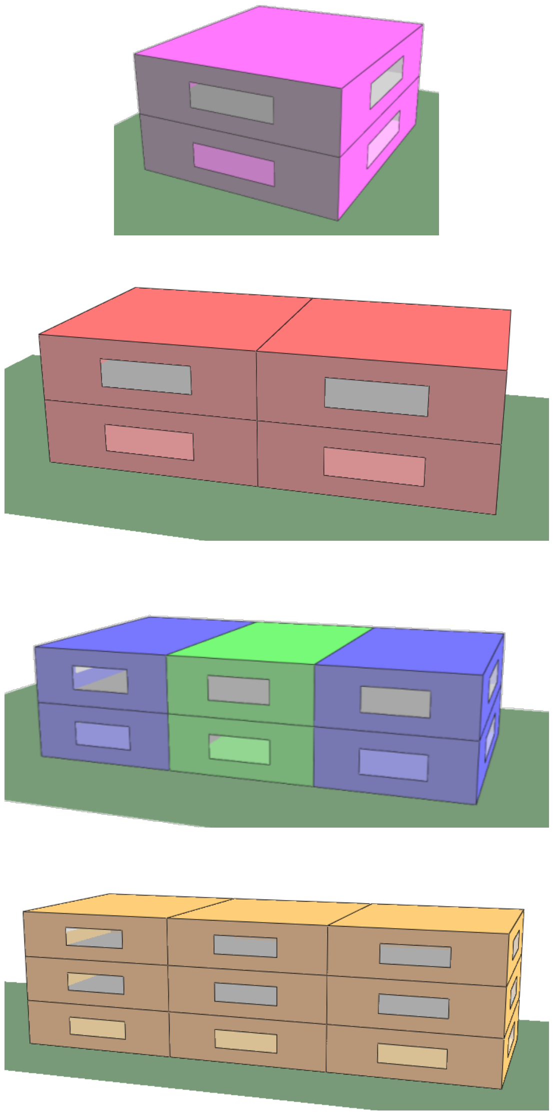


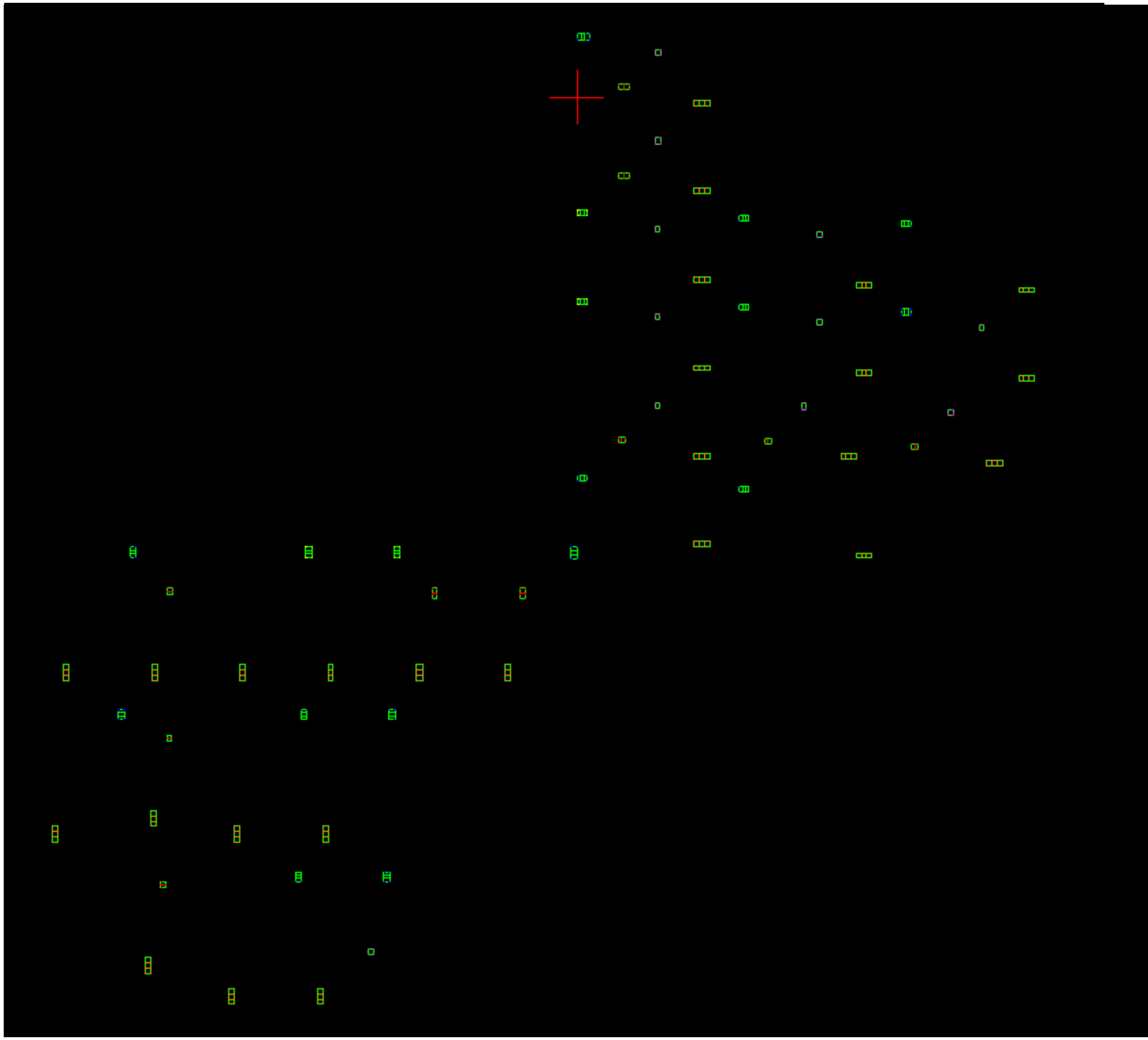
Flat

ground / mid / top floor

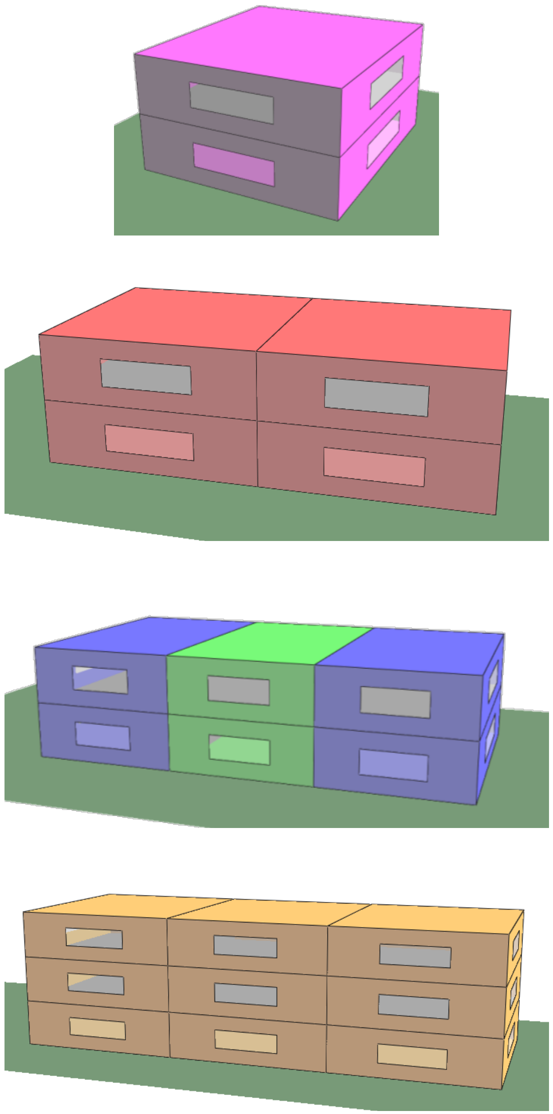
end and mid-terrace

Thermal and Geometric Properties





Thermal and Geometric Properties



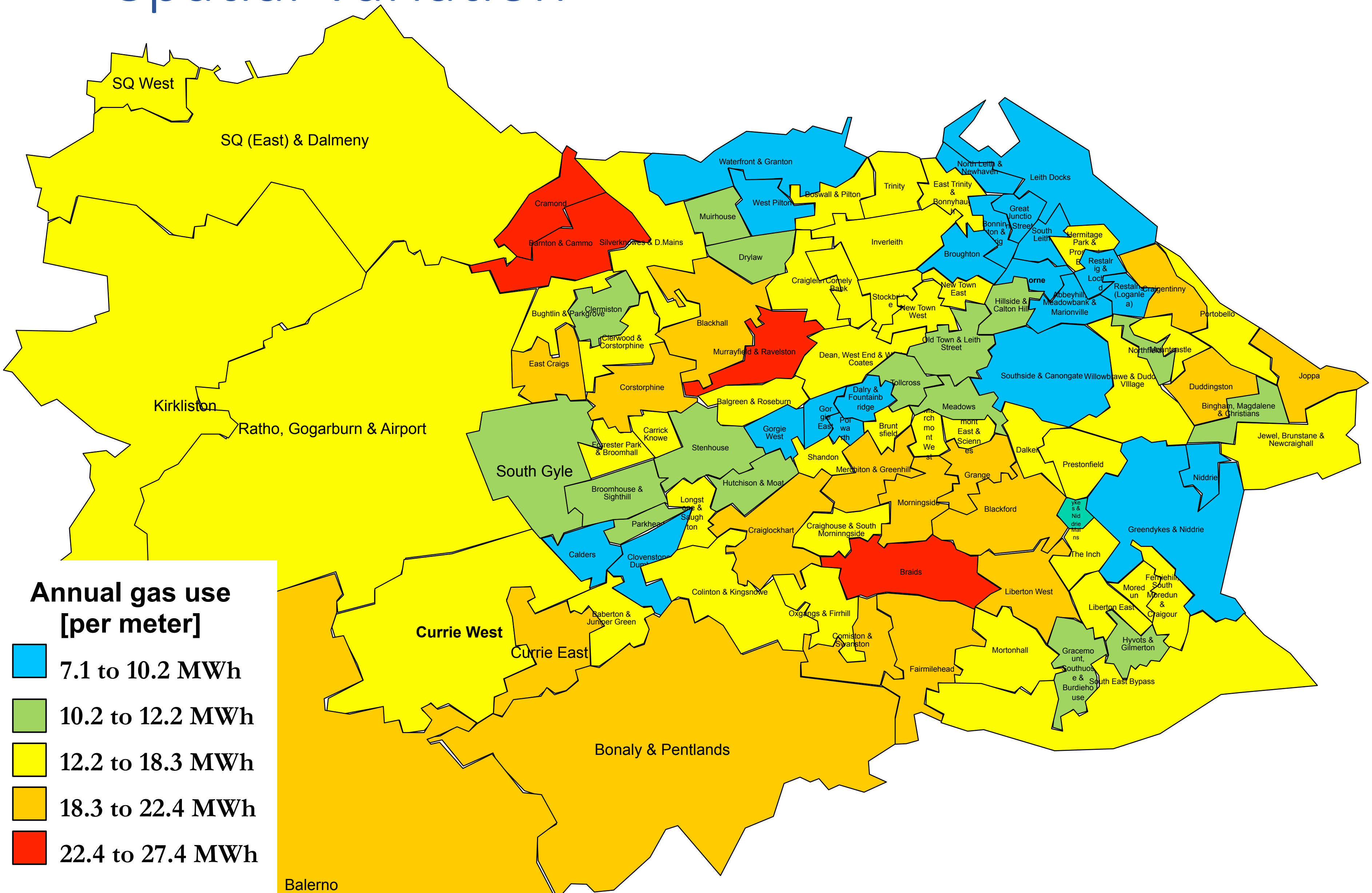
Grouped by construction type:

- Sandstone
- Granite/whin
- Brick
- Blockwork
- Timber
- Concrete
- System build

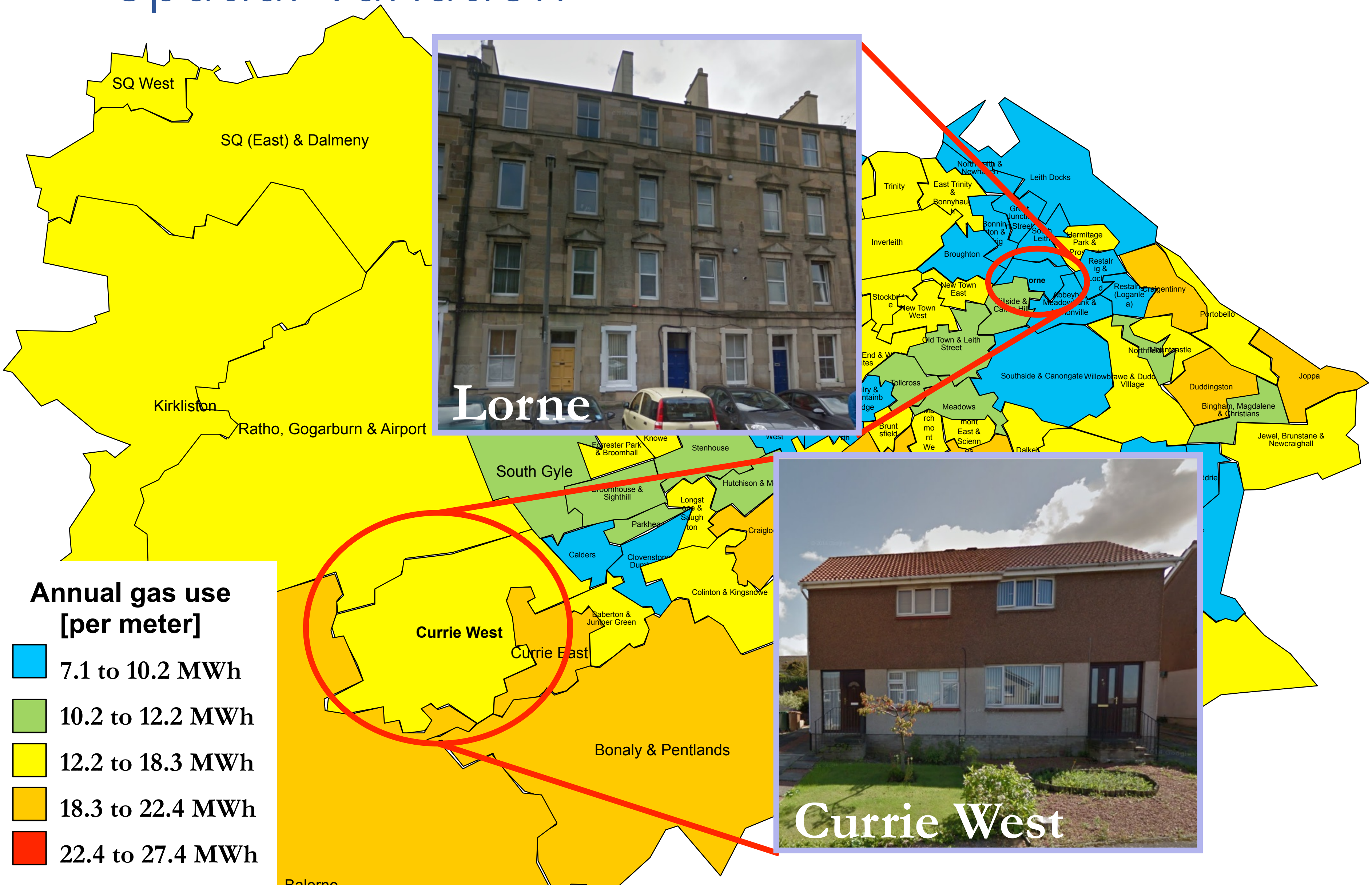
NHER age bands to categorise:

- Thermal properties
- Typical dimensions

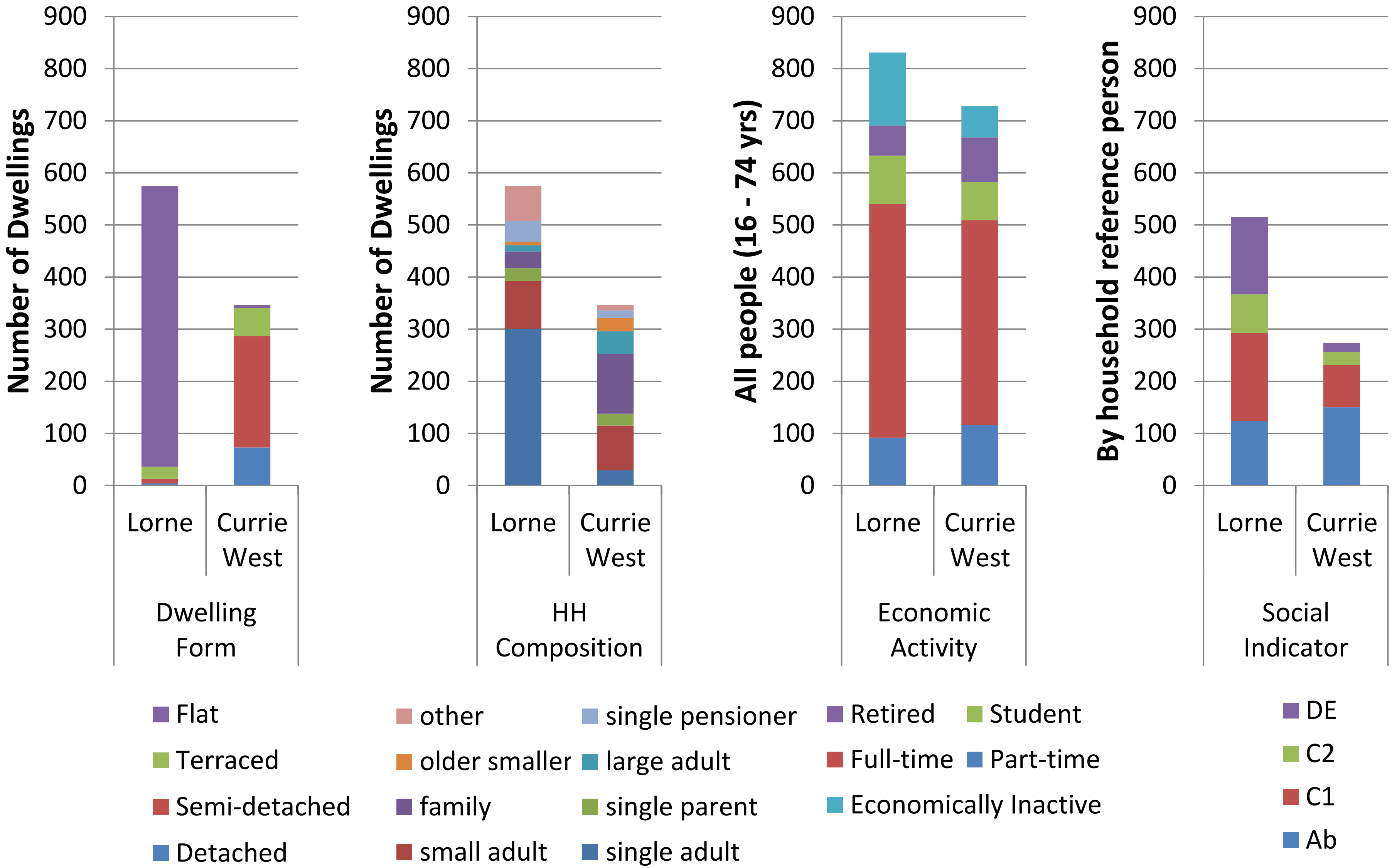
Spatial Variation



Spatial Variation

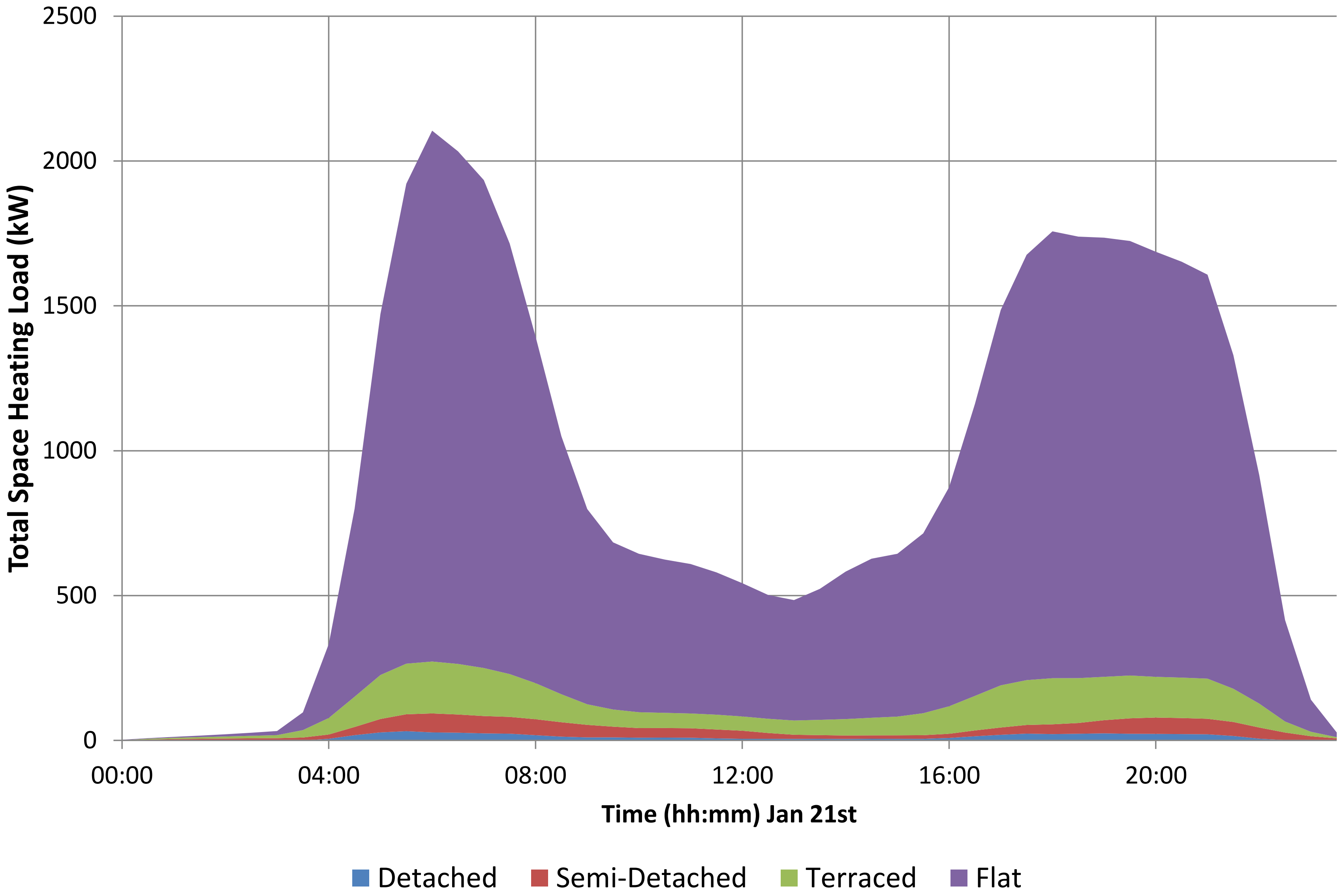


Comparison

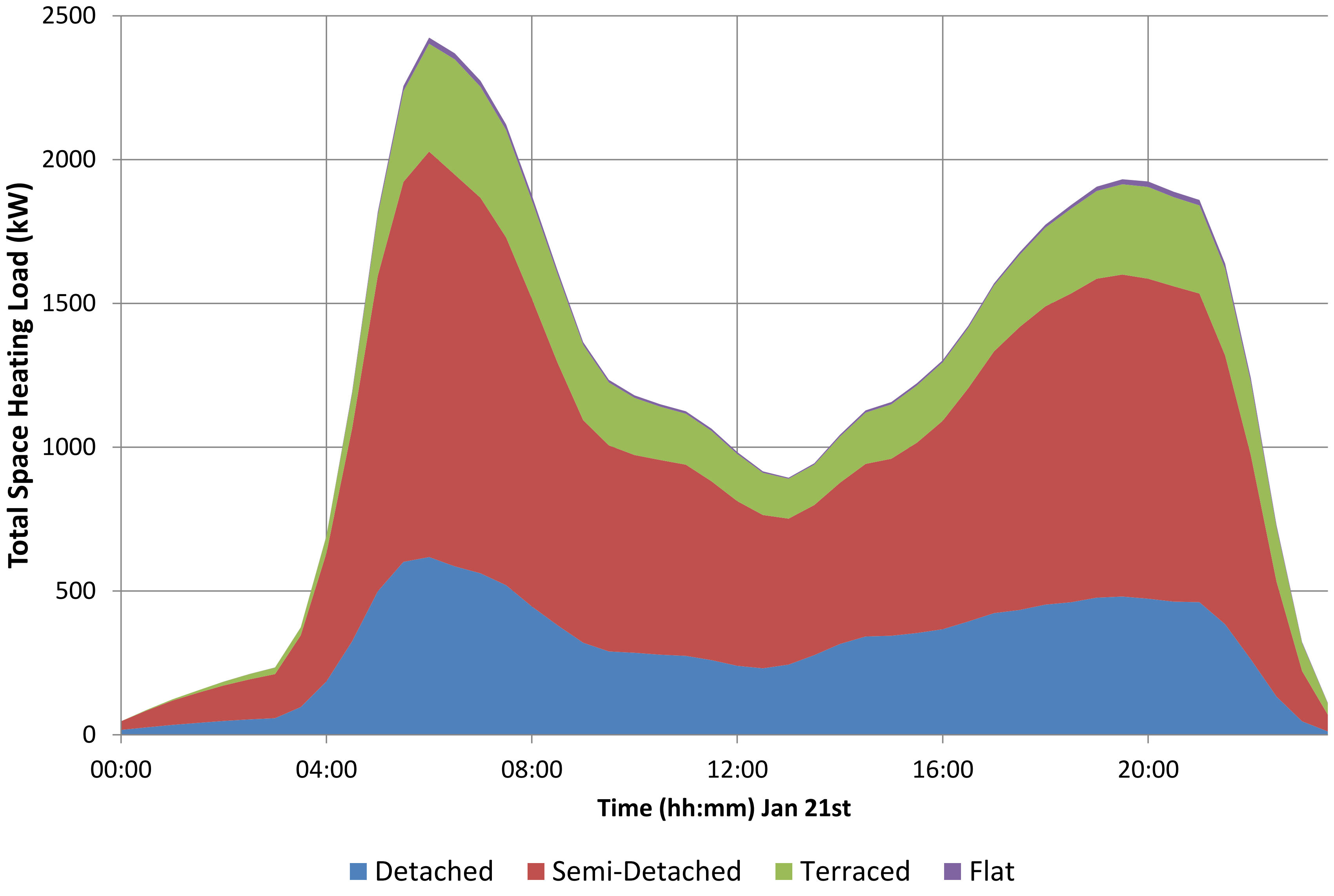


Number of Dwellings
Number of Dwellings
All people (16 - 74 yrs)
By household reference person
900
800
700
600
500
400
300
200
100
0
Lorne
Currie West
Dwelling Form
HH Composition
Economic Activity
Social Indicator
Flat
Terraced
Semi-detached
Detached
other
older smaller
family
small adult
single pensioner
large adult
single parent
single adult
Retired
Student
Full-time
Part-time
Economically Inactive
DE
C2
C1
Ab

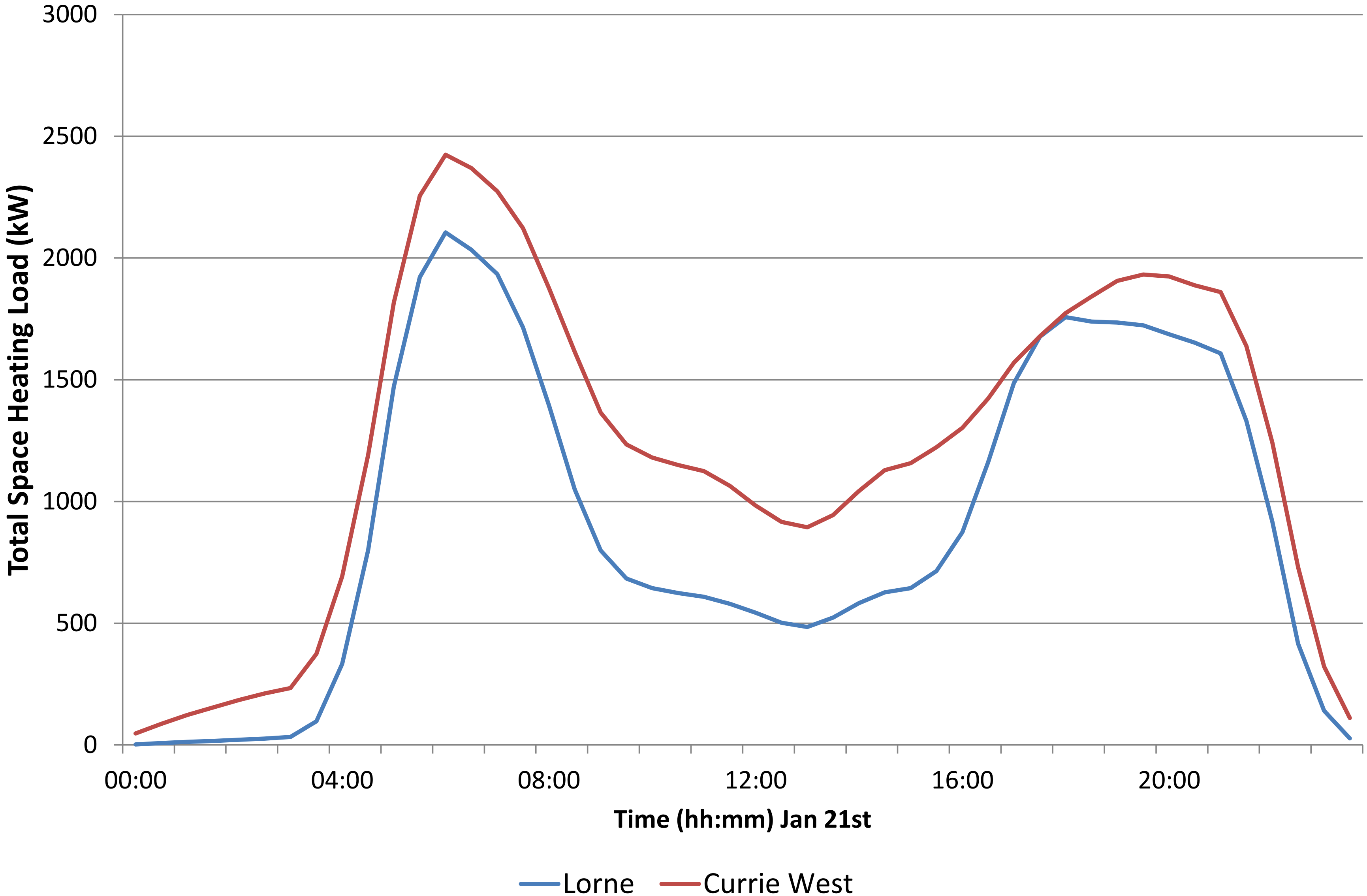
Lorne Data Zone



Currie West Data Zone



Comparison of Profiles



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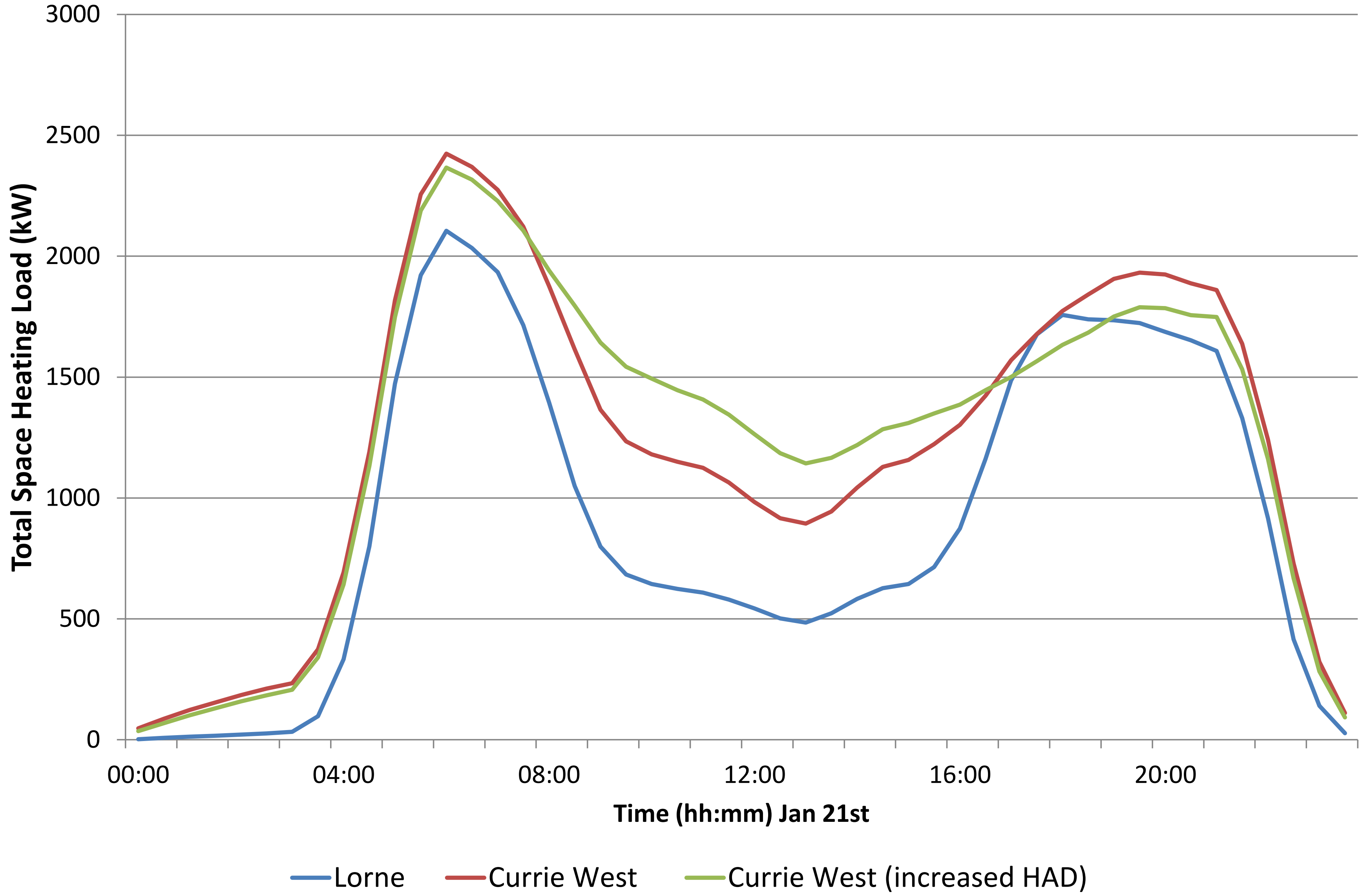
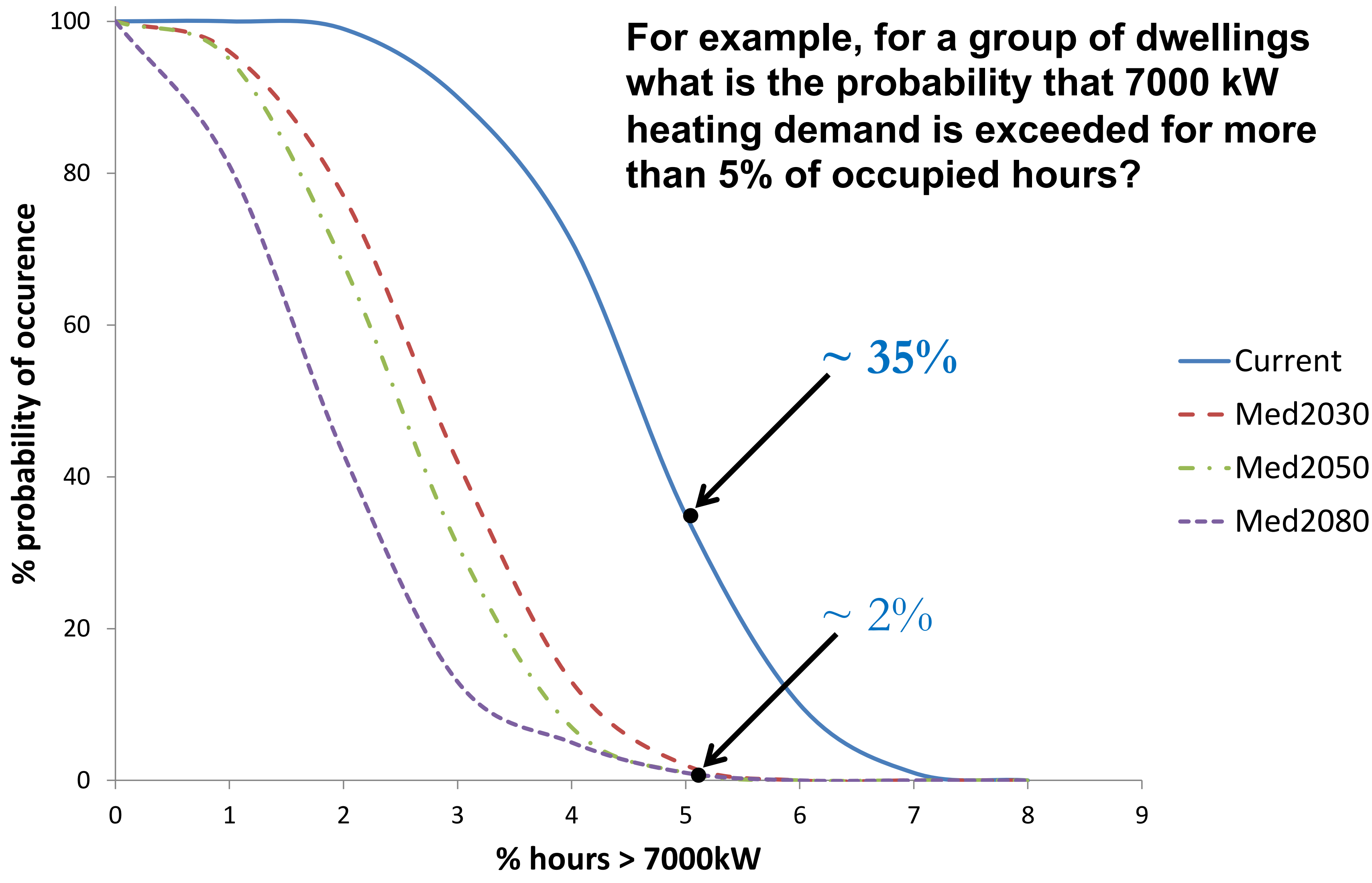


Applying Climate Projections

- The methodology enables multiple buildings to be assessed simultaneously
- The Low Carbon Futures emulator can then be used to run thousands of different climate files on those aggregated building models
  - This emulates the effect of climate on building performance based on a single simulation
- Results can be presented in terms of risk of occurrence
  - More consistent with how climate models actually work

Applying Climate Projections



Jenkins et al., Quantifying change in buildings in a future climate and their effect on energy systems, Buildings 5(3), 2015

Conclusion

- Developed method to model energy demand on a range of spatial and temporal levels that is compatible with energy supply models
- This can be projected for UKCP’09 climate projections
- Future technology changes can also be applied to the model to create different pictures of the future
- Risks of “failures” can be defined and explored by the user

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