Network Capacity Documentation

This is the technical documentation for the project segment that focused on determining what effect transitioning heating sources in domestic homes in the West Midlands from non-electric heating sources to heat pumps will have on the electrical grid. Specifically, determining if the substations can handle the additional load being put on the network after mass heat pump retrofitting. This documentation will be broken down into several sections.

1. Data
2. Methodology
3. Results

During this process, we made several assumptions which we erred on the conservative side, often making decisions that would result in a higher load calculated for the network. **This was done because we assumed that underestimating the potential load, possibly resulting in power outages or transformer damage, was a more hazardous choice than overestimating the load, which may cause more preparations to be made than necessary.** When assumptions are being described throughout this text, they will be in bold as above to draw specific attention to them.

Data

Several data sources are required to perform the calculations for determining the effect of installing heat pumps on large numbers of homes in the West Midlands:

- EPC Database
- UK Average Home Heating Data
- UK national electricity consumption
- Western Power Distribution Network Capacity information
- The outputs from the EPC and heating description models

Methodology

To determine the total additional energy placed on the electrical network, we first had to determine the peak load expected from each home that converted from a non-electric heating source to a heat pump. This calculation was done as follows:

1. **Calculate the peak ratio using the *demanddata_2017.csv* file.**

   We are looking for the peak electricity demand for the year. However, we do not know these figures for each household or postcode area. We only have data at the national level. Therefore, we will derive this figure using a peak ratio.

   The peak ratio is the ratio of peak electricity demand for the year over the total national electricity demand. The demand data shows the amount of electricity used nationally in the UK at half-hour intervals in 2017. We integrated the graph to get the total electricity used nationally for the year. Then, we divided the peak electricity demand over the total electricity demand to find the peak ratio.

We use this ratio to find the approximate peak electricity demand for each house based on the additional yearly power used in a single home from switching to a heat pump. Finally, we aggregate this value over the various service areas.

calculating_peak_ratio() in *'models/combining_results_for_output.py'*

2. Bin floor footprint area ('*calculatedAreaValue*') into four groups, using the 25th, 50th, and 75th percentile marks as the dividing points.

line 107 in '*models/combining_results_for_output.py*'

3. Group the EPC data by EPC ratings, binned floor areas, and the heating type. There will be 56 unique groups in the end.

line 110 in '*models/combining_results_for_output.py*'

4. Divide the average heating cost for each bin by the total average heating costs of the dataset to get the heating cost ratio for each group.

line 111 in '*models/combining_results_for_output.py*'

5. Multiply the heating cost ratio with the average home heating power (15,000 kWh/year) to get each group's expected yearly heating power.

The average home heating power usage across the UK was provided by the [Department for Business, Energy & Industrial Strategy]().

line 112 in '*models/combining_results_for_output.py*'

6. Divide each group's expected yearly heating power with a coefficient of performance (COP) to get the amount of electricity required to produce that much heating power with a heat pump.

A conservative estimate was made on the coefficient of performance which was set to 1. Heat pumps have the capability of reaching a COP of between 2-4. A conservative estimate was made here due to changes in the performance of heat pumps when the temperature goes below freezing, which is when the largest draw of electricity for their use would be expected to spike.

line 143 in *'models/combining_results_for_output.py'*

7. Multiply the yearly electricity usage for heating with the peak ratio to convert the kWh/year value to the peak kWh/year value.

Substations care mainly about the peak usage rather than the average.

line 167 in *'models/combining_results_for_output.py'*

8. The value for the discrete grouped bins with an electric heating source is then taken as the value of the peak electrical energy added to the network for a home that switched to an electric heat pump. This is an overestimation for several reasons.
    - The COP is set to 1
    - The data is calculated for all electric heating sources, including less efficient ones that would presumably raise the cost and thus the expected peak.

9. Once the predictions have been made for all homes, not in the EPC database, the appropriate peak load is mapped to each home.

line 166 in *'models/combining_results_for_output.py'*

10. Aggregate the additional peak loads using the polygons for the substation distribution areas.
11. Compare the aggregated total to the station headroom that serves that polygon to get the load difference for these areas.

This does make a direct comparison between the additional peak load (MWh) and the demand headroom (MVA). While the two units are the same, their operation may have practical differences. Some additional caveats:

- Only polygons which contained a substation datapoint have the calculation performed. The areas without a substation data point or an empty headroom value for the substation do not appear in the load difference plots.
- When comparing, areas with multiple substations use the sum of the multiple station headrooms.
- Negative values indicate areas where the additional load is larger than the current headroom, and a substation would have to be upgraded to handle the load.

This calculation was only done for the Primary station level, as this is one of the only levels where the stations have a value for the headroom. This work can be easily propagated to the Bulk Supply level. Some other levels such as the distribution level have only discrete 'extensive capacity available', 'capacity available', and 'no capacity available' values for the substations. No data that would allow for a numerical value to be attached to these labels could be found. Future work should concentrate on this more fine-grained distribution level and determining these numerical values. The same methods described above would apply, and the additional peak load can be aggregated for these smaller polygon areas for a comparison to be made.

Results

Below are some of the resulting plots for the additional peak load and the load difference. Figure 1 is the additional peak load for the Bulk Supply Point areas. The additional peak load varies greatly between the supply areas. Figure 2 is a similar plot for the Primary Supply point areas. Figure 3 shows the load difference for the Primary Supply point areas. As can be seen, several areas are missing indicating there was no data available for the stations serving those areas. In this plot, several areas require upgrades to their electrical network before the mass adoption of heat pumps.

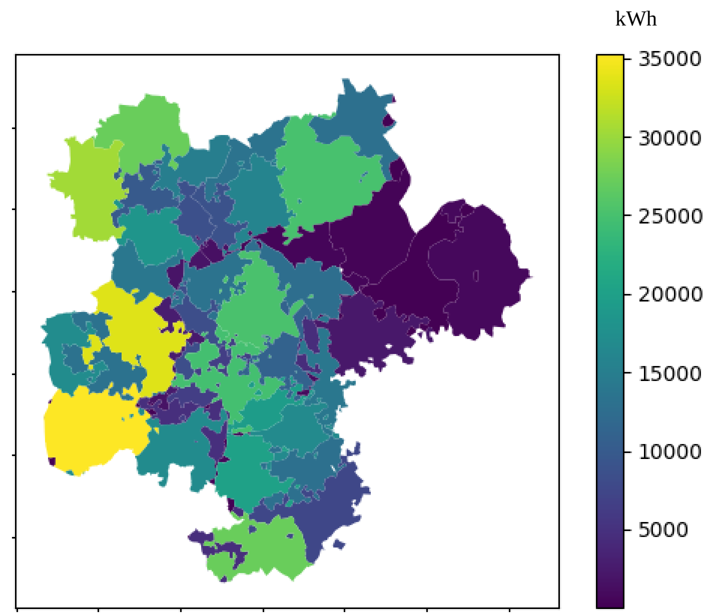

Figure 1 Bulk Supply Point aggregated additional peak loads.

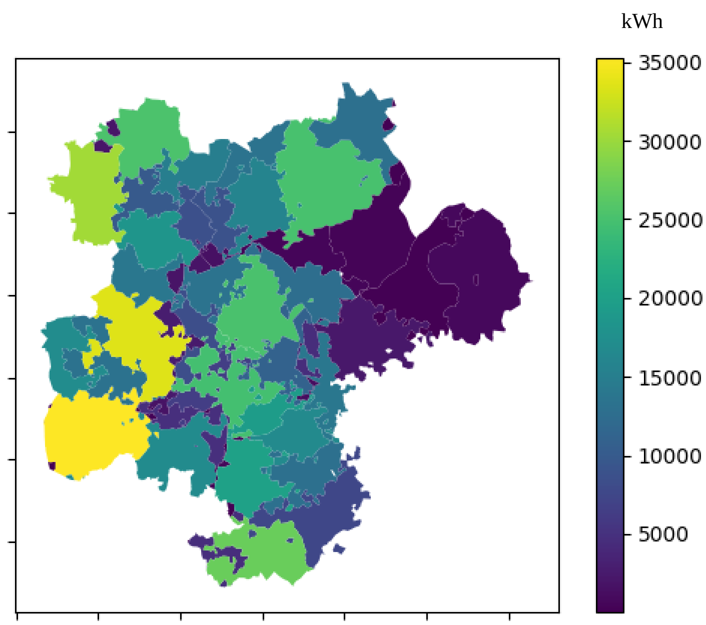

Figure 2 Primary Distribution area additional peak loads

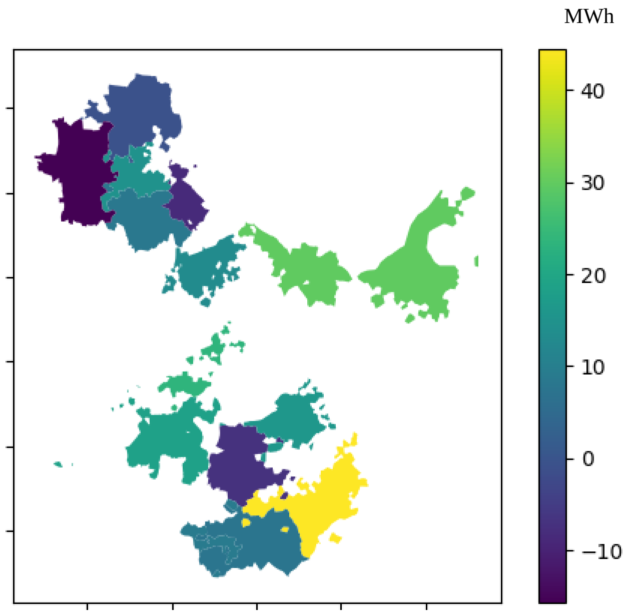

Figure 3 Primary distribution point peak load difference