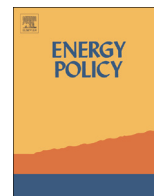




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Short communication

## Raising the temperature of the UK heat pump market: Learning lessons from Finland



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## HIGHLIGHTS

- Heat pumps are expected to play a key role in meeting the UK's 4th carbon budget.
- Today, heat pump deployment per capita in the UK is one of the lowest in Europe.
- Finland offers some policy lessons given its high level of heat pump deployment.
- Policies: raising build rates, building standards and heat pump cost-effectiveness.
- Deployment efforts should focus on buildings not heated by relatively low-cost gas.

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## ABSTRACT

Heat pumps play a central role in decarbonising the UK's buildings sector as part of the Committee on Climate Change's (CCC) updated abatement scenario for meeting the UK's fourth carbon budget. However, the UK has one of the least developed heat pump markets in Europe and renewable heat output from heat pumps will need to increase by a factor of 50 over the next 15 years to be in line with the scenario. Therefore, this paper explores what lessons the UK might learn from Finland to achieve this aim considering that its current level of heat pump penetration is comparable with that outlined in the CCC scenario for 2030. Despite the two countries' characteristic differences we argue they share sufficient similarities for the UK to usefully draw some policy-based lessons from Finland including: stimulating new-build construction and renovation of existing stock; incorporating renewable heat solutions in building energy performance standards; and bringing the cost of heat pumps in-line with gas fired heating via a combination of subsidies, taxes and energy RD&D. Finally, preliminary efforts to grow the heat pump market could usefully focus on properties unconnected to the gas-grid, considering these are typically heated by relatively expensive oil or electric heating technologies.

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## 1. Introduction

The UK has committed to reduce its greenhouse gas emissions (GHGs) by 80%, relative to 1990 levels by 2050 (CCC, 2015). To ensure it makes regular progress towards meeting this long-term target the Committee on Climate Change (CCC)<sup>1</sup> was established to set five-yearly carbon budgets. The fourth carbon budget (2023–

27) was ratified in 2014 and this process led to an updated 2030 abatement scenario that outlined how an emissions reduction of 63% by 2030 on 1990 levels could be achieved (CCC, 2013b).

Decarbonisation of heat sits at the centre of the fourth carbon budget considering that in 2012 direct emissions<sup>2</sup> from heat consumption in buildings accounted for approximately 12% of total UK GHGs, (CCC, 2013c). These emissions are expected to fall by half under the 4th carbon budget, falling from 91 MTCO<sub>2</sub>e in 2012 to 46 MTCO<sub>2</sub>e by 2030 (CCC, 2013c). Achieving this target will require a radical transformation of the UK's heat sector considering the

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<sup>1</sup> The Committee on Climate Change (the CCC) is an independent, statutory body established under the Climate Change Act 2008 whose purpose is to advise the UK Government and Devolved Administrations on emissions targets and report to Parliament on the progress made towards reducing greenhouse gas emissions and preparing for climate change.

<sup>2</sup> Direct GHG emissions are from sources owned or controlled by the reporting entity. In buildings this relates to space heating, cooking, hot water etc.

inefficiency of its building stock and the prevalence of gas fired heating (Eyre and Baruah, 2015).

The wide-scale deployment of heat pumps<sup>3</sup> is central to decarbonising heat under the CCC scenario, despite accounting for only a tiny fraction of the UK's current building heat supply at present (approx. 0.2%). In contrast, some European countries have enjoyed wide-scale heat pump deployment over the last 10 years (Nowak et al., 2014). Finland represents one such market leader where levels of heat pump penetration are comparable with that envisaged under the CCC's scenario for 2030. Consequently, this paper examines two questions: (1) what level of UK heat pump deployment is outlined between now and 2030 under the CCC scenario; and (2) what lessons can the UK learn from Finland to help realise this level of deployment?

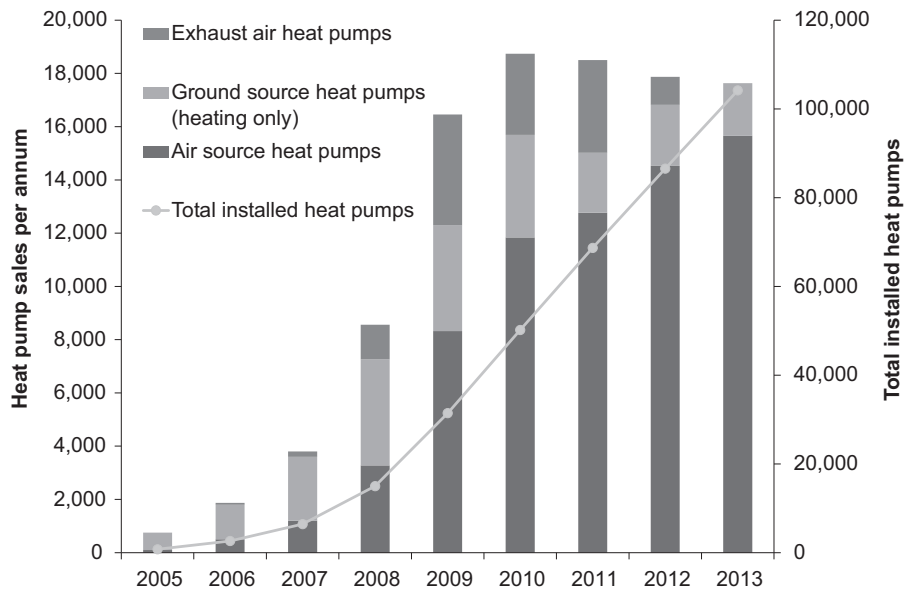


Fig. 1. UK heat pumps sales per annum and total operational devices (Nowak et al., 2014).

## 2. Methodology

To address the first question three datasets were examined to identify the size of the UK heat pump market (DECC, 2014b, 2014c; Nowak et al., 2014). These were compared against current deployment levels in Finland (Statistics Finland, 2013c) and those outlined in the CCC's 2030 UK scenario (CCC, 2013a, 2013c). To address the second question academic, government and industry literature was examined to identify the factors responsible for driving growth within the Finnish heat pump market. Statistical evidence from national databases and energy sector reports was subsequently used to scrutinise whether or not lessons could be helpfully transferred to the UK. The authors are conducting original empirical work to test the robustness of these drivers and their applicability to the UK. Results will be presented in a full-length academic paper.

<sup>3</sup> A heat pump is defined as 'a machine, a device or installation that transfers heat from natural surroundings such as air, water or ground to buildings or industrial applications by reversing the natural flow of heat such that it flows from a lower to a higher temperature. For reversible heat pumps, it may also move heat from the building to the natural surroundings' (EU, 2010 p.19).

## 3. Results

### 3.1. An overview of UK heat sector and heat pump market

In 2013 the UK's domestic and service sector heat demand stood at 598TWh (DECC, 2014b), with the majority of this being satisfied by gas fired boilers (77%) and the rest by electricity (12%), oil (7%), bioenergy and waste (2%), solid fuel (1%) and district heating (1%) (DECC, 2014a). Heat pumps accounted for only 0.2% of the total domestic and service sector heat consumption<sup>4</sup> (DECC, 2014a), with 104,000 heat pumps (Nowak et al., 2014) generating 1TWh of primary energy<sup>5</sup> (DECC, 2014c) (Fig. 1).<sup>6</sup>

### 3.2. UK heat sector under the 2030 CCC scenario

Heat pumps play a central role in decarbonising the UK's heat sector under the CCC scenario, delivering a 14 MtCO<sub>2</sub>e reduction in emissions by 2030 on 2012 levels (CCC, 2013c). Four million domestic heat pumps across 13% of homes provide 31 TWh of primary energy production in the residential sector. A further 20 TWh generated from approximately 600,000 heat pumps in non-domestic buildings, accounting for around 30% of non-residential heat demand (CCC, 2013c; Verco, 2014). Together these 4.6 million heat pumps produce 51 TWh of renewable heat by 2030, accounting for approximately 12% of the UK's 435 TWh building sector heat consumption in 2030.<sup>7</sup>

Between 2010 and 2013 UK heat pump sales per annum averaged 18,000 units (Nowak et al., 2014). Were this pattern to continue between 2013 and 2030 the UK would see only 400,000

<sup>4</sup> It is unclear from the statistics whether this includes industrial heat pumps.

<sup>5</sup> This excludes their electricity input.

<sup>6</sup> EHPA data available only from 2005, thus excluding heat pumps installed before this date. Figure 1 assumes that all devices sold since 2005 are still in operation today. Air source category contains a small number of sanitary hot water only devices. Exhaust HPs includes both air to water and other varieties.

<sup>7</sup> The consumption value taken from in-house CCC calculations undertaken for the revised 4th Carbon Budget reports. Demand is lower than today primarily due efficiency improvements in the building stock (CCC, 2013d).

units installed by 2030,<sup>8</sup> less than 9% of the 4.6 million heat pumps envisaged by the CCC scenario. Instead sales would need to average 265,000 units a year, almost 15 times the current rate. Additionally, these sales would need to deliver a 3 TWh increase of primary energy output per annum if output is to reach 51 TWh by 2030, representing a factor 50 increase on current levels. These examples illustrate the sheer scale of the challenge facing the UK if it is to realise these high levels of heat pump deployment.

### 3.3. An overview of Finland's heat sector and heat pump market

Historically Finland has relied heavily on the small-scale combustion of biomass and oil (light and heavy) for heating, together accounting for 90% of its space heating supply in 1970 (Statistics Finland, 2013b) (Fig. 2). However, by 2012 its heat supply mix had changed dramatically with district heating (DH) accounting for 40%, electricity 21%, biomass 21%, oil 11% and heat pumps 6%,<sup>9</sup> with gas contributing only 1% (Statistics Finland, 2013b, 2013d).

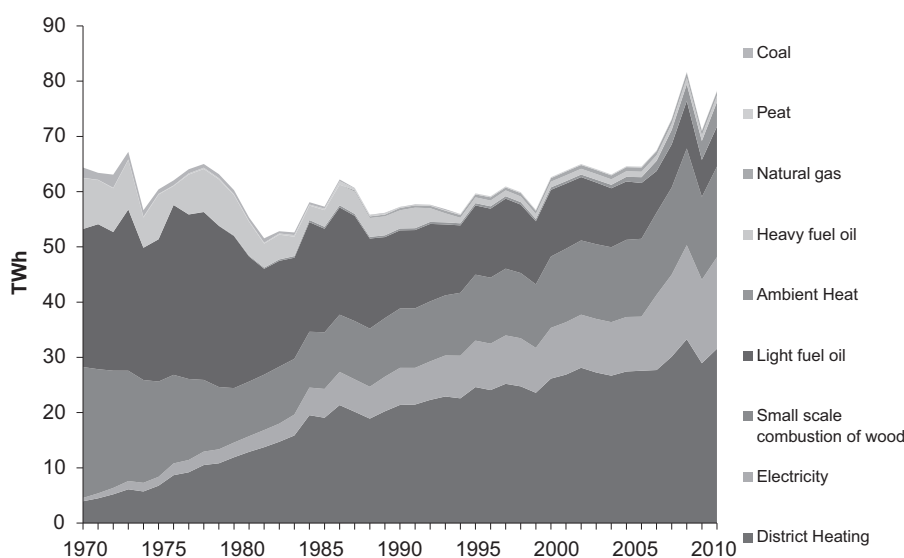


Fig. 2. Space heating supply mix for residential, commercial and public buildings in Finland 1970–2012 (Statistics Finland, 2013b).

The contribution from heat pumps is relatively new. In 1976 there were only 200 heat pumps producing 6 GWh of primary energy and by 1984 this had grown to nearly 14,000 in operation (Statistics Finland, 2013d). The market subsequently stagnated during the late 1980s and 1990s but sparked into life once more in the early 2000s. There was a 12 fold increase in the primary energy output from heat pumps between 2003 and 2012<sup>10</sup> (Statistics Finland, 2013d) and by 2012 there were just over half a million heat pumps producing 4.1 TWh of primary energy (Statistics Finland, 2013d), with the majority of output coming from air-source heat pumps<sup>11</sup> (61%) and the remainder from ground source heat pumps (GSHPs) (39%) (Fig. 3). The domestic sector dominated supply accounting for 93% of heat pump output in 2012, with heat pumps installed in 18% of all homes<sup>12</sup> (Statistics Finland, 2014b).

### 3.4. Comparing the Finnish heat pump market with UK and Europe

Fig. 4 illustrates the impressive size of the Finnish heat pump market compared with the UK and its other European counterparts (Nowak et al., 2014). We find that in 2013 the total number of heat pumps operating per capita was the third highest in Europe ( $n=21$ ) with one device installed per 10 people. In comparison the UK ranked 16th with two devices per 1,000 people; only 2% of Finland's level. Finland also achieved the second highest sales per capita in Europe ( $n=21$ ), with more than one heat pump sold per 100 people in 2013. In comparison the UK ranked 18th with three heat pumps per 10,000 people; only 3% of Finland's level. Finally, in 2012 Finland ranked second highest in Europe ( $n=22$ ) in terms of heat output<sup>13</sup> per capita, recording 756 kWh/capita/annum. In comparison the UK ranked 20th achieving 10 kWh/capita/annum (Eurobserv'er, 2013); only 1% of Finland's level.

### 3.5. Comparing 2030 UK heat pump market with today's Finnish market

By comparing the level of heat pump penetration in Finland today (Section 3.3) to that outlined in the CCC's UK 2030 updated abatement scenario we find a number of similarities. For instance, the current number of heat pumps sold per capita in Finland for 2013 is almost double the annual rate envisaged under the CCC scenario for 2030, which is approximately 6 heat pumps sold per 1,000 people<sup>14</sup> (CCC, 2013c). Furthermore in 2012 Finland had heat pumps operating in approximately 18% of homes, compared to 13% of UK homes in the CCC scenario for 2030<sup>15</sup> (CCC, 2013c). Finally, in 2012 Finland's primary energy output from heat pumps per capita was greater than the 718 kWh/capita/annum outlined in the CCC

<sup>8</sup> This assumes that any faulty heat pump stock is replaced during this period.

<sup>9</sup> Primary energy output, i.e. excluding energy input such as electricity.

<sup>10</sup> 2012 is the latest available year for heat pump data released from Statistics Finland.

<sup>11</sup> This includes air-to-air and air-to-water.

<sup>12</sup> This ratio assumes that in 2012 there were 476,751 domestic heat pumps and 2,594,999 households in Finland (Statistics Finland, 2014c), equating to 18% of homes. The heat pump figure is calculated as 92% of total installed heat pumps, representative of the sectoral balance of HP output in Table 7.3. It assumes that heat pumps are on average the same size across these two sectors, which may in fact

(footnote continued)

underestimate the total number of domestic heat pumps as heat pump capacity (i.e. MW) is typically greater in the non-residential sector. It also assumes that one heat pump is installed per building, which may not always be the case in larger buildings.

<sup>13</sup> 2013 values not available for European comparison of heat pump output.

<sup>14</sup> CCC targets 400,000 per annum by 2030, with a population of 70 million people.

<sup>15</sup> Estimate is taken from the CCC, which envisages 4 million heat pumps across 30 million homes by 2030.

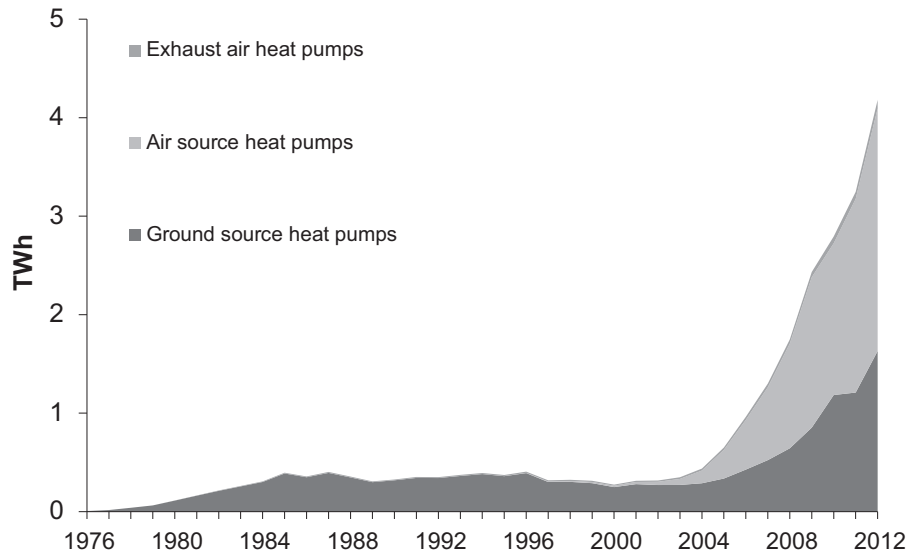


Fig. 3. Primary energy production of heat pumps in Finland 1976–2012 (Statistics Finland, 2013d).

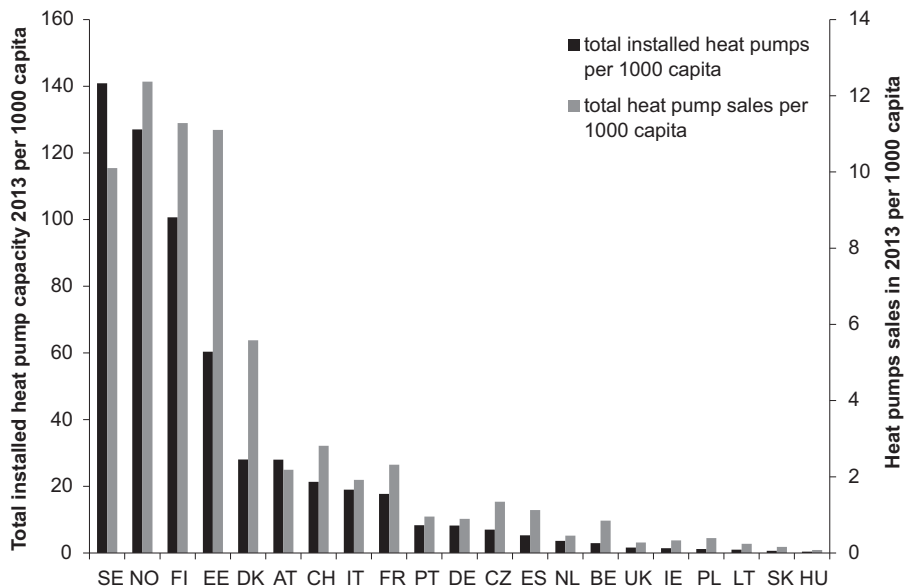


Fig. 4. Total heat pump capacity and number of installations per capita in 2012 (Nowak et al., 2014).

scenario<sup>16</sup> for 2030. Consequently, we now consider the factors responsible for this impressive level of deployment in Finland (Section 4.1) and whether lessons can be transferred to the UK to help accelerate its heat pump deployment (Sections 4.2 and 4.3).

## 4. Discussion

### 4.1. Factors driving Finnish heat pump market growth

To date little academic work has examined the reasons why the Finnish heat pump market has flourished. However, work undertaken by the European Heat Pump Association (EHPA) (Nowak et al., 2014), International Energy Agency (IEA) (IEA, 2013a) and

Finnish heat pump trade association (SULPU) (SULPU, 2014) identifies numerous drivers of Finnish heat pump adoption (Table 1).

### 4.2. Transferring lessons from Finland to the UK

Whilst the UK's and Finland's energy sectors exhibit some fundamental characteristic differences we argue that they share sufficient similarities to warrant a comparison to transfer some valuable lessons from Finland to help accelerate UK heat pump deployment. These include similar: (a) *high-level energy policy drivers*; and (b) *liberalised energy market structures*.

Focusing on the former we find that both countries have in place Climate Change Acts that include the same legally binding target of an 80% reduction on GHGs by 2050 compared to the 1990 levels (Ministry of Environment, 2015; CCC, 2015). They also have a shared focus on raising *energy security* and improving *energy affordability* through a combination renewable energy and energy

<sup>16</sup> CCC 2030 primary energy output from heat pumps is approx. 51 TWh and the population approx. 71 million.

**Table 1**  
Factors driving growth of Finnish heat pump market (SULPU, 2014; IEA, 2013a; Nowak et al., 2014).

Theme	Factor
Geographical	<ul style="list-style-type: none"> <li>● Cold climate creates large demand for heat</li> </ul>
Government policies	<ul style="list-style-type: none"> <li>● 2020 renewable energy target of 47% of gross final energy consumption in heating and cooling</li> <li>● Fossil fuel taxation has tripled since 2011</li> <li>● National Building Code (SRMK) outlines stringent energy performance standards that account for the carbon intensity of the building's heat supply</li> <li>● Government subsidy scheme to cover up to 20% of the costs of switching from oil &amp; electric-heating to renewable heating systems (e.g. heat pumps)</li> <li>● Between 45% and 60% of the labour costs of household renovations and extensions are tax-deductible</li> </ul>
Infrastructural	<ul style="list-style-type: none"> <li>● Gas network limited to the south and district heating networks to the cities leading to high propensity of relatively costly oil and electric heating systems</li> <li>● A strong new-build sector where heat pumps are installed in over half of new build homes</li> <li>● High concentration of modern, spacious and energy efficient housing</li> </ul>
Market	<ul style="list-style-type: none"> <li>● Strong ties with Sweden have enabled it to replicate effective business models and practices (e.g. marketing)</li> <li>● Comprehensive product and installer certification and training</li> <li>● Lobbying to influence the design of: national construction codes, subsidy programs, drilling licensing codes, EU-wide F-gas Act etc.</li> </ul>
Research and Development (R&D)	<ul style="list-style-type: none"> <li>● Falling heat pump prices due to technological and supply chain advances</li> <li>● Membership on IEA's heat pump R&amp;D implementation agreement has stimulated new business opportunities and working relationships</li> </ul>

efficiency policies (IEA, 2013b, 2012a) in the context that they have similar energy security<sup>17</sup> concerns, medium-term electricity price trends<sup>18</sup> and standards of living.<sup>19</sup> These policy drivers are also underpinned by another important similarity; their joint-membership to the EU. This means they are similarly constrained and/or enabled by EU law to implement energy policy. This comparison illustrates how both national governments are driven by similar high-level pressures to introduce sustainable energy technologies like heat pumps.

The other important similarity is that both countries have moved to liberalise their energy markets, placing a strong focus on market competition through the establishment of energy market regulators and competition authorities (IEA, 2012a, 2013b). On this basis we can assume that both countries are unable to simply initiate a nationwide roll-out of heat pumps via nationally owned energy companies. Instead this can be achieved primarily through market-based policy interventions. Additionally, both countries have predominantly unregulated heat markets where DH companies set competitive prices that are monitored through general competition law (Aronsson and Hellmer, 2009; DECC, 2013b), suggesting similar institutional barriers to entry for heat pump driven DH systems.

Despite these similarities the two countries exhibit some important differences, such as *housing stock*, *energy infrastructure* and *climate*, which are likely to have contributed to their different levels of heat pump penetration. We acknowledge that not all these factors can be easily replicated in the UK. Even so these differences illustrate how the UK potentially faces a greater challenge to develop its heat pump market than Finland, emphasising the critical need to make a concerted policy effort to overcome these barriers.

<sup>17</sup> In 2012 the percentage of net imports in gross inland consumption and bunkers, based on tonnes of oil equivalent, stood at 45% in Finland and 42% in the UK (Eurostat, 2014).

<sup>18</sup> Between 2010 and 2013 Finland's electricity price averaged 12.5 p/kWh and the UK 13.3 p/kWh (DECC, 2015). Figures are adjusted for exchange rates and include taxes.

<sup>19</sup> In 2013 GDP per capita stood at \$34,776 in the UK and \$32,164 in Finland (OECD, 2015).

Comparing the *age* of each country's housing stock we find that almost 20% of England's housing stock was built before 1919 (DCLG, 2014a), compared with 3% of the stock in Finland (Statistics Finland, 2013a). Older homes are typically less energy efficient than new ones due to the tightening of building regulations and advances in building fabric technologies. This impacts upon heat pump penetration given that they operate less efficiently in homes with high thermal losses (Delta Energy, 2014; Frontier Economics and Element Energy, 2013).

The countries' housing *type* is also different with 40% of Finland's housing stock being detached (Statistics Finland, 2014b) compared to England's share of 26%<sup>20</sup> (Randall, 2011). Detached homes are normally larger than other housing types making it easier to install GSHPs considering that they require working fluid pipes to be laid underground outside. With detached homes accounting for 85% of Finland's non-industrial primary heat pump output and GSHPs more than a third of total output (Statistics Finland, 2013d) (Fig. 2), the high concentration of detached homes is likely to have supported high-levels of heat pump penetration.

Turning to *energy infrastructure* the UK's gas infrastructure is much more extensive than Finland's. It stretches 285,000 km long (IEA, 2012a), serving more than 84% of homes (i.e. 23.2 million households) (DECC, 2014b). In contrast Finland's gas grid is constrained to the south and stretches only 3100 km long (IEA, 2013a), serving less than 1% of homes (i.e. 22,000 households) (Energy Market Authority, 2013). Unlike in Finland, the wide-scale availability of relatively affordable natural gas for heating in the UK has had a negative impact on heat pump adoption (Fawcett, 2011). Additionally, the ubiquity of gas heating means that most UK homes are typically fitted with gas-fired high temperature central heating systems that are incompatible with low-temperature output heat pumps (Delta Energy, 2014). Conversely, Finland has a much more comprehensive heat network than the UK<sup>21</sup> and this could offer an advantage considering that large heat pumps are

<sup>20</sup> English Housing Survey is only for England, not the UK as a whole.

<sup>21</sup> Finland's heat network serves 141,000 customers (Finnish Energy Industries, 2013) compared to 212,000 in the UK (DECC, 2013b), despite having only 8% the population.

compatible with district heat networks.

Finally, Finland's *climate* is generally much cooler<sup>22</sup> than the UK's, which contributes to Finland holding the highest energy consumption per capita of all the IEA countries (IEA, 2012b). We argue that this relatively high energy demand makes Finland a natural marketplace for heat technologies.

#### 4.3. Policy recommendations to raise UK heat pump deployment

Housing stock energy efficiency is normally improved either through replacing existing buildings with more efficient ones or by renovating the existing stock. The former is considered to have been crucial to the growth of Finland's heat pump market (SULPU, 2014). It has the advantage of presenting a natural opportunity for installing a new heating system at low cost and with minimum levels of disruption. Heat pump systems can also be fully integrated into a building's architecture (e.g. low-temperature central heating system) to work more efficiently. In 2013–14 Finland granted 29% more permits to build homes per capita than the UK (Statistics Finland, 2014a; Williams, 2013), presenting proportionally more opportunities for cost-effective heat pump installation. Consequently, we support current UK policy to increase the supply of both new-build homes (DCLG and HCA, 2015).

In parallel it is essential that regulations are in place to ensure new buildings meet very high energy efficiency standards and that these account for renewable heat solutions, as in Finland. Consequently, we support the inclusion of the 'in-house' renewable heat solution dimension of the UK's 'zero carbon homes' policy (DCLG, 2014b). Whilst new-build construction is important it is expected that 80% of the UK's in 2050 building stock has already been built (UKGBC, 2008), emphasising how important retrofitting will be to heat pump deployment. Looking to Finland, this might be encouraged in the UK through tax-breaks for homeowners to undertake renovations or extensions.

Another key difference is the countries' energy infrastructure. Unlike Finland, the UK has an extensive gas grid that means heat pumps are in direct competition with cheaper gas-fired heating (Nowak et al., 2014).<sup>23</sup> Consequently, before on-grid homes adopt heat pumps at scale they will need to become cost-competitive with gas heating. This could be facilitated by raising levels of support for publicly funded research, development and deployment (RD&D) to improve heat pumps' coefficient of performance<sup>24</sup> (COP) (LCICG, 2012). However, the UK's spend on energy RD&D programmes is comparatively low, ranking 19th out of 25 OECD countries in 2011 compared to Finland which ranked first<sup>25</sup> (IEA, 2013c).

The UK could also replicate Finland's introduction of capital grants or tax breaks to help cover the upfront cost of heat pumps (Table 1). A capital grant scheme called the Renewable Heat Premium Payment (RHPP)<sup>26</sup> was recently discontinued in the UK and replaced with the Renewable Heat Incentive (RHI), which instead of upfront capital offers a long-term<sup>27</sup> financial incentive per unit

of heat generated by 'low-carbon' heat technologies (e.g. heat pumps). Running these two schemes in parallel could ease the high upfront cost barrier and provide a long-term incentive to adopt low-carbon heat technology (Hannon et al., 2013; Hannon et al., 2015). However, funds would need to be reappropriated from other subsidies (e.g. RHI) and/or generated through other means (e.g. taxes). Again, the UK could follow Finland's lead by increasing fossil fuel taxation to raise the cost of gas heating compared to heat pumps, simultaneously raising low-carbon heat subsidy funds and making gas heating less attractive to consumers. However, raising taxation is unlikely to be politically feasible at present given the negative impact it will likely have on the fossil fuel industry and consumers' energy bills.

Finally, we support the recommendation from the National Grid (2014) and Delta Energy (Delta Energy, 2014) to initially focus efforts on promoting heat pump adoption amongst the 3.6 million off-gas-grid centrally heated homes<sup>28</sup> (DECC, 2014b). Whilst not all these properties will be heat pump compatible, this approach could make a significant contribution to realising the CCC scenario's 4.6 million installed heat pumps. However, this assumes that off-grid electrical and oil heating is less economical than gas and that heat pump cost-effectiveness is unlikely to dramatically improve over the next few years.

## 5. Conclusions and policy implications

The UK's 4th carbon budget is extremely ambitious and is likely to require a major transformation of the UK's heat sector by 2030, not least the wide-scale deployment of heat pumps. The CCC's updated abatement scenario sees renewable heat output from heat pumps increase by a factor of 50 over the next 15 years. The scale of this challenge points to the need for the UK to learn lessons from other countries, like Finland, whose current heat pump deployment is similar to that outlined under the UK's 2030 CCC scenario.

Whilst many of Finland's characteristics have facilitated its particularly high level of heat pump penetration (e.g. housing stock, energy infrastructure and climate) we argue that the UK and Finland share sufficient similarities (e.g. energy policy objectives, liberalised energy market and EU membership) for us to reasonably transfer some valuable policy lessons to stimulate UK heat pump deployment. These include: (1) promoting new-build construction and/or renovation of existing stock; (2) incorporating renewable heat solutions within building regulations; (3) bringing heat pump costs in-line with gas fired heating via subsidies, taxes and energy RD&D; and (4) initially focusing heat pump deployment efforts on off-gas-grid properties, which are typically heated by comparatively expensive oil or electricity. Ongoing fieldwork will analyse and refine these recommendations to inform the UK's heat decarbonisation strategy.

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<sup>22</sup> The average temperature in Helsinki is 5.4 °C compared to 9.6 °C in London (Climatedata, 2014).

<sup>23</sup> EHPA estimate domestic gas at €0.053/kWh, heat pump (useful energy) at €0.082/kWh and electricity at €0.17/kWh. These are fuel input-heat output costs and disregard capital (e.g. upfront investment) and other operational costs (e.g. maintenance).

<sup>24</sup> This represents the efficiency of the heat pump and is calculated as energy output divided by energy input.

<sup>25</sup> The UK spent 0.022% of its GDP on public energy RD&D compared to Finland, which spent 0.14%.

<sup>26</sup> The RHPP scheme made one-off payments to householders to help them buy renewable heating technologies such as heat pumps.

<sup>27</sup> Payments are for 7 years for domestic and 20 years for non-domestic installed technologies (Ofgem, 2015b, 2015a).

<sup>28</sup> The majority of homes unconnected to the gas grid in England (data unavailable for UK as a whole) are in rural areas, with more than half of these relying on oil-fired heating (DECC, 2013a). A smaller proportion of off-grid homes are in urban areas, normally heated by electricity or district heating systems (DECC, 2013a).

paper's analysis.

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