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Electrification of Heat and the Impact on the Scottish Electricity System: Executive Summary

Delta Energy and Environment / Smarter Grid Solutions

1. Background

Approximately half of the final energy consumed across Scotland is used to provide heating and cooling services in the domestic and non-domestic built environment. With the direct and indirect reliance on conventional fuels to supply heat, transformative change in the energy supply and demand sectors will be required to achieve the Scottish Government's stretching climate change targets.

To better understand the potential impacts of electrifying a proportion of heat demand the Scottish Government commissioned a model to represent the electrification of heat and electricity network capacity (referred to here as the "Tool"). The research also produced a detailed report assessing the potential uptake of a range of heating technologies in Scotland, and their technical and economic impacts and limitations. The scenario as presented represents one plausible scenario for the expansion of electric heat demand.

2. Key findings

- By 2050, peak electricity demand in Scotland on a peak winter weekday could exceed 10 GW depending on the assumption around the uptake of electric-based heating technologies such as heat pumps, especially in the residential and commercial sector [Note: For the purpose of this study, Delta-ee looked only at the potential for electric-based heating in buildings within the residential, commercial, and industrial sector, and did not consider other sectors such as transport, street lighting, and agriculture]. This is an estimated 66% increase of 4 GW from a base case (current) of 6 GW peak electricity demand. This peak is expected in the 12 – 6 PM time block (after 4.30 PM in preparation for occupants to come back from work / school; and while commercial and industrial sectors are still within working hours).
- With the displacement of some electric storage heaters by heat pumps, the peak in the 12-6 AM time block reduces in relation to the other peaks. Less electricity is consumed overnight and is reallocated to later time blocks, especially the 12-6 PM time block.
- The increase in peak electrical demand by 2050 is observed despite the extension of district heating schemes to meet an estimated 7.4TWh of Scotland's heating demand by 2050 (up from the current 0.3 TWh) and offsetting some individual electric-based central heating, and despite efficiency improvements made e.g. better insulation levels in newbuilds, demolitions of poorly insulated buildings, improvements in industrial

process efficiencies, etc. The peak demand output displayed in Figure 2 does not take into account peak shaving solutions (such as increased uptake of thermal storage technologies) or the introduction of dynamic time-of-use pricing.

- Due to the high level of uncertainty over the future heating market, particularly given the time period of the study further scenarios exploring sensitivities could be run. This includes different assumptions including incentives and regulation, different energy prices, faster or slow technology cost reduction and performance improvement, customer attitudes and heating industry investment.
- By 2050 and based on the loads illustrated in Figure 2, there could be substantial power network reinforcements required across Scotland as a result of the increase in electrical heat demand (assuming there are no increases in current connected generation capacity) and scope for smart approaches to manage the new electrical heating demand.

3. Introduction

There are a number of potential opportunities in decarbonising electricity supply, and using low carbon energy sources to displace conventional heating and transport fuels. However, several factors will influence the extent of the impact on the whole energy system.

The peaks and troughs in heat demand (both within a day and across the seasons) are far greater than the variations in electrical demand. They create a challenge for electricity generating assets which, in the absence of storage, may be underutilised for long periods. A higher penetration of electrical heating may also require additional investment in low (or lower) carbon generation sources to meet this additional demand. This introduces a complex short and long-term dynamic, where short-term increases in load may be met by increased (higher carbon) thermal output prior to the system adapting to this change in demand.

Electrification of heating can also place further pressure on the network infrastructure required to deliver the additional power to demand centres. There are potential impacts on the high voltage transmission network, particularly if the background generation is located in different geographical zones within the GB system, but there is likely to be a substantial impact on the distribution network, particularly if electrification of heat is rolled out in localised clusters.

4. Methodology

In order to build the Tool, two models were merged:

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Electric Heating Demand Model	*Electricity Network Capacity Model*	*Electrification of Heat and Electricity Network Capacity Model: Scotland*
STEP 1	**STEP 2**	**STEP 3**

Step 1: Delta-ee calculated electric heating demands (and in the case of Combined Heat and Power technologies, production) across four time blocks on an average peak winter weekday based on Delta-ee's calibration scenario of

technology deployment up to 2050 [see Appendix for scenario assumptions]. The key output of this exercise was the aggregated winter peak load profiles segmented by end-user type (residential, commercial, and industrial), year, and region (B0-B6 as per the GB Transmission System Boundaries – see Figure 1). The four time blocks (12 AM – 6AM; 6AM – 12PM; 12PM – 6PM; 6PM – 12AM) were applied instead of half-hourly profiles to be in alignment with the Scottish Government Electricity Dispatch Model.

Step 2: The outputs of Delta-ee's Electric Heating Demand model was directly fed into Smarter Grid Solutions' Electricity Network Capacity Model. The model was constructed using publicly available information from Long Term Development Statements (LTDS) for the network elements, and data from the EA Technology TRANSFORM report on network reinforcements. This model took the peak demands from the Delta-ee model and projected this onto the Scottish power network model. The key output of this part of the model was the identification of future network constraints, and the cost of potential reinforcements to relieve these constraints. The model focused on 33kV networks with assumptions made in regard of 11kV and LV network upgrades.

Step 3: The merged Tool demonstrates the aggregate electric heating demand changes and its constraints on the Scottish grid out to 2050. The aggregate demand changes were aligned to the input requirements for the Scottish Government Electricity Dispatch Model, to allow a more detailed system wide impact study to be undertaken. Considerations were also made to be consistent with, and be able to support the use of, the Whole System Energy Model for Scotland currently being developed from a UK TIMES basis. The capability to increase generation plant capacity, electric vehicle uptake, and demand peak shaving has been incorporated into the merged Tool (in a percentage format). The model considers thermal constraints at substations and transformers across Scotland, but does not account for the more complex constraints in circuits.

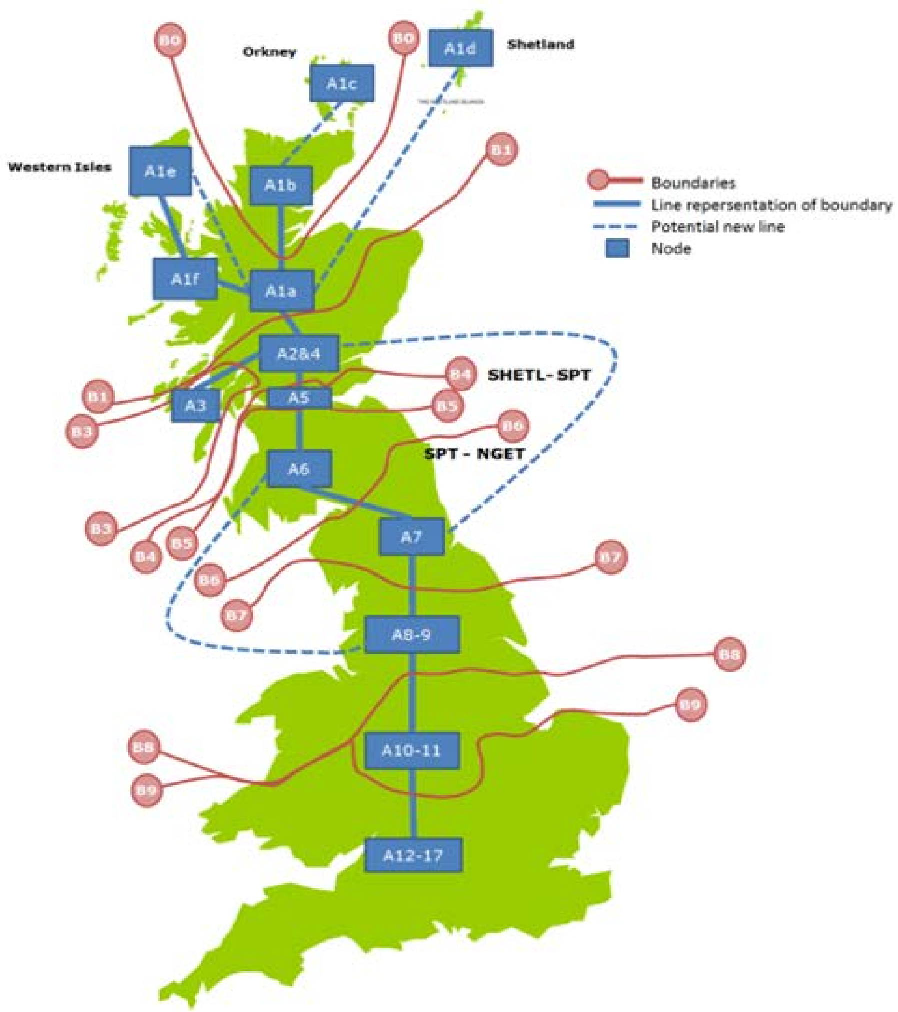


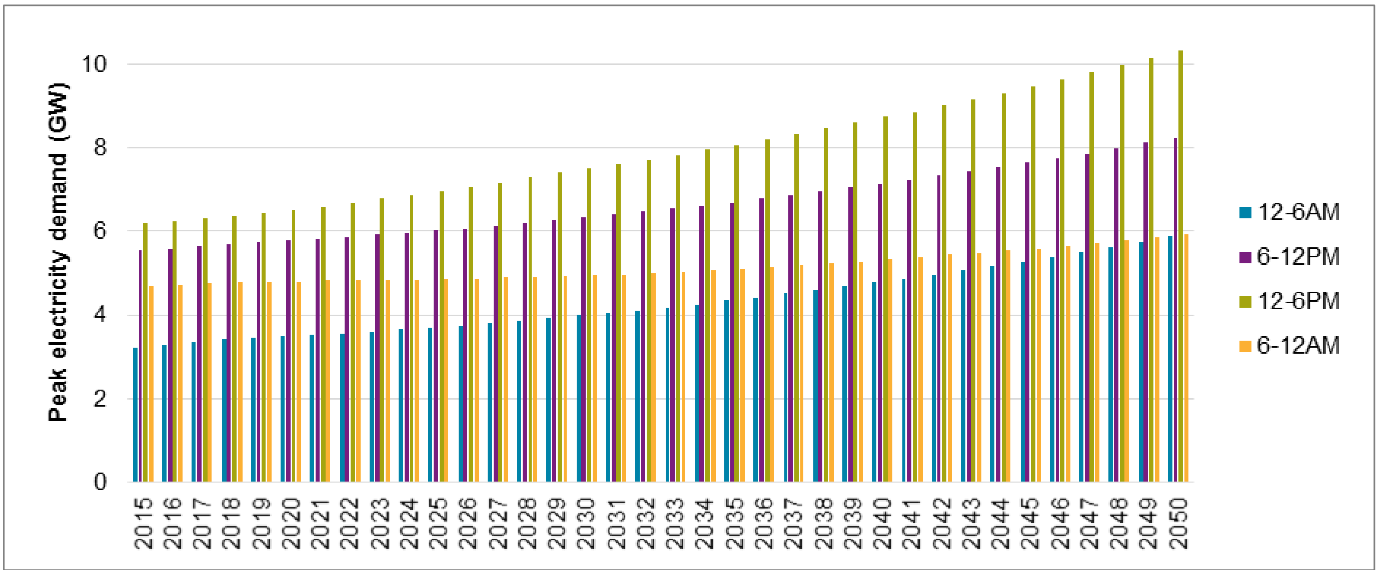
Figure 1: GB Transmission System boundaries (B0 –B6) and the Scottish Government Electricity Dispatch Model boundaries (A1-A6)

5. Results

Potential Peak Electric Demand (2015 -2050)

The outputs contained in the in-depth report refer to Delta-ee's reference scenario, deemed as a plausible but challenging evolution of the sector. It is important to note that there is a high level of uncertainty about future UK government heat policy as well as other factors affecting the heating market, particularly given the time period being studied. Further scenarios incorporating different assumptions for incentives and regulation; different energy prices; faster or slow technology cost reduction and performance improvement; customer attitudes; and heating industry investment could be run to explore sensitivities.

Figure 2: Forecast Peak Electric demand, Scotland (2015 – 2050) [Winter Peak, Weekday]



Note: Delta-ee recommend using half-hourly or hourly time bands to understand peak electric heating demand for future research. By using 4 broad time bands, we are unable to model diversity factors which would lower total estimated peak demand.

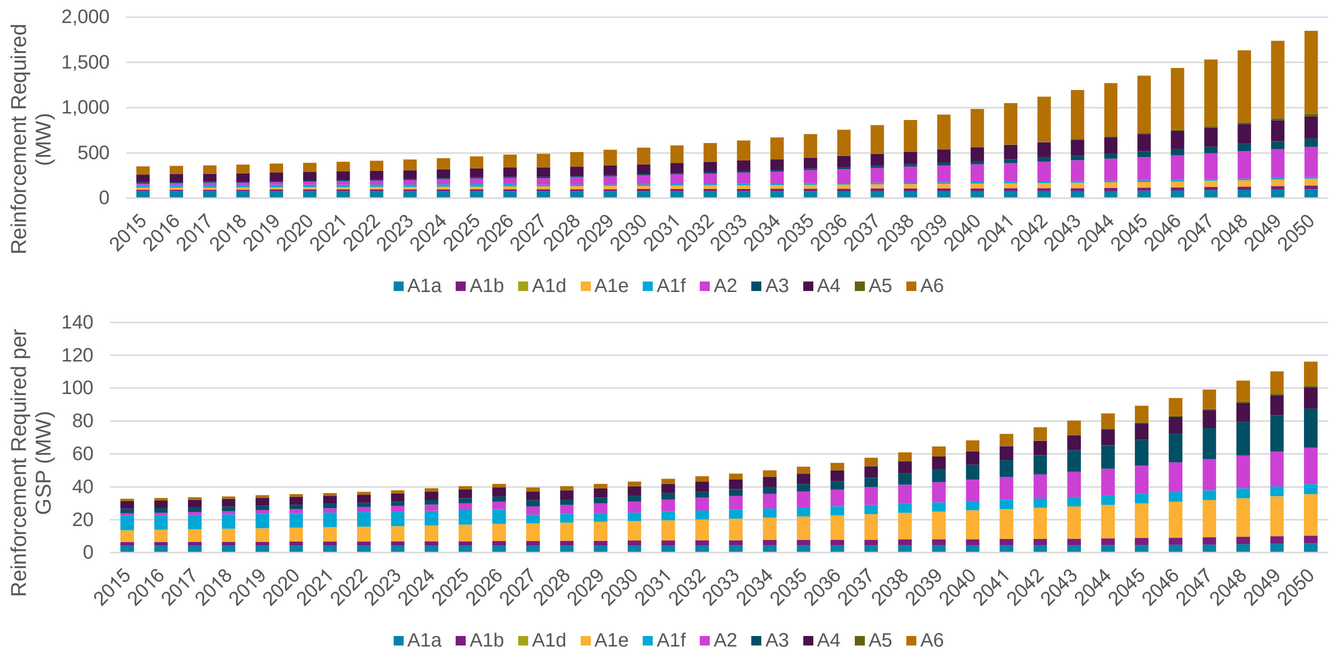
Potential Reinforcement Requirements

By 2050 and based on the loads illustrated in Figure 2, substantial reinforcements could be required across Scotland as a result of the increase in electrical heat demand (assuming there are no increases in current connected generation capacity that would reduce the net peak demand increase).

From 2035 onwards, the rate of change in number of reinforcements required increases significantly. This may be counteracted in part by increase in the use of energy storage technology, demand response measures, and growth in distributed generation.

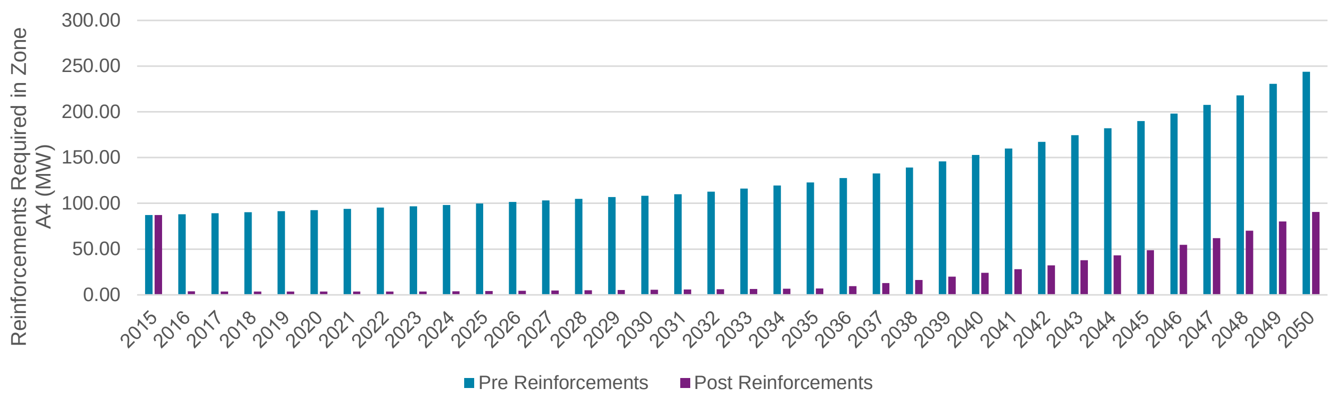
Of all the regions, A6 has the biggest increase in reinforcement overall (see Figure 1 for breakdown of regions). A1e and A1f have the greatest reinforcement required per grid supply point (GSP) – these zones cover Skye and Harris. The reinforcements are greatest here because the network is composed of either single transformer GSPs, or GSPs with relatively small N-1 secured capacity. The increasing electrical demand in these areas will lead to significant reinforcement requirements. The thermal limits of the subsea cables which link these GSPs to the mainland will also play a limiting factor on future increases in demand or generation.

Figure 3: Reinforcement requirements per region



The required reinforcements across all transformers in the A4 network region are shown in Figure 4 below for pre and post reinforcements. A selection of conventional and smart reinforcement options were applied, in key years in order to increase the available capacity at the transformers. Pre-reinforcement figures represent the reinforcement required at the transformers before applying upgrades options. Post-reinforcement figures represent the reinforcement required at the transformers after applying upgrades to the network.

Figure 4: Reinforcement required in region A4 (MW)



6. Appendix

Below, a short summary is provided of the key factors that shaped and influenced Delta-ee's reference forecast. Please note that this is one plausible scenario which has not been designed to be a projection or preferred scenario.

Rather, the aim of this scenario is to provide insight into one plausible evolution of the sector, and is used to calibrate and test the overall model operation.

<table>
<tr><th>POLICY AND ENERGY PRICES</th><th>TECHNOLOGY</th></tr>
<tr><td>‘Electrification of heat’ ambition remains, but is delayed
Renewable Heat Incentive reduces gradually in the next few years to 2020, and disappears completely by 2026. However we simulate further incentives by reductions in the electricity price for electric heating.
New build regulations do not tighten until 2021/22, at which point air-source HPs become the base case in off-gas dwellings.
Insulation in retrofit is the ‘low cost’ option that policy makers focus on for savings energy and reducing carbon emissions.
2020 renewable and carbon targets are missed or just about met. Commitment to hitting 2050 targets remains, but are only met close to 2050.
Gas CHP provides annual carbon savings through to 2030 under DECC’s central grid decarbonisation trajectory assumptions, after which additional CHP leads to net increase in annual emissions. First time installations of industrial CHP assumed to be near zero after 2030 – mainly replacement market.
Electricity prices rise at faster rate than gas prices. By 2050, electricity prices on average 28% higher than 2015 prices.</td><td>Slow growth in heat pump and CHP sales results in gradual cost reductions
Heat pump manufacturer and boiler makers continue to offer HP solutions and gradually add hybrids to their portfolio.
Fully installed prices still fall quickly in the short term as installer skill improves, but more slowly in the longer term as uptake post 2020 is low.
Efficiency still gradually improves for heat pumps and CHP due to technology performance improvements coming from Asia / Germany, and as system design, insulation levels of buildings and lower temperature heat distribution systems become more common.
Industrial HP technology advancement to handle medium temperature process heat by 2040.</td></tr>
<tr><th>CUSTOMERS AND INSTALLERS</th><th>INDUSTRY ‘PUSH’</th></tr>
<tr><td>Customer awareness for low carbon heating remains low initially, with installers continuing to focus on conventional heating systems for some time
No real change in customer awareness and attitude until 2020 at which point building regulations help drive the awareness and trust in heat pump technology.
Customer confidence for ‘low carbon’ remains low following a sharp reduction in FiT for PV and a small reduction in the RHI in 2016.
Installers and heating industry remain cautious about investment in training to install heat pump and CHP technologies, and continue to focus on offering conventional heating systems until 2020 - 2025</td><td>Appliance manufacturers and energy suppliers slow to invest in the low carbon heating market
Conventional heating manufacturers don’t invest in upskilling installers and driving heat pump sales for several years.
Heat pump manufacturers continue to introduce more products to the UK, but are more cautious about the opportunity in the UK market following revisions in the RHI.
Energy suppliers invest in innovative heat business models such as selling heat-as-a-service. Electricity suppliers introduce heat pump electricity tariffs post 2030 to help stimulate uptake of HPs.</td></tr>
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