Industrial Heat Pumps in the UK
Current Constraints and Future Possibilities

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Future Work
Energy Pricing in the UK
Energy Pricing in the UK - Electricity

Eurostat (2018)
Electricity in the UK

UK Pence/kWh

- Medium
- Large
- Ex. Large

UK
Energy Pricing in the UK - Gas

Eurostat (2018)
Energy Pricing in the UK - Gas

UK Pence/kWh

Small
Medium
Large
# Energy Pricing in the UK

<table>
<thead>
<tr>
<th>RHI Commercial paid over 20 years</th>
<th>p/kWh from 1 Jan 2015</th>
<th>p/kWh from 1 Apr 2015</th>
<th>p/kWh from 1 Jul 2015</th>
<th>p/kWh from 1 Oct 2015</th>
<th>p/kWh from 1 Jan 2016</th>
<th>p/kWh from 1 Apr 2016</th>
<th>p/kWh from 1 Jul 2016</th>
<th>p/kWh from 1 Oct 2016</th>
<th>p/kWh from 1 Jan 2017</th>
<th>p/kWh from 1 Apr 2017</th>
<th>p/kWh from 1 Jul 2017</th>
<th>p/kWh from 1 Oct 2017</th>
<th>p/kWh from 1 Apr 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar thermal</td>
<td>10.0</td>
<td>10.16</td>
<td>10.16</td>
<td>10.16</td>
<td>10.28</td>
<td>10.28</td>
<td>10.28</td>
<td>10.28</td>
<td>10.44</td>
<td>10.44</td>
<td>10.44</td>
<td>10.44</td>
<td>10.75</td>
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<tr>
<td>GSHPs</td>
<td>8.7</td>
<td>8.84</td>
<td>8.84</td>
<td>8.84</td>
<td>8.95</td>
<td>8.95</td>
<td>8.95</td>
<td>8.95</td>
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<td>9.09</td>
<td>9.09</td>
<td>9.09</td>
<td>9.36</td>
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<tr>
<td>ASHPs</td>
<td>2.5</td>
<td>2.54</td>
<td>2.54</td>
<td>2.54</td>
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<td>2.57</td>
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<td>2.57</td>
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<td>2.61</td>
<td>2.61</td>
<td>2.61</td>
<td>2.69</td>
</tr>
</tbody>
</table>

RHI rates published by Ofgem - rates change with inflation each year from April.

RHI rates for ground source heat pumps fall to 2.79p for use over 15% of the full rated annual capacity.

¹ RHI rates for biomass fall to 2.14p for use over 35% of the full rated annual capacity.

¹ RHI tariff for biomass has fallen from 8.8 in June 2014 down to 3.05p from 1 April 2018.
Seasonal Performance (Hughes, 2018)
Seasonal Performance (Hughes, 2018)

SPFH4 vs Mean temperature lift by type of heat emitter

- Radiators
- Rads not upsized
- Underfloor heating

Points labeled with S01, S02, S05, S07, S10, S14, S27, S29, S30, S34, S35, S39, S51, S57.
Replacing R410A
R410A Replacement

[Graph showing performance of different refrigerants and their lifts.]
And Waste Heat?
Waste Heat Potential in the UK

The potential for recovering and using surplus heat from industry Final Report for DECC 05/03/2014 Led by Element Energy Limited
Waste Heat Potential in the UK

However there are disparities in the capacities....
Element Energy 300 TWh of industrial heat with 1/6 wasted = 50 TWh/y
Element Energy state that for district heating = 28 TWh/y
Element Energy state that ¼ of this heat is recoverable = 12.5 TWh/y
Cooper et al state that max. recoverable energy in DH = 7.5 TWh/y

Limitations identified by Cooper et al (2015) include temperature, distance of networks, heat losses, seasonal needs and economics.
Booster Heat Pumps
For upgrading low grade heat
R245fa Booster HP Research

<table>
<thead>
<tr>
<th>Evaporator</th>
<th>Condenser</th>
<th>POWER</th>
<th>Heat Cap.</th>
<th>COP</th>
</tr>
</thead>
<tbody>
<tr>
<td>M (kg/s)</td>
<td>ΔT (K)</td>
<td>M (kg/s)</td>
<td>ΔT (K)</td>
<td>Win (kW)</td>
</tr>
<tr>
<td>0.8</td>
<td>9.26</td>
<td>1.26</td>
<td>7.16</td>
<td>6.93</td>
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<tr>
<td>0.96</td>
<td>8.18</td>
<td>1.26</td>
<td>7.52</td>
<td>7.12</td>
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</tbody>
</table>
R245fa Booster HP Research

COP & Qheat

Heating Capacity
COP

Heating Capacity (kW)

COP

HP Cycles

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Replacing R245fa

![Graph showing COP for different refrigerants (R134a, R245fa, R1233zd, R1234ze, Propane) at different temperatures (80C, 120C, 160C).]
Replacing R245fa - Baseline
R1233zd(e) Performance
And Compressor Lubrication

\begin{align*}
  y &= -0.9367x + 102.97 \\
\end{align*}

Oil Solubility and Transport Observations
State of the Art

And 200°C?

Sarkar et al, 2007

100 Bar A equivalent
And I have great help

Ulster University has been working with heat pumps since 1975 and in the last 10 years has attracted > £10M R&D funds

We have watched the COP grow from 2.0 to 7.0 (application dependent)

We have worked with many working fluids and their respective compressor lubricants

We work with energy markets i.e. demand side response while satisfying thermal comfort and hot water demands through thermal storage

We intend to push to 200°C and more for industrial applications

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