Quantifying the influence social and dwelling characteristics have on patterns of internal temperature and heating demand in English households over winter and how they have changed in recent years.

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Background

In England, as in many other Western countries, one-quarter of all energy is consumed directly in households, and the main part of this relates to maintaining a comfortable indoor climate. Moreover, it's observed the average number of heating hours and temperature ranges significantly between households in winter, with the length of heating often ranging 4-24hours a day, and common internal temperatures ranging from 12°C-24°C. Moreover, little is known about how heating habits and temperature profiles in households has changed in recent years.

This work will primarily use EFUS 2011, EFUS 2017 and the DEFACTO dataset all which provides information on the dwelling, the heating practices and socio-economic characteristics as well as monitoring temperature. A small temperature test will also be carried out to check the accuracy of studies.

Aims

- Establish common heating patterns in English households.
- Determine the groups of occupants and dwellings that have significantly higher temperatures or significantly longer heating durations.
- Establish how internal temperature and heating patterns in English households have changed over the last decade.

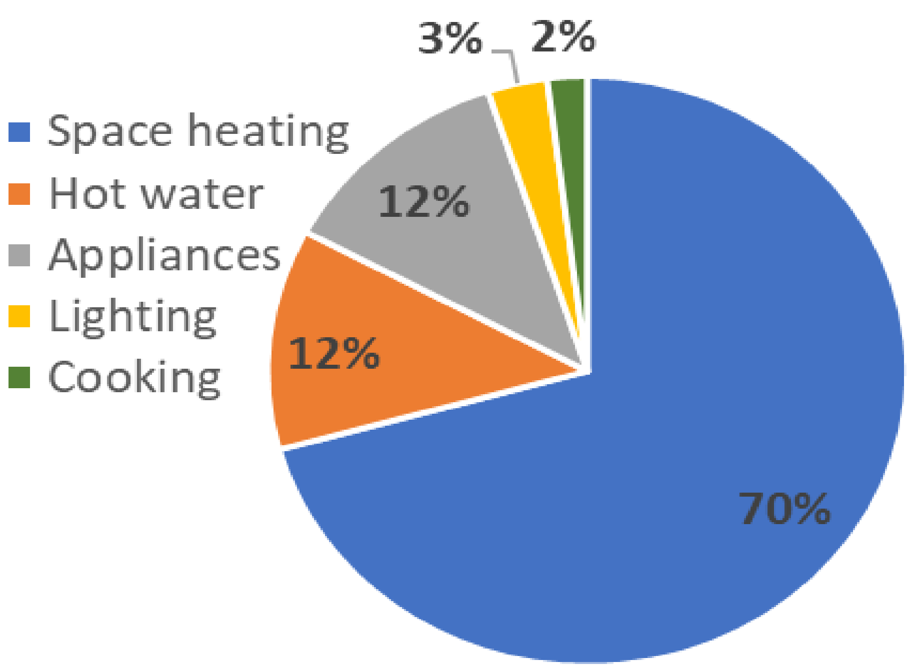

Figure 1: Shows where energy is used in a UK home.

Research program

1. A comprehensive literature review examining; residential energy policy, the impact social and dwelling factors have on heating demand and analysing how energy stock models estimate heating demand and temperature setpoint.
2. Carry out a small temperature monitoring study using three different temperature sensors (HOBO pendant, Tiny tag and a type T thermocouple). To establish whether temperature sensors can capture household heating on/off times.
3. Determine a suitable method and algorithms to estimate heating on/off times from temperature data.
4. Apply the method to EFUS 2011 and EFUS 2017 dataset to discover the common heating patterns in English households on a national scale.
5. Determine a suitable method to normalise EFUS 2011 and EFUS 2017 for appropriate variables such as whether to allow a fair comparison of heating patterns.
6. Compare the heating patterns of different social and dwelling groups (particularly households classed as fuel poor) establish how heating and temperature have changed with time make future predictions.
7. Make recommendations for energy policy, energy models and further research.

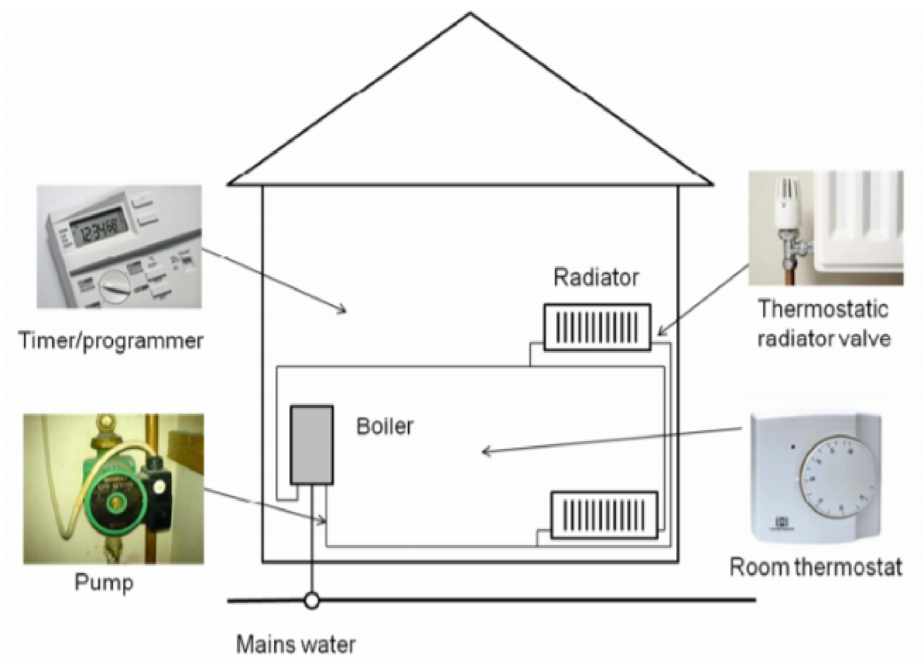

Figure 2: Typical components in a central heating system used in a UK dwelling.

Preliminary method and analysis

- A short temperature monitoring study was carried out using three different temperature sensors (HOBO pendant, Tiny tag and a type T thermal couple); where the temperature profiles were compared to the heating pattern, which for both dwellings was on from 7am-9am and 4pm-11pm. Observe in figure 4 as soon as the heating system switches on, the temperature increases, no time lag or internal gains. However, in the evening heating period their notable oscillations caused by the temperature reaching the thermostat setpoint, resulting in the boiler switching off and the temperature significantly decreasing before switching back on.

Figure 3: Photo of temperature measuring equipment

- Each past and suggested method to estimate heating on/off times from temperature data was calculated for the two monitored homes and compared against household's actual heating times. Additionally, 20 homes from the EFUS dataset (a 2011 study which monitored the temperature of 823 households for a year) was used to compare the predicted heating on/off times according to each method to the heating on/off estimated by visual inspection. Most methods struggled to capture the heating patterns for all households. The method most suitable was one that focused on the length of time the temperature decreases to determine on/off times.

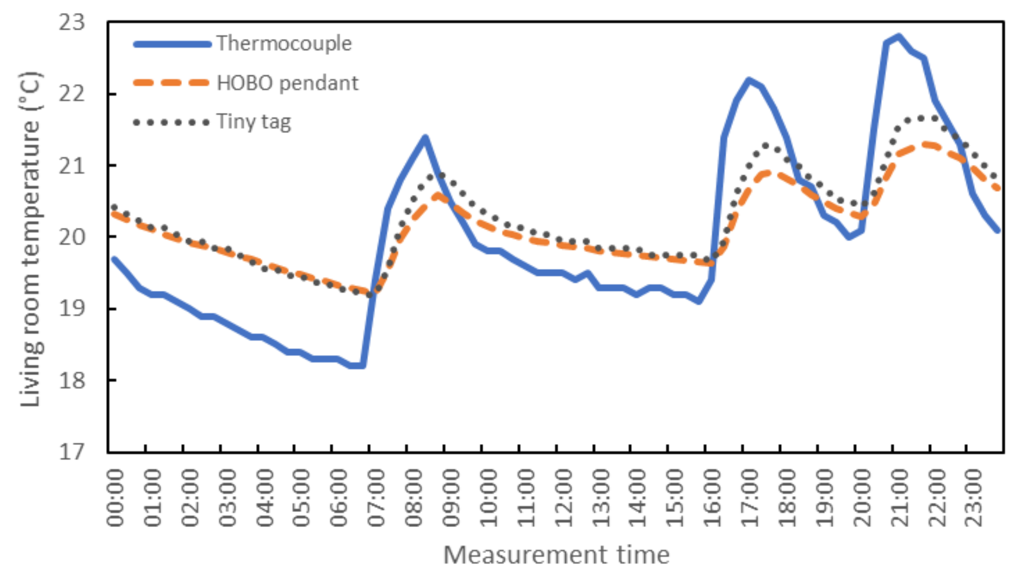

Figure 4: The graph compares the temperature of three sensors for a dwelling with a heating pattern 7-9am and 4-11pm.

- The heating times of all the homes in EFUS 2011 was estimated using the most suitable method. This was followed by using cluster analysis, grouping households of a similar heating pattern together. Four common heating patterns are observed; two-peak pattern, daytime pattern, 24hour pattern and an irregular pattern. The two-peak pattern was most common on weekdays with 40% of the sample heating in this way.

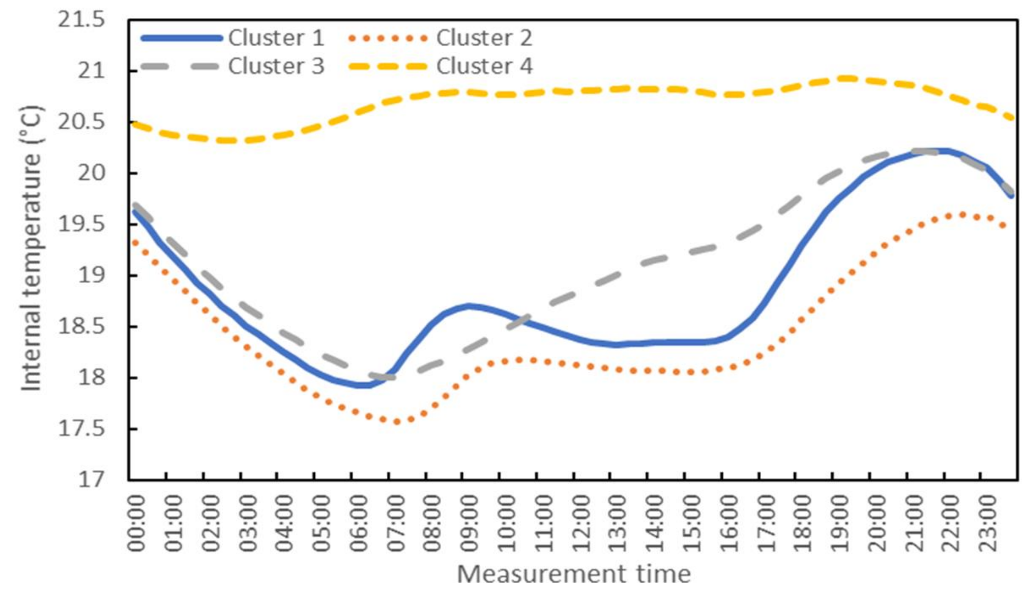

Figure 5: The graph illustrates the internal temperature of each cluster for weekdays

Current Conclusions

- Temperature sensors can estimate heating patterns if algorithms that limit the impact of the thermostat setpoint dead-band are applied.
- None of the current methods captures heating patterns perfectly, but time method offers the best approximation.
- Four common heating patterns are observed; two-peak pattern, daytime pattern, 24hour pattern and no pattern.