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Electrification of Heat and the Impact on the Scottish Electricity System

Commissioned by ClimateXChange / Scottish Government

Sample outputs, methodology and assumptions

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Project introduction

- 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 out to 2050, the Scottish Government commissioned a study and model to represent the electrification of heat and electricity network capacity.

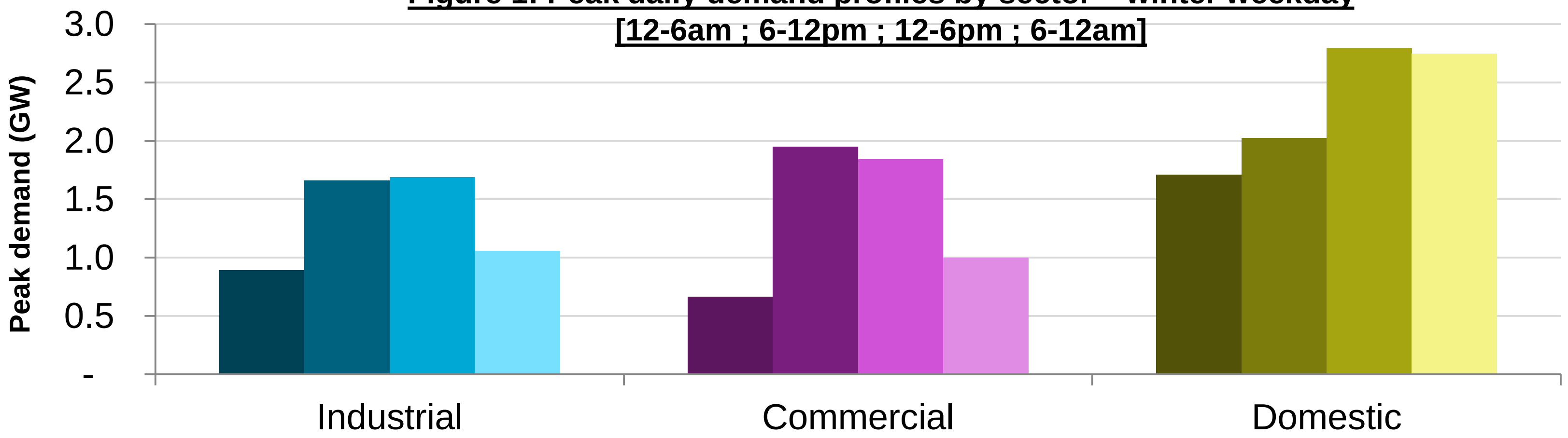
DELTA Energy & Environment	+	smarter grid solutions	=	
Electric Heating Demand Model		***Electricity Network Capacity Model***		***Electrification of Heat and Electricity Network Capacity Model: Scotland***
STEP 1		**STEP 2**		**STEP 3**

What does Scotland's electricity grid currently have to cope with?

Estimates of current (2014) electricity demand – winter peak

- Over the course of a typical winter weekday (24 hours), the shape of peak electricity demand profiles differ per sector. For the commercial sector, peaks occur during work hours, while in the domestic sector peaks are more visible in the later half of the day.
- In Figure 1, we show this as four time blocks (12 AM – 6AM; 6AM – 12PM; 12PM – 6PM; 6PM – 12AM) instead of half-hourly profiles to be in alignment with the Scottish Government Electricity Dispatch Model.

Figure 1: Peak daily demand profiles by sector – winter weekday [12-6am ; 6-12pm ; 12-6pm ; 6-12am]



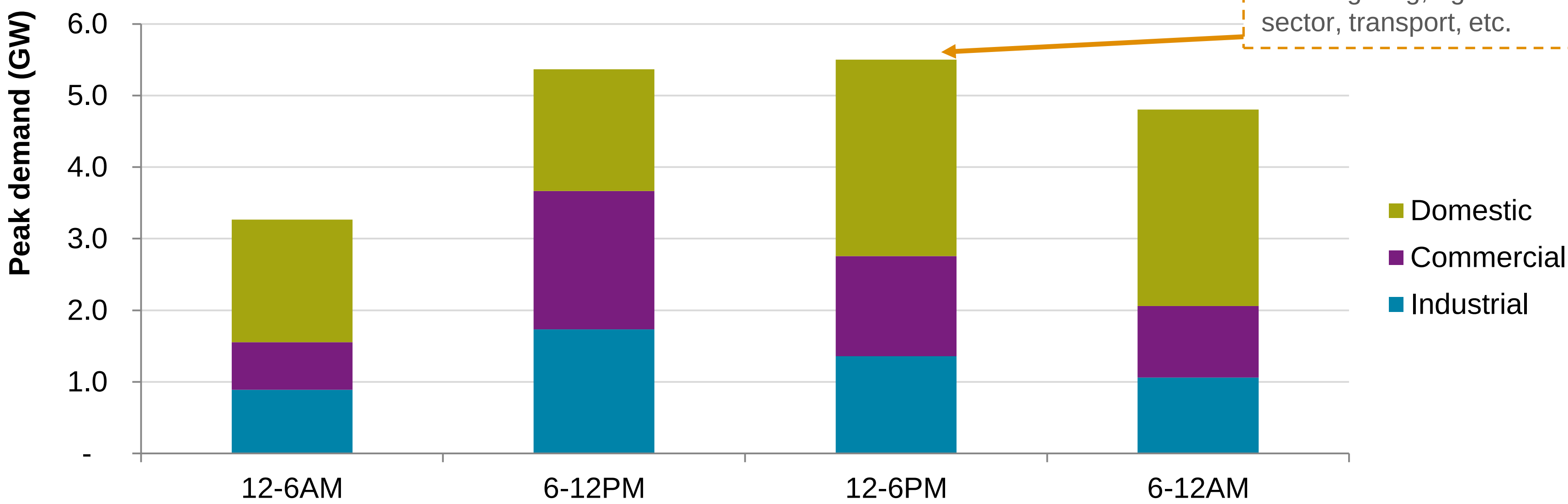
Note: The half-hourly peak demand within any time block may be different across sectors (eg. 7am for residential but 11am for commercial within the 6-12pm block).

Estimates of current (2014) electricity demand – winter peak

- **When added together, this would give us a system demand profile for the whole of Scotland as in Figure 2, with peak demand per time block. This includes all uses of electricity (appliances, lighting, heating, cooling, etc.).**
- **So, today peak electricity demand in Scotland is estimated to be between 5 – 6 GWe. This happens around 4 – 6 pm.**

Note: Actual peak electricity demand on a winter weekday is higher (~ 6 GW) – the graphs do not include street lighting, agriculture sector, transport, etc.

Figure 2: Peak system demand – winter weekday



Regional peak electricity demand

- Today peak electricity demand in Scotland is estimated to be between 5 – 6 GWe.
- The main demand centers are in regions B5 and B6 in the south of Scotland (e.g. where Glasgow, Edinburgh, etc. are located).

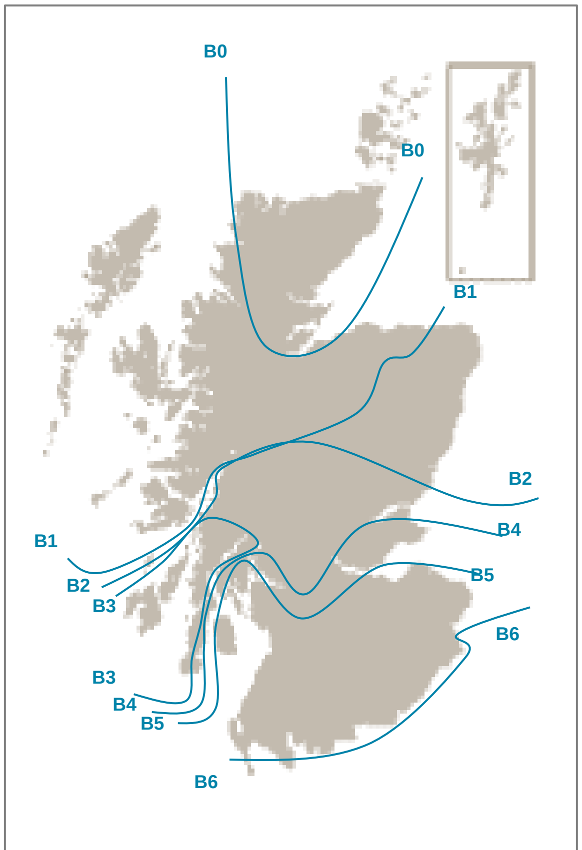
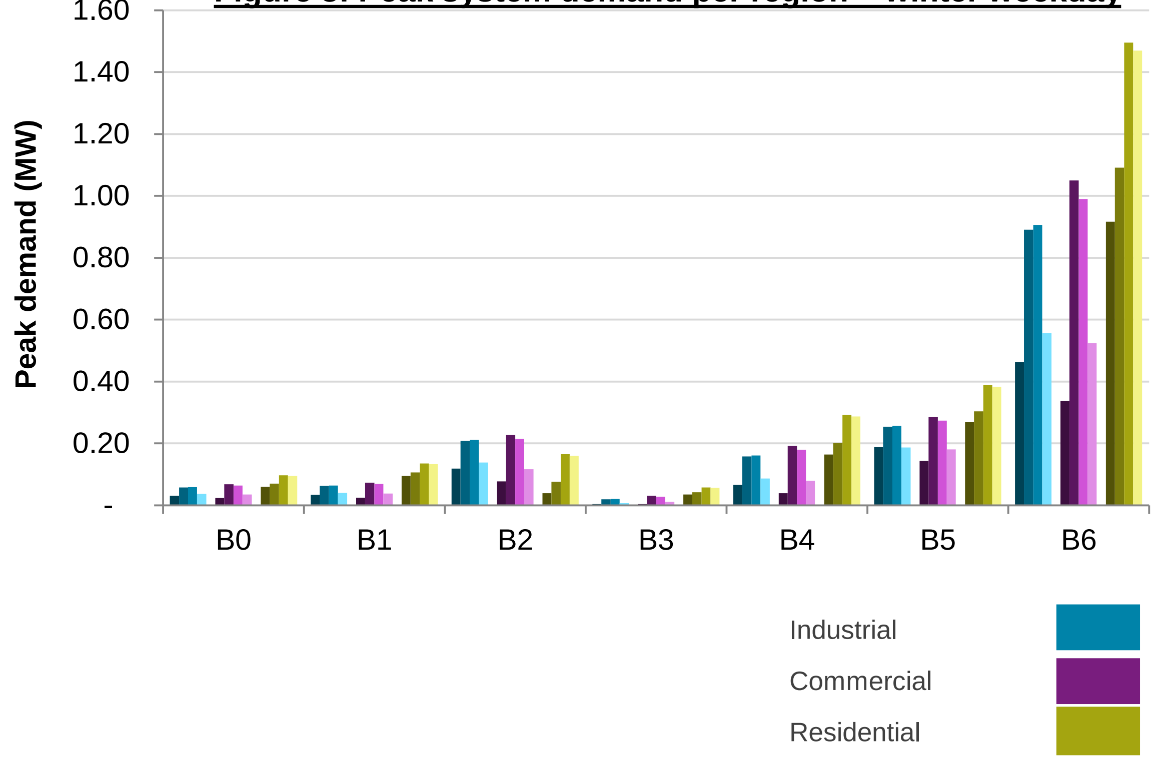
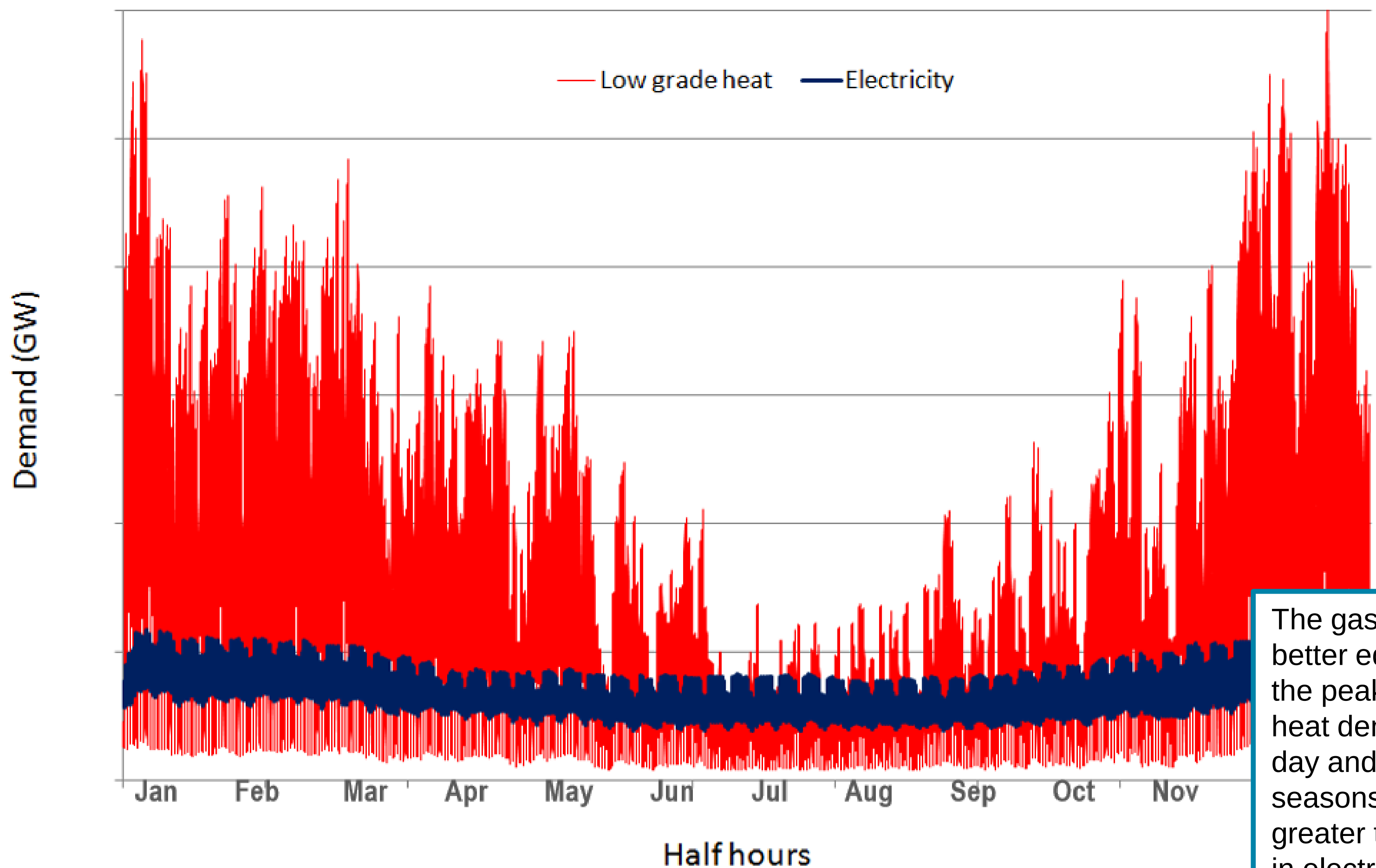


Figure 3: Peak system demand per region – winter weekday



What happens when a proportion of heat demand is electrified?

The heat challenge

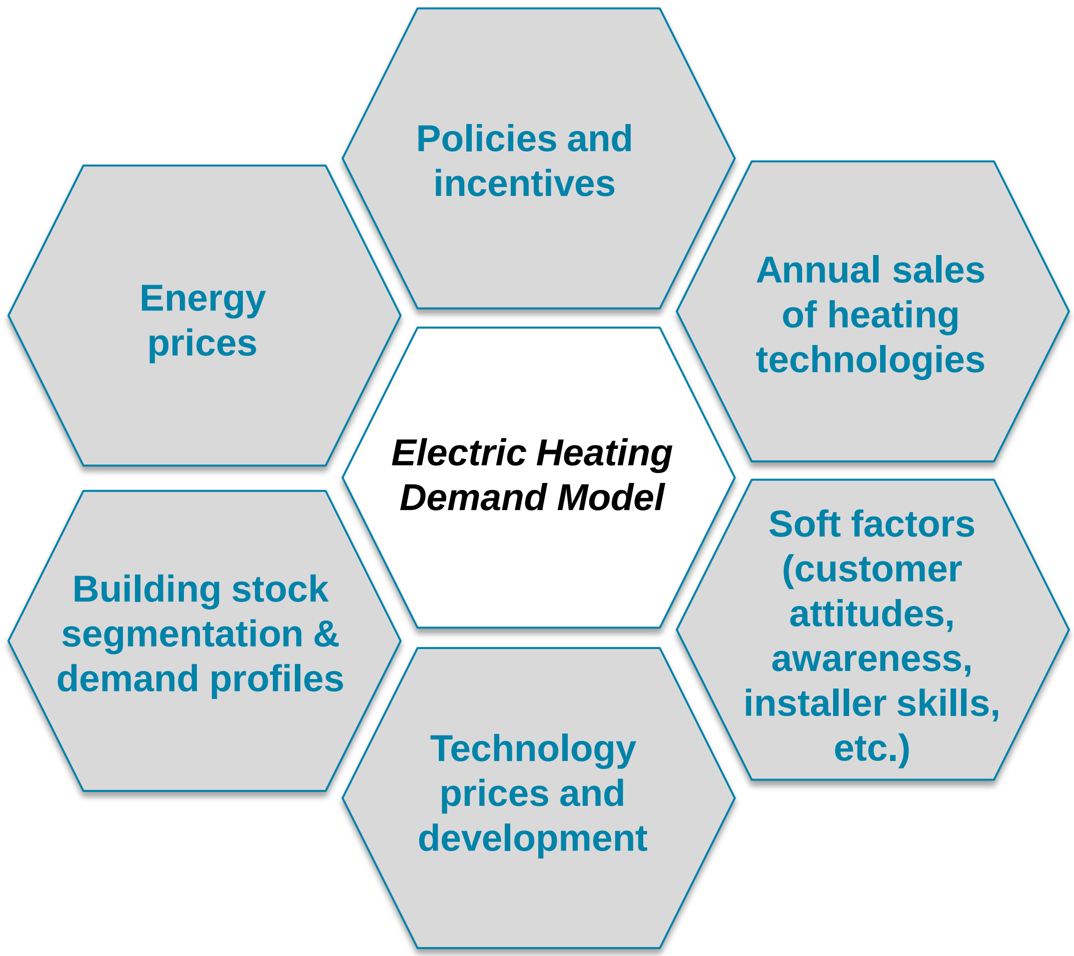


The gas grids are currently better equipped to handle the peaks and troughs in heat demand, both within a day and across the seasons, which are far greater than the variations in electrical demand.

Source: Robert Sansom, Imperial College (2011)

Reference scenario used to hypothesize electric heating demand to 2050

Inputs and assumptions



Note:
The outputs contained in the in-depth report refer to Delta-ee's reference scenario. 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.

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.

High level breakdown of the Scottish housing stock used within Delta-ee's housing stock model

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Property types: 22% Detached; 23% Semi-Detached; 19% Terraced; and 37% Tenements/ Flats. There is a high proportion of tenements in the B6 region which consists of high-density urban areas such as Edinburgh and Glasgow.

Most of Scotland's housing stock is on-gas properties. However, the B0 region which consists of Orkney Islands and a part of the Highlands differs from this national average [electric, oil, and other non-gas fuel types make up 71% of central heating system types in B0].

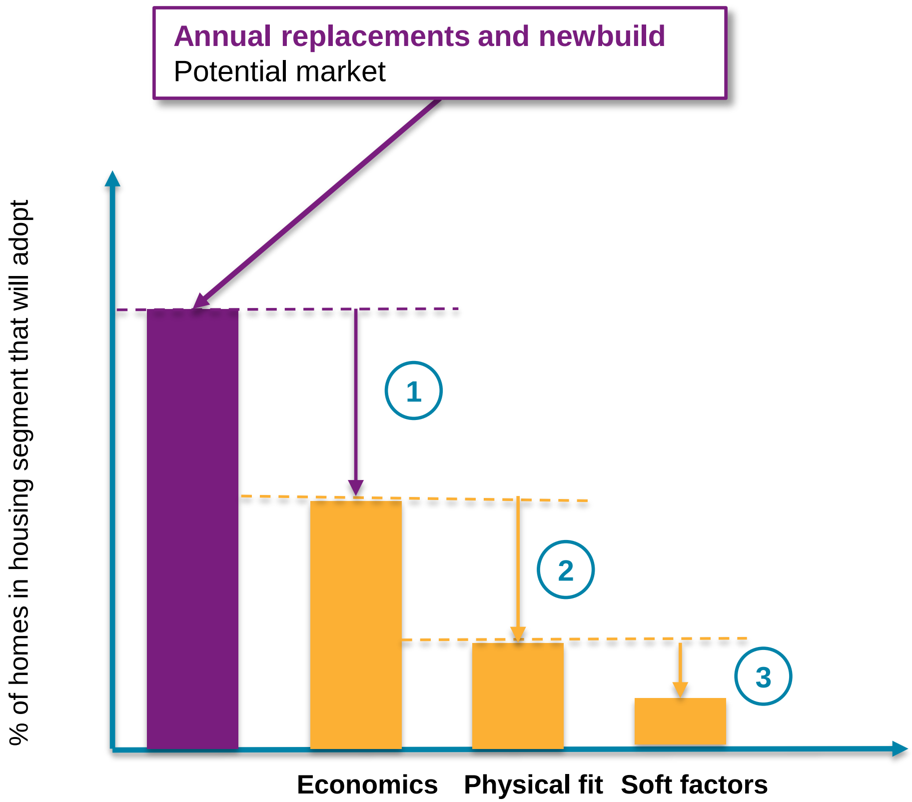
	DETACHED	SEMI-DETACHED	TERRACED	TENEMENTS / FLATS	Gas	Elec.	Oil	Others
B0	*~ 27,400 Properties*	*~ 16,900 Properties*	*~ 8,800 Properties*	*~ 7,400 Properties*	29%	27%	27%	17%
B1	*~ 36,100 Properties*	*~ 23,700 Properties*	*~ 13,200 Properties*	*~ 9,900 Properties*	46%	19%	22%	13%
B2	*~ 69,800 Properties*	*~ 57,700 Properties*	*~ 31,900 Properties*	*~ 68,600 Properties*	64%	15%	13%	8%
B3	*~ 14,300 Properties*	*~ 8,600 Properties*	*~ 5,100 Properties*	*~ 11,900 Properties*	44%	27%	14%	15%
B4	*~ 74,000 Properties*	*~ 71,400 Properties*	*~ 46,800 Properties*	*~ 97,300 Properties*	70%	17%	6%	7%
B5	*~ 66,100 Properties*	*~ 78,600 Properties*	*~ 63,200 Properties*	*~ 89,000 Properties*	86%	8%	2%	4%
B6	*~ 223,800 Properties*	*~ 278,800 Properties*	*~ 269,600 Properties*	*~ 578,000 Properties*	79%	12%	3%	6%

= 10,000 properties

Residential customer uptake: Methodology

Customer uptake for one technology depends on economics, physical fit and 'soft factors'
If one of these criteria is not appealing, the customer is likely to turn to other technologies and ultimately to 'typical boilers' (gas/electrical/oil/LPG)

CUSTOMER UPTAKE METHODOLOGY – ECONOMICS, PHYSICAL FIT AND SOFT FACTORS



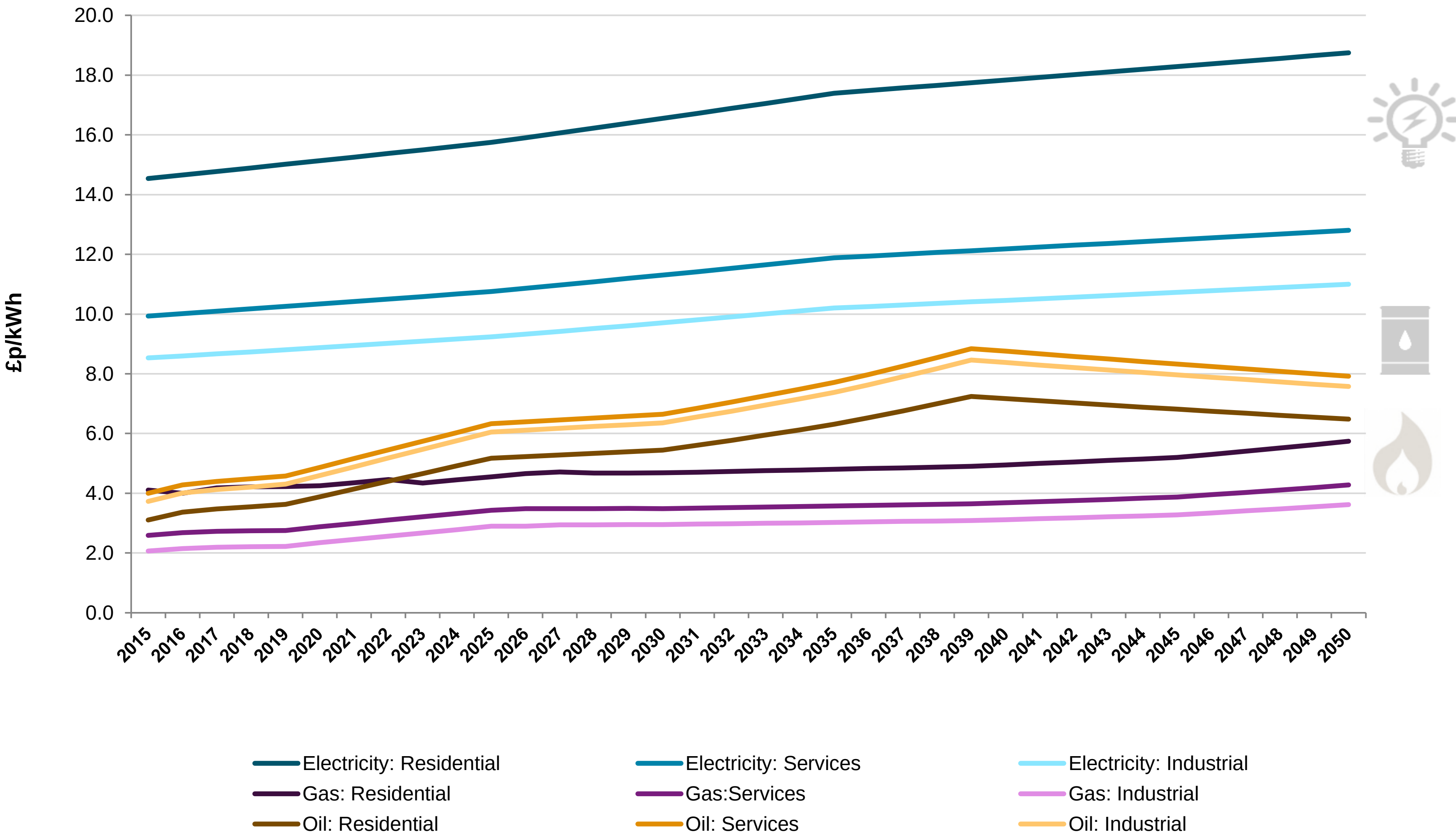
1. **Economics** is used as the first filter – as the primary decision factor for a majority of customers is the cost of technology. If the economics are very poor, only innovators will take up a technology

2. **Physical fit** is used as the second filter as some technologies will be automatically ruled out or have lesser uptake if it is difficult to install

3. **Soft factors** are the final filter – customers' preferences and other factors that impact decision making. Technology aesthetics, time to install, disruption etc.

Energy prices – current prices and high level view on change in prices to 2050

Scotland retail energy prices (£p / kWh]



Fully installed costs of residential heating technologies: current & future

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Definition of fully installed costs:
Includes the heating appliance, any auxiliary equipment, and labour (installation) costs. This is the final amount that the average customer pays for an installed system. All prices below are expressed in GBP (£). Subsidies are not included. The (possible) rise in VAT for low carbon technologies from 5% to 20% is not reflected in the table below – this is because we have assumed that this is absorbed by manufacturers or installers (which will incur shrinking margins) and not passed on to the final customer.

Fully installed cost for **conventional** heating systems **(boilers)**

Prices include the cost of a chimney & a hot water storage tank	2015	2020	2025	2030	2050
Non condensing gas boiler (30kW)	2,650	No longer allowed	No longer allowed	No longer allowed	No longer allowed
Condensing gas boiler (30kW)	2,650	2,650	2,650	2,650	2,650
Non-condensing oil boiler	3,100	No longer allowed	No longer allowed	No longer allowed	No longer allowed
Condensing oil boiler	3,100	3,100	3,100	3,100	3,100
The above prices include the cost & installation of e.g. radiators, cylinders, a hot water storage tank , etc.	*1,000 – 1,500*	*1,000 – 1,500*	*1,000 – 1,500*	*1,000 – 1,500*	*1,000 – 1,500*

Fully installed costs for **conventiona**l **electric heaters**

Values are in £ / year	2015	2020	2025	2030	2050
Electric storage heaters	3,150	3,150	3,150	3,150	3,150

Fully installed cost for **electrically driven heat pumps & gas driven heat pumps**

Values are in £ / year	2015	2020	2025	2030	2050
ASHP monoblock (air – water) (8 – 10 kW)	9,500	8,250	7,000	6,000	5,000
ASHP split (air – water) (8 – 10 kW)	8,520	7,375	6000	5,000	4,500
GSHP Borehole (14 – 16 kW)	14,333	13,916	13,500	12,500	11,500
GSHP Trench (14 – 16 kW)	12,833	12,416	12,000	11,000	10,000
Gas driven heat pump (8 – 10 kW)	10,000	9,000	7,500	6,500	5,500

Fully installed cost for **hybrid heat pumps ('boiler plus ASHP')**

Values are in £ / year	2015	2020	2025	2030	2050
Hybrid heat pump gas boiler high capacity (8kW ASHP plus ~20 kW boiler)	8,166	7,333	6,500	5,800	5,000
Hybrid heat pump gas boiler low capacity (4kW ASHP plus ~20 kW boiler)	5,857	5,500	4,500	4,000	3,500
Hybrid heat pump oil boiler high capacity (8kW ASHP plus ~20 kW boiler)	14,666	13,833	13,000	12,000	11,000
Hybrid heat pump oil boiler low capacity (4kW ASHP plus ~20 kW boiler)	7,000	6,375	5,750	5,000	4,500

Fully installed cost for **micro CHP (engine based and fuel cell)**

Values are in £ / year	2015	2020	2025	2030	2050
Micro-CHP – gas, Stirling engine (1 kWe)	10,083	7,791	5,500	5,000	4,800
Micro-CHP – gas, internal combustion engine (1 kWe)	12,000	8,750	5,500	5,000	4,800
Fuel cell, PEM (Proton exchange membrane) (1 kWe)	18,000	13,000	8,000	7,000	6,000

GSHPs will typically be installed in larger dwellings (e.g. detached properties) with higher thermal demands and space for ground loops, and therefore we display a larger thermal capacity system in the table above. For ASHPs, we believe these will typically be installed in mid – smaller thermal demand properties and therefore use smaller capacity systems. Note – for both systems, we scale the size of the system (and therefore the installed price) up and down depending on the thermal demand of the dwelling it is being installed in.

Annual maintenance costs of residential heating technologies: current & future

DELTA Energy & Environment

Definition of annual maintenance costs:
Includes the annual (labour) maintenance of the heating system and auxiliary equipment, replacement of parts under warranty, etc. This does not include other operational costs such as fuel prices. All prices below are expressed in GBP (£). Subsidies are not included.

Typical maintenance costs for **conventional** heating systems **(boilers)**

Values are in £ / year	2015	2020	2025	2030	2050
Non condensing gas boiler (30kW)	75	75	75	75	75
Condensing gas boiler (30kW)	75	75	75	75	75
Non-condensing oil boiler	100	100	100	100	100
Condensing oil boiler	100	100	100	100	100

Typical maintenance costs for **conventiona**l **electric heaters**

Values are in £ / year	2015	2020	2025	2030	2050
Electric storage heaters	25	25	25	25	25

Typical maintenance costs for **electrically** **driven heat pumps &** **gas** **driven heat pumps**

Values are in £ / year	2015	2020	2025	2030	2050
ASHP monoblock (air – water) (8 – 10 kW)	71	60	50	50	50
ASHP split (air – water) (8 – 10 kW)	92	71	50	50	50
GSHP Borehole (14 – 16 kW)	96	85	75	75	75
GSHP Trench (14 – 16 kW)	96	85	75	75	75
Gas driven heat pump (8 – 10 kW)	150	100	75	60	60

Typical maintenance costs for **hybrid heat pumps (‘boiler plus ASHP’)**

Values are in £ / year	2015	2020	2025	2030	2050
Hybrid heat pump gas boiler high capacity (8kW ASHP plus ~20 kW boiler)	117	96	75	75	75
Hybrid heat pump gas boiler low capacity (4kW ASHP plus ~20 kW boiler)	117	96	75	75	75
Hybrid heat pump oil boiler high capacity (8kW ASHP plus ~20 kW boiler)	138	106	75	75	75
Hybrid heat pump oil boiler low capacity (4kW ASHP plus ~20 kW boiler)	117	96	75	75	75

Typical maintenance costs for **micro CHP (engine based and fuel cell)**

Values are in £ / year	2015	2020	2025	2030	2050
Micro-CHP – gas, Stirling engine (1 kWe)	138	106	75	75	75
Micro-CHP – gas, internal combustion engine (1 kWe)	400	358	300	250	250
Fuel cell, PEM (Proton exchange membrane) (1 kWe)	500	300	200	100	100

Technology performance of residential heating technologies: current & future

Definition of performance measures:
Thermal and electrical efficiencies are higher heating values (HHV).
'SPF' = seasonal performance factor. This is the average thermal efficiency (COP for heat pumps) achieved by the heating appliance over the course of the year.

SPF for **conventional** heating systems **(boilers)**

Overall thermal efficiency (%)	2015	2020	2025	2030	2050
Non condensing gas boiler (30kW)	75	No longer allowed	No longer allowed	No longer allowed	No longer allowed
Condensing gas boiler (30kW)	84	84	84	86	88
Non-condensing oil boiler	80	No longer allowed	No longer allowed	No longer allowed	No longer allowed
Condensing oil boiler	84	84	84	84	84

SPF for **conventional electric heaters**

Overall thermal efficiency (%)	2015	2020	2025	2030	2050
Electric storage heaters	100	100	100	100	100

SPF for **electrically driven heat pumps & gas driven heat pumps**

SPF for space heating & hot water production	2015	2020	2025	2030	2050
Space heating efficiencies					
ASHP monoblock (8 – 10 kW) [apply the same values to the heat pump part of hybrid heat pumps]	2.93	3.02	3.10	3.20	3.40
ASHP split (8 – 10 kW) [apply the same values to the heat pump part of hybrid heat pumps]	2.74	2.84	2.95	3.05	3.25
GSHP Borehole (14 – 16 kW)	3.25	3.37	3.50	3.60	3.80
GSHP Trench (14 – 16 kW)	3.25	3.37	3.50	3.60	3.80
Gas driven heat pump (8 – 10 kW)	1.25	1.30	1.45	1.55	1.75
Hot water production efficiency					
ASHP monoblock (8 – 10 kW) [apply the same values to the heat pump part of hybrid heat pumps]	2.43	2.51	2.60	2.70	2.80
ASHP split (8 – 10 kW) [apply the same values to the heat pump part of hybrid heat pumps]	2.24	2.34	2.45	2.55	2.65
GSHP Borehole (14 – 16 kW)	2.61	2.66	2.70	2.80	2.90
GSHP Trench (14 – 16 kW)	2.61	2.66	2.70	2.80	2.90
Gas driven heat pump (8 – 10 kW)	1.25	1.30	1.45	1.55	1.75

SPF for **micro CHP (engine based and fuel cell)**

Overall thermal efficiencies and electrical efficiencies (%)	2015	2020	2025	2030	2050
Thermal efficiency					
Micro-CHP – gas, Stirling engine (1 kWe)	75	75	75	73.5	73
Micro-CHP – gas, internal combustion engine (1 kWe)	64	63	62	59	56
Fuel cell, PEM (Proton exchange membrane) (1 kWe)	55	54	52	49	46
Electrical efficiency					
Micro-CHP – gas, Stirling engine (1 kWe)	14	15	16	16	17
Micro-CHP – gas, internal combustion engine (1 kWe)	26	28	30	32	35
Fuel cell, PEM (Proton exchange membrane) (1 kWe)	35	38	40	42	45

Policy incentives for residential heating technologies (FiT, RHI, and export tariff levels): current & future

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Technology	Comments on central scenario assumptions	2015 incentives	2020 incentives	2025 incentives	2030 incentives	2050 incentives
ASHP	Strong government focus on this technology.	RHI: 7.4p / kWh	RHI: 6.5p / kWh	RHI: 5.7p / kWh	HP tariff: Level uncertain. We estimate 50% of retail rate	No longer available
GSHP	Strong government focus on this technology.	RHI: 19.1p / kWh	RHI: 14.7p / kWh	RHI: 11.4p / kWh	HP tariff: Level uncertain. We estimate 50% of retail rate	No longer available
Hybrid	UK government starting to become more confident on this technology – strong support expected.	RHI: 7.4p / kWh for heat pump output	RHI: 6.5p / kWh for heat pump output	RHI: 5.7p / kWh for heat pump output	HP tariff: Level uncertain. We estimate 50% of retail rate	No longer available
Gas heat pump	UK government modelling shows strong economic opportunity – likely to be supported, but level of support uncertain.	Not available	RHI: Level uncertain We estimate 2p / kWh	RHI: Level uncertain We estimate 2p / kWh	Uncertain *(new subsidy mechanism to meet targets?)*	No longer available
Micro CHP	FiT currently available, but little government confidence or support – long term support uncertain & likely to decline after 2020.	FiT: 12.9 p / kWh Export tariff: 4.6 p / kWh	FiT: 12.9 p / kWh Export tariff: 4.6 p / kWh	FiT: 8p / kWh Export tariff: 4.6 p / kWh	Uncertain *(new subsidy mechanism to meet targets?)*	No longer available

Physical fit: Suitability of different types of heating technologies

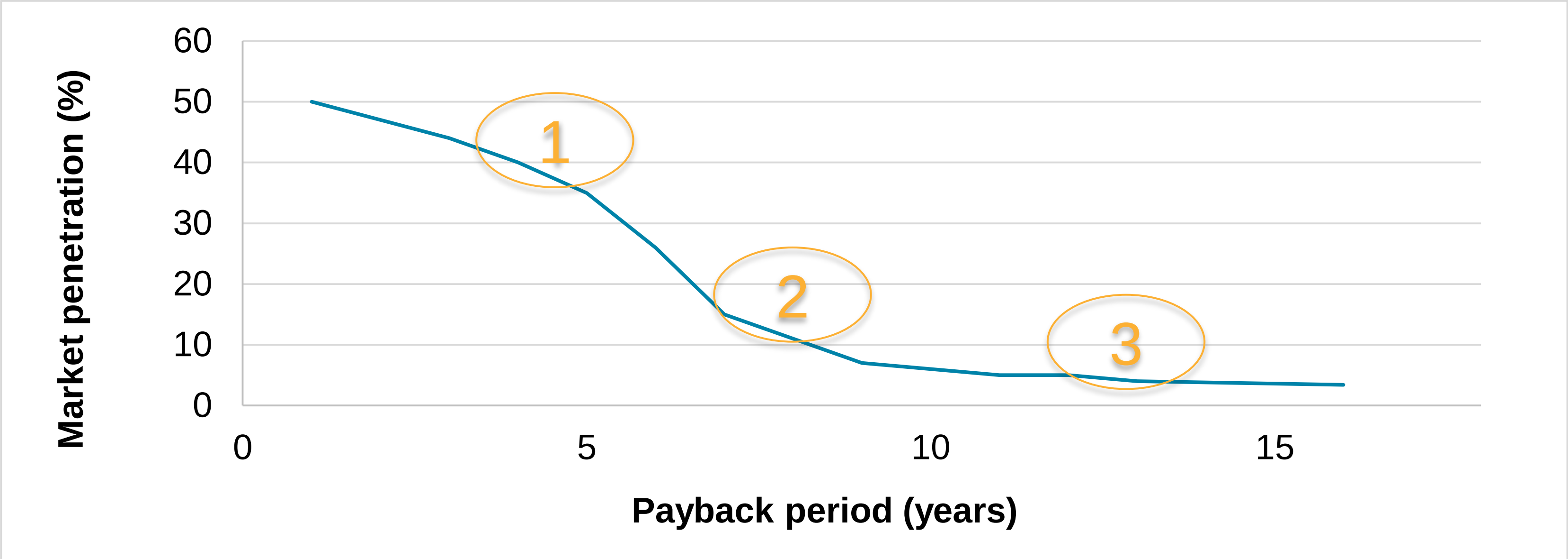
	DETACHED	SEMI-DETACHED (individual system)	TERRACED (individual system)	TENEMENTS / FLATS (individual system)
ASHP monoblock	*Perfect*	*Perfect*	*Moderate*	*Ex difficult*
ASHP split	*Perfect*	*Perfect*	*Moderate*	*Ex difficult*
Electric storage heater	*Perfect*	*Perfect*	*Perfect*	*Perfect*
Gas boiler high efficiency	*Perfect*	*Perfect*	*Perfect*	*Perfect*
GSHP Borehole	*Good*	*Difficult*	*Zero*	*Zero*
GSHP Trench	*Difficult*	*Ex difficult*	*Zero*	*Zero*
Hybrid heat pump gas boiler high capacity	*Perfect*	*Good*	*Difficult*	*Ex difficult*
Hybrid heat pump gas boiler low capacity	*Perfect*	*Good*	*Difficult*	*Ex difficult*
Hybrid heat pump oil boiler high capacity	*Perfect*	*Good*	*Difficult*	*Ex difficult*
Hybrid heat pump oil boiler low capacity	*Perfect*	*Good*	*Difficult*	*Ex difficult*
Micro-CHP engine - gas ICE	*Good*	*Good*	*Difficult*	*Zero*
Micro-CHP engine - gas stirling	*Good*	*Good*	*Difficult*	*Zero*
Oil boiler high efficiency	*Perfect*	*Perfect*	*Perfect*	*Perfect*

Factors that influence the suitability of different types of heat pumps for different house types:

1. Available **space inside the dwelling** for hot water tanks and internal units.
2. Available **space outside the dwelling** for external units or for ground loops.
3. Availability of **gas connection** – a gas connection is required for hybrid heat pumps with a gas boiler to be deployed.
4. The **density of housing**. Rural vs urban locations can be used as a proxy for the density of housing.

Economics: Customer uptake versus payback

ANTICIPATED MARKET PENETRATION OF LOW CARBON HEATING APPLIANCES VERSUS PAYBACK FOR UK CUSTOMERS



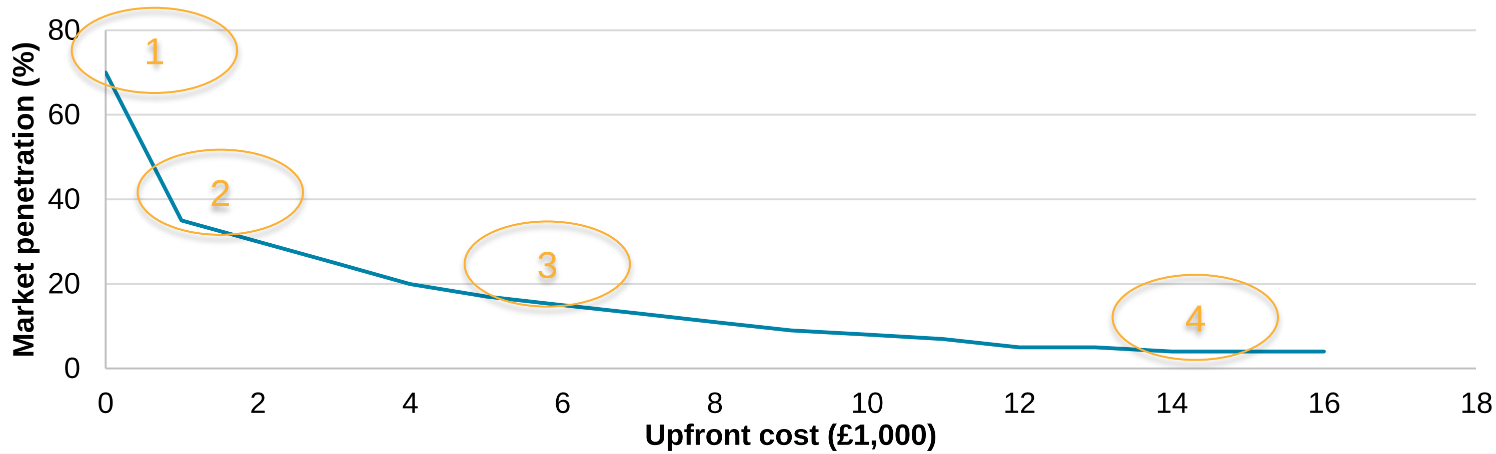
1 – 30-40% of customers state that the payback period must be less than 5 years if there were to consider investing.

2 – The average length of time that a home owner stays in the same property is ~7 years in the UK. Very few people are therefore interested in low carbon technologies with longer payback as they are not thinking that far ahead. A payback of less than 7 years is when customer interest in low carbon technologies begins to grow.

3 – Only 5% of customers would be willing to invest in low carbon heating appliances when the payback period is over 10 years.

Economics: Customer uptake versus upfront cost

Anticipated market penetration of low carbon heating appliances versus upfront cost for UK customers



1 – Customers are cautious and 'fear' new technologies – in the UK there will always be some inertia to moving away from trusted heating technologies. A small proportion of customers will not switch away from their current heating system (even if a more efficient system was offered for free).

2 – 30-40% of UK customers would consider investing in low carbon heating systems if the additional upfront costs are low (<£1,000 more than a boiler). Most customers will continue to opt for a 'typical boiler' if this is the cheapest replacement solution,

3 – Despite ambitions to be 'greener', customers are not willing to pay for it – once the cost of heating system is more than £3,000 – 4,000 more than a boiler, less than 20% of customers will consider investing.

4 – A small proportion of UK customers are willing to pay significant amounts of money to become independent of energy suppliers and to lower their energy bills. An estimated 5% of the market would consider investing in low carbon heating systems with high upfront cost.

Soft factors: Customer appeal assumptions
Understanding customers and installers

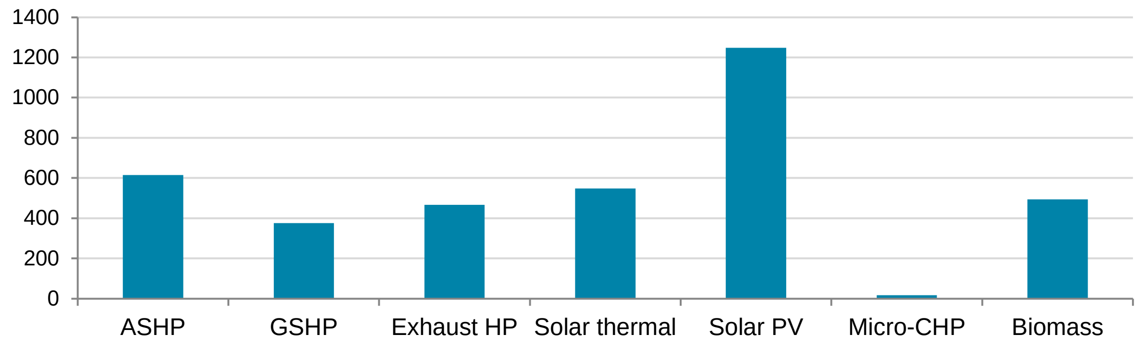
Installers

Most Scottish heating installers are 'conservative' when it comes to new technologies

The MCS (Microgeneration Certification Scheme) is a 'quality passport' for installers for low carbon technologies. It ensures that the installer has been trained, and has quality control procedures in place.

- Few installers skilled in technologies other than PV, ASHP and solar thermal.

NUMBER OF ACCREDITED INSTALLERS PER TECHNOLOGY IN SCOTLAND



Key uncertainties

- How quickly will installers get 'trained up' in new technologies
- Once trained in a 'new' technology, how effectively will installers 'upsell' the technology to customers? Or how much will they wait for customers to ask for the technology?

Registered Social Landlords

RSLs represent around 23% of the Scottish existing stock.

Their main driver for installing microgeneration is to reduce the fuel poverty for their tenants. A technology with high cost savings will be favoured.

The key barrier to RSLs is the upfront costs of the technology as they have a limited budget for their stock.

Soft factors: Customer appeal assumptions
Understanding customers and installers

Homeowners

Comprising 58% of the Scottish housing stock, most homeowners replace their heating system in two ways:

- *Distressed purchase* – their boiler breaks down, often in winter, and the customer needs to install a new system as quickly as possible
- *Procrastinators* – they know their boiler is close to failure, and eventually replace it.

Most UK homeowners have traditionally had very low awareness of the brand and type of boiler they install – relying on the installer to specify the product. They are very much cost driven.

Key uncertainties

- The proportion of homeowners that make more considered, researched 'investments' in their heating system, and how quickly this grows
- The response of homeowners to installer or other 'recommendations' on a lower carbon technology

Housing developers

Housing developers represent ~60% of the new build stock.

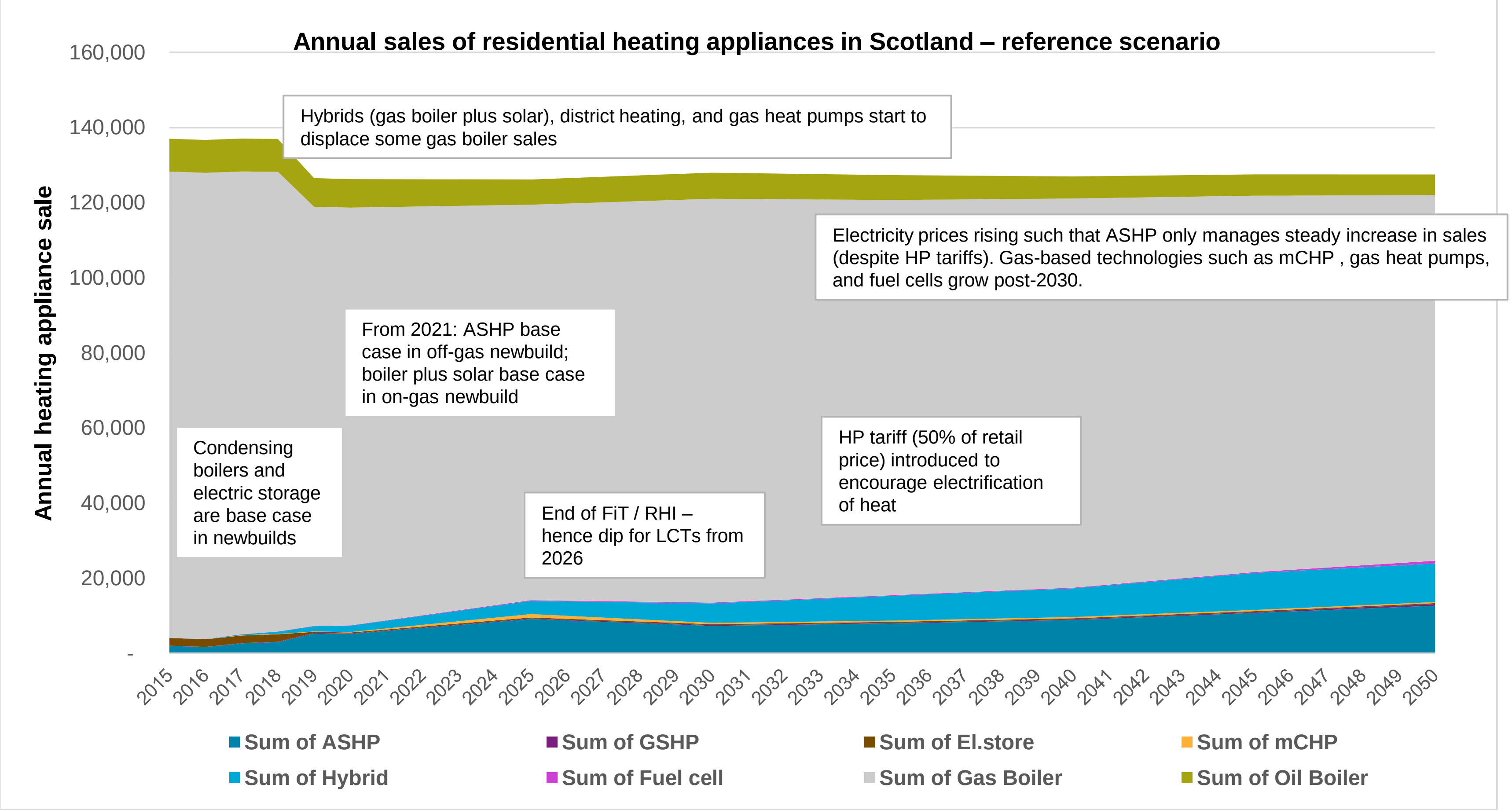
Their main driver for installing microgen is the building regulations.

They will focus on the lowest cost, simplest to install technology. They will want to avoid technologies that have complexity / potential for mistakes in installation, and that customers might think complex or unattractive.

- No evidence so far that customers will pay more for a home with an efficient heating system. Unlikely to change significantly.

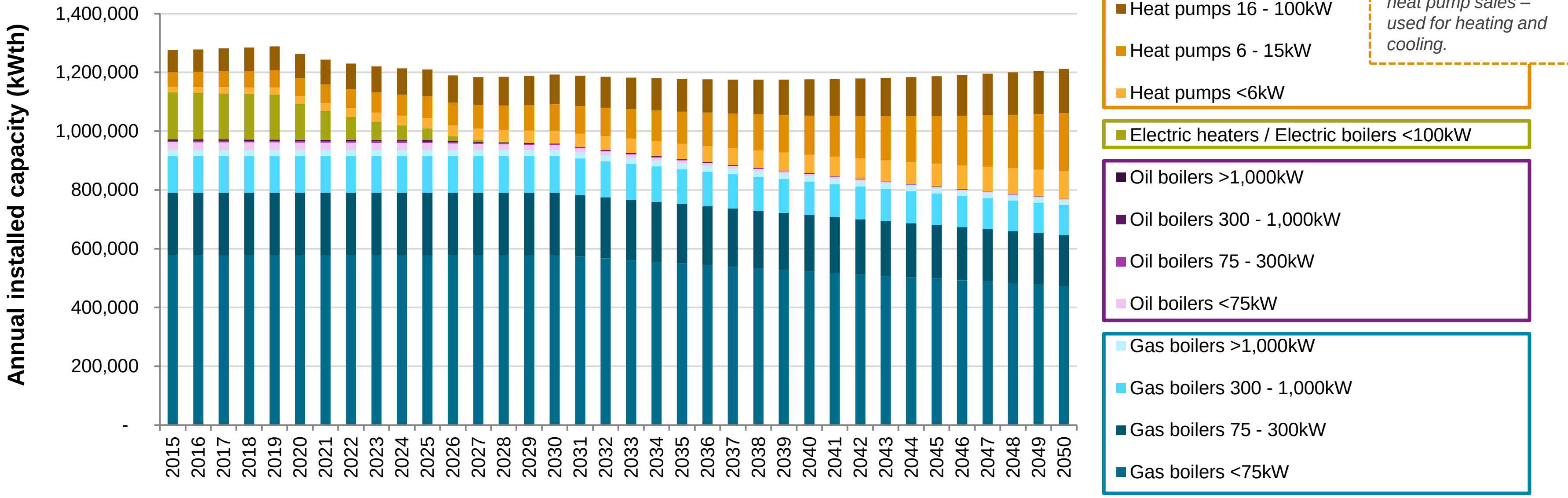
Forecast for annual sales of residential heating appliances

- Based on the inputs and assumptions used, condensing gas boilers still maintained majority share of annual heating appliance sales up to 2050.
- Electric-based heating technologies see only a small increase in annual sales in 2050 compared to 2015.

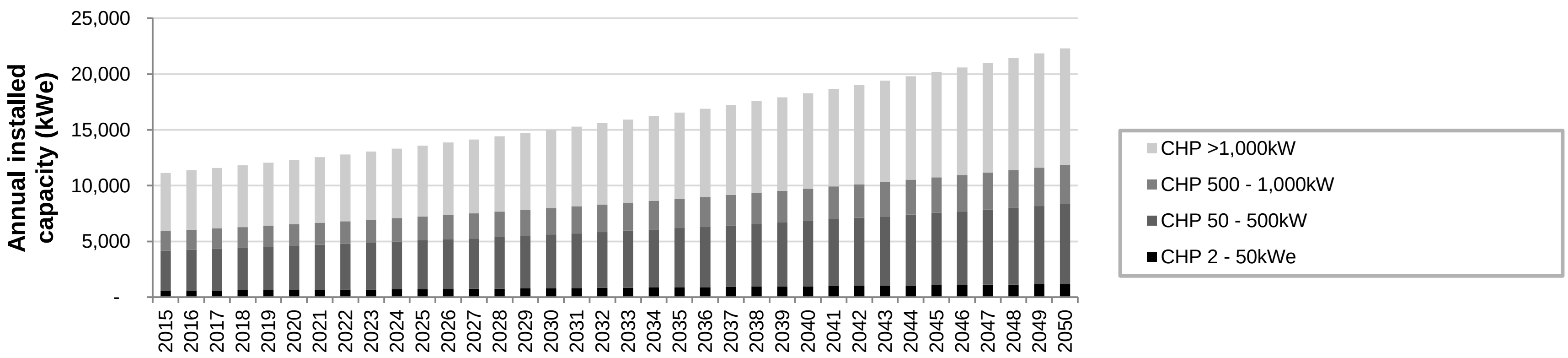


Forecast for annual sales of commercial heating appliances

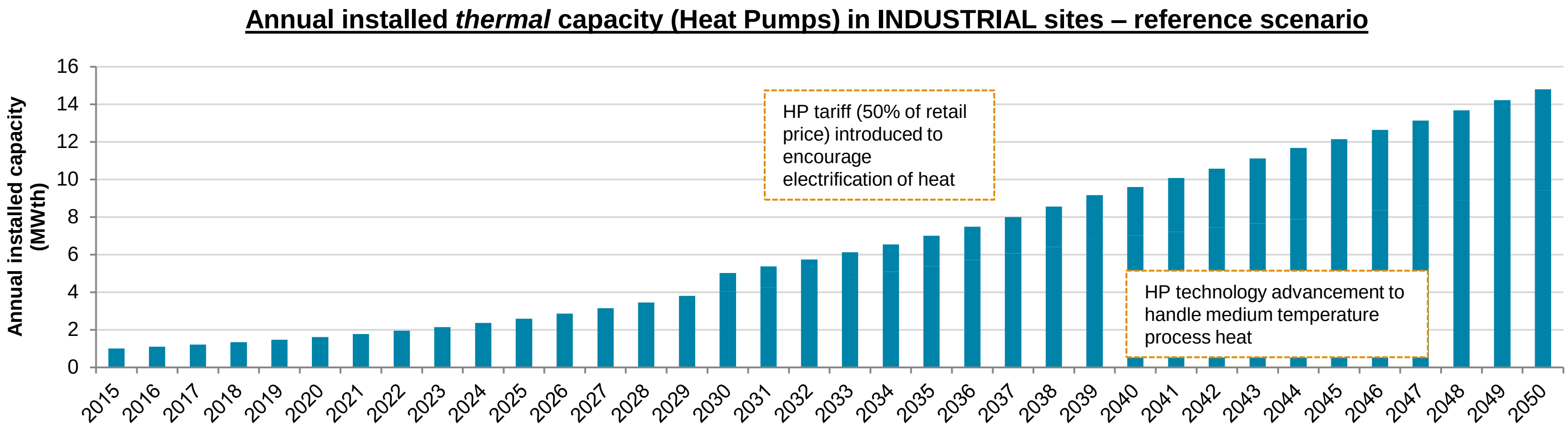
Annual installed *thermal* capacity in COMMERCIAL buildings – reference scenario

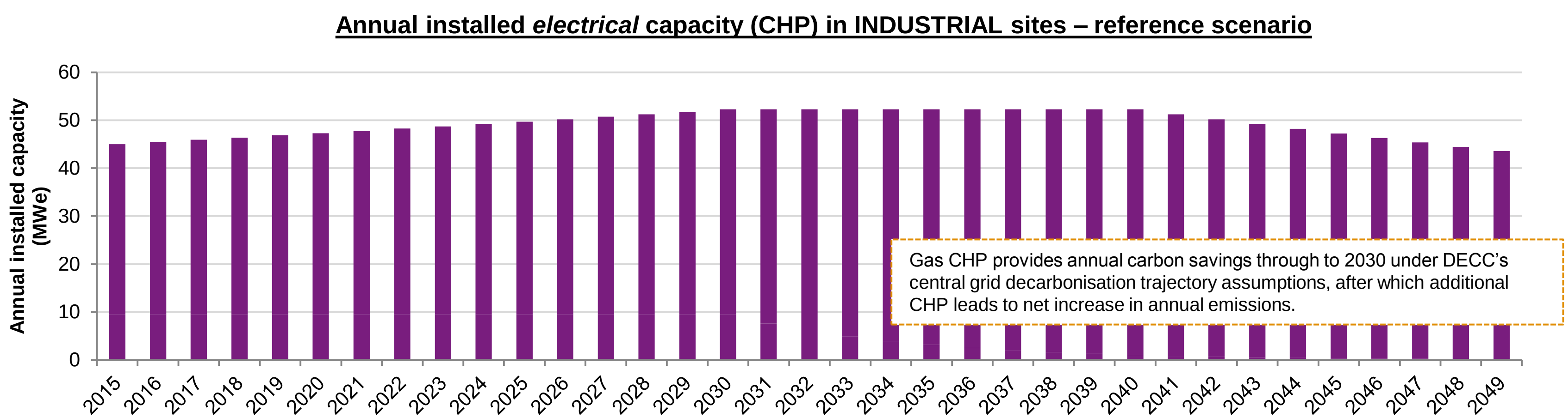


Annual installed *electrical* capacity (CHP) in COMMERCIAL buildings – reference scenario

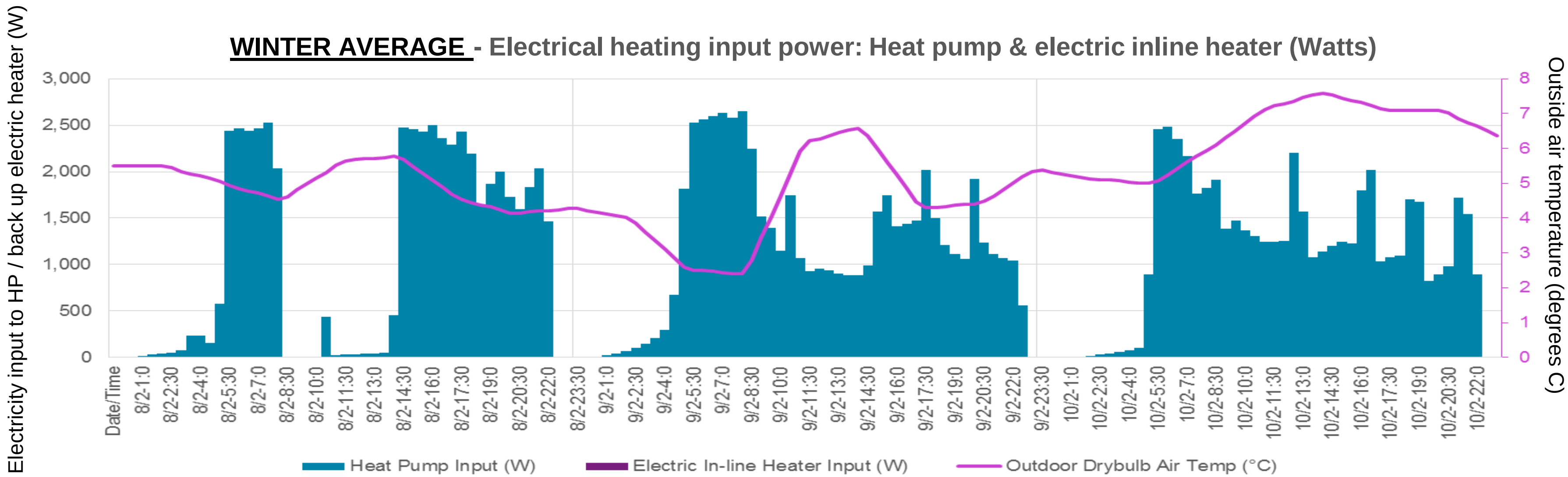


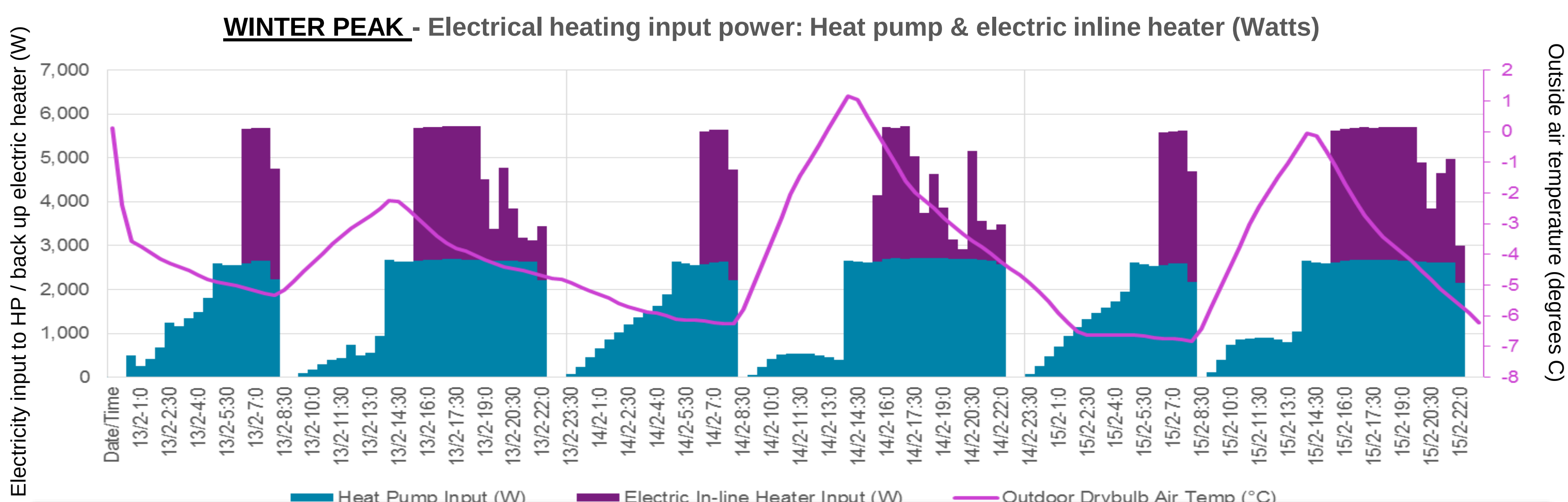
Forecast for annual sales of industrial heating appliances





Example load profiles for heat pumps: High temperature ASHP in a semi detached dwelling (3 days)

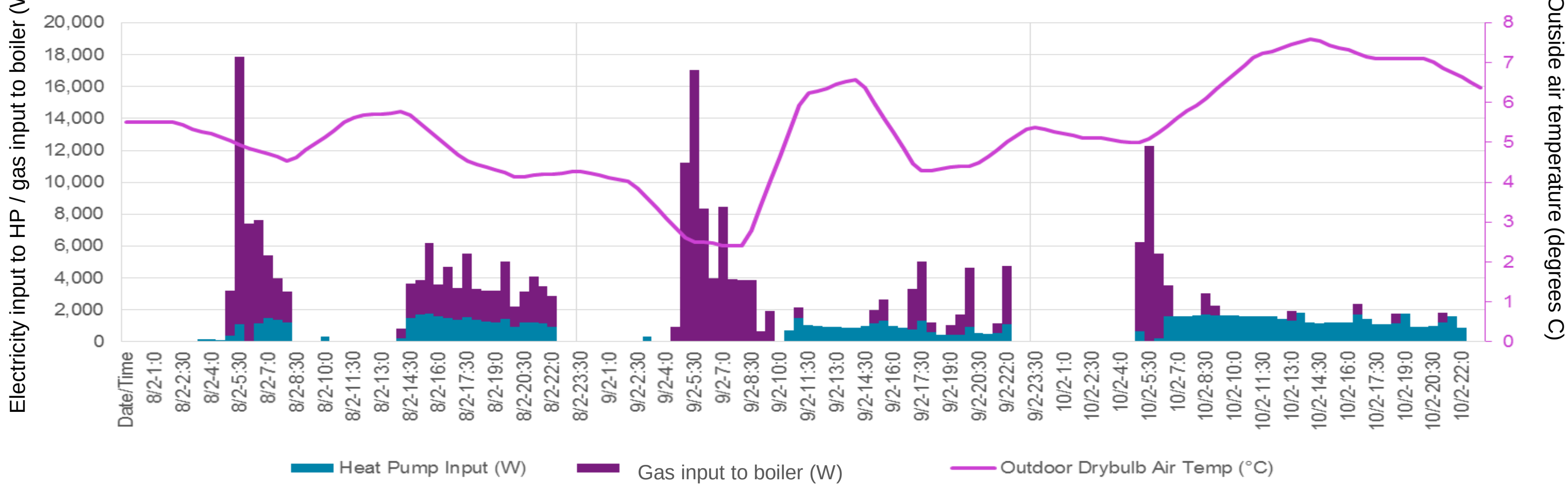




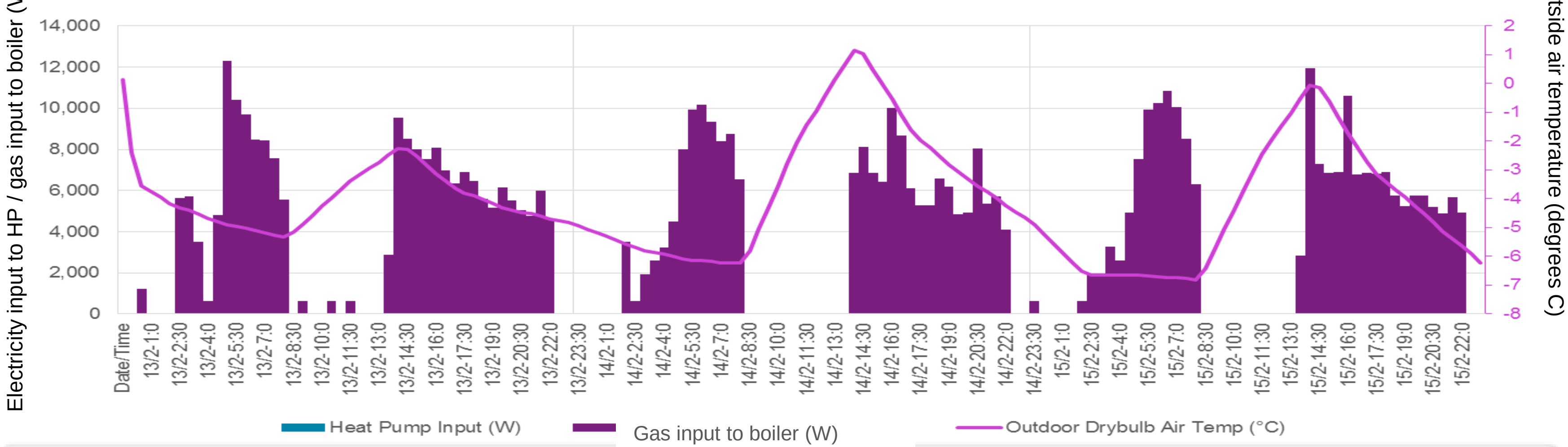
In extreme winter conditions, the gas boiler takes over full supply of heat (as demonstrated in the second diagram). But, for this project we have chosen the "worst case scenario" peak behaviour whereby the heat pump is allowed continued operation despite the very cold weather.

Example load profiles for heat pumps: Hybrid heat pump in a semi detached dwelling (3 days)

WINTER AVERAGE - Electrical & gas heating input power: Heat pump & gas boiler (Watts)



WINTER PEAK - Electrical & gas heating input power: Heat pump & gas boiler (Watts)



So, what will the new peak electricity demand profiles look like if a proportion of heat is electrified?

- By 2050, peak electricity demand in Scotland on a peak winter weekday may exceed **10 GW** due to the increasing uptake of electric-based heating technologies such as heat pumps especially in the residential and commercial sector. This is an 66% increase of 4 GW from a base case (current) of 6 GW peak electricity demand.

- With the displacement of electric heaters for 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 (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).

- The increase in peak demand by 2050 is observed despite district heating schemes being installed to meet 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.

RESIDENTIAL: Peak electricity demand (including additional electric heating demand)

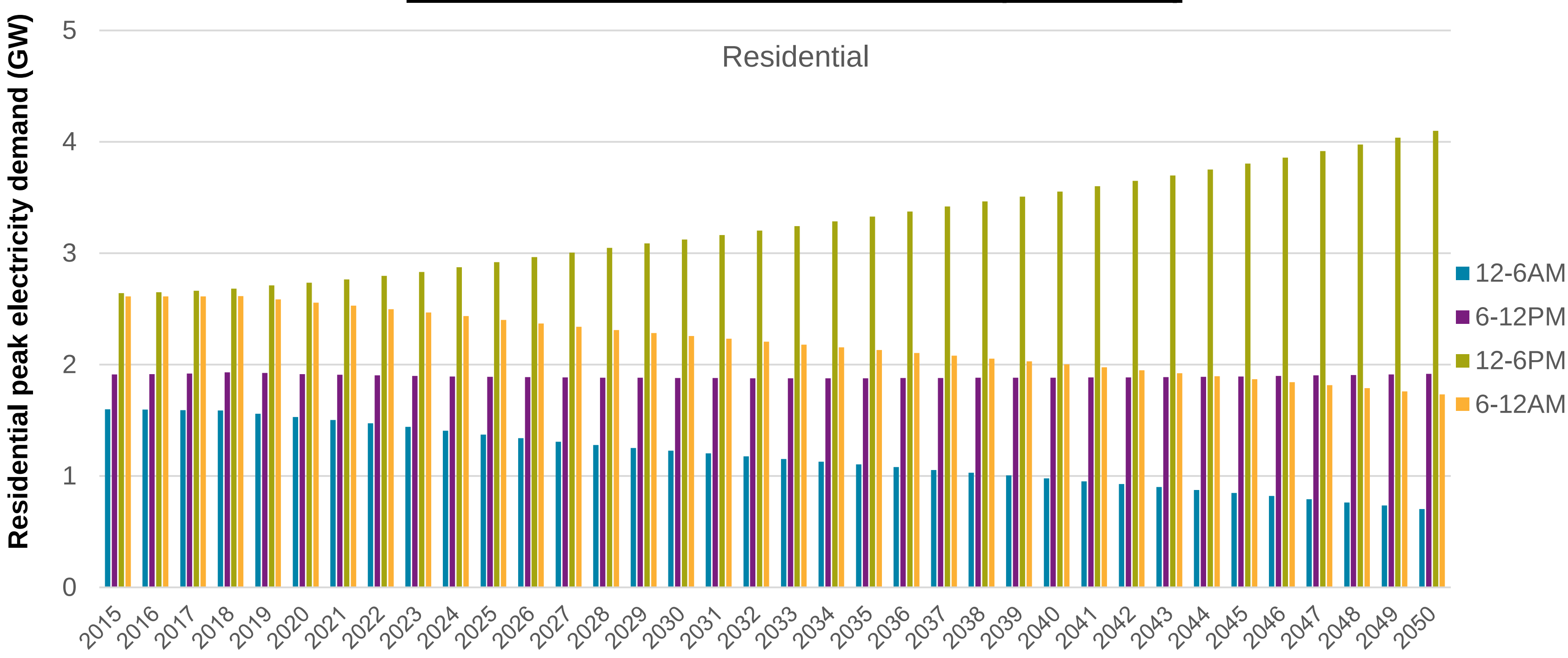
DELTA Energy & Environment

Overview:

- By 2050, residential peak electricity demand on a peak winter weekday may reach 4.1 GW (base case electricity demand plus additional electric heating demand) due to the increasing uptake of electric-based heating technologies in homes. This is an increase of 2.6 GW.
- Over the period to 2050, the replacement of storage heating with HPs results in a reduction in night time peaks, in particular for the **12-6 AM** time block. There is a significant increase (about 50%) increase in peak for the **12-6 PM** time block (after 4.30 PM in preparation for occupants to come back from work / school).

Note: The peak demands below do not take into account peak shaving solutions or the introduction of dynamic time-of-use pricing.

Forecast Peak Electric demand, Scotland (2016 – 2050)



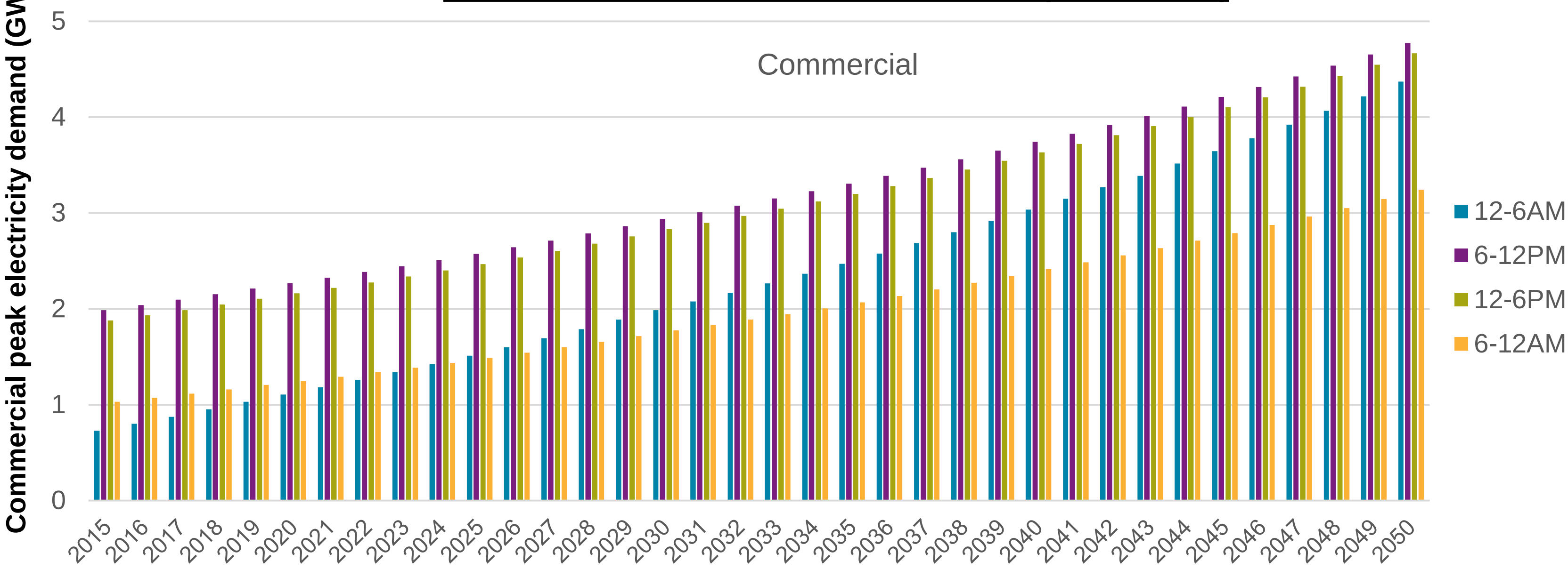
COMMERCIAL: Peak electricity demand (including additional electric heating demand)

Overview:

- By 2050, commercial peak electricity demand on a peak winter weekday may reach 4.6 GW (base case electricity demand plus additional electric heating demand) due to the increasing uptake of electric-based heating technologies in commercial premises such as offices, supermarkets, and others. This is an increase of 2.7 GW.
- Over the period to 2050, there is an increase in peaks across all four time bands, especially the **12-6AM** time block (more than double by 2050). This is because (unlike in the residential sector where there is a substantial offset of electric heaters with heat pumps), the starting base of heating technologies in the commercial sector does not include much electric storage heaters which would have caused a higher starting peak for the 12-6AM time band nor direct electric heaters which would have caused higher starting peaks across other time bands as well. Hence, electrification in the commercial sector will very likely always increase peak demand.

Note: The peak demands below do not take into account peak shaving solutions or the introduction of dynamic time-of-use pricing.

Forecast Peak Electric demand, Scotland (2016 – 2050)



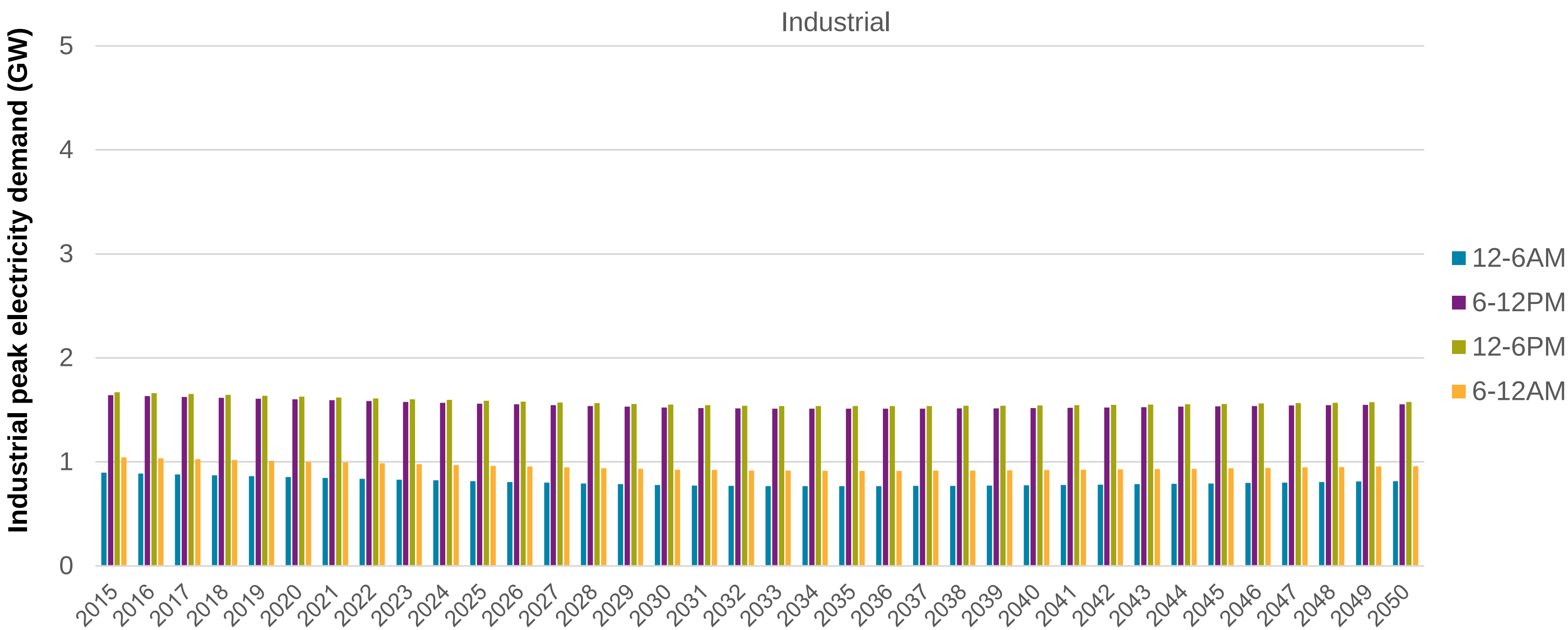
INDUSTRIAL: Peak electricity demand (including additional electric heating demand)

Overview:

- By 2050, industrial peak electricity demand on a peak winter weekday may stay relatively constant at around 1.6 GW (base case electricity demand plus additional electric heating demand) due to the growth in heat pumps being offset by replacement of some direct electric technologies, and increase in CHP generation.

Note: The peak demands below do not take into account peak shaving solutions or the introduction of dynamic time-of-use pricing.

Forecast Peak Electric demand, Scotland (2016 – 2050)

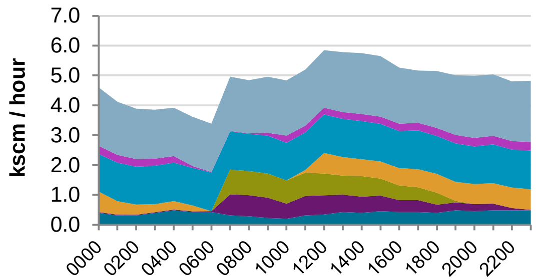


Why is electricity demand in the industrial sector relatively unchanged?

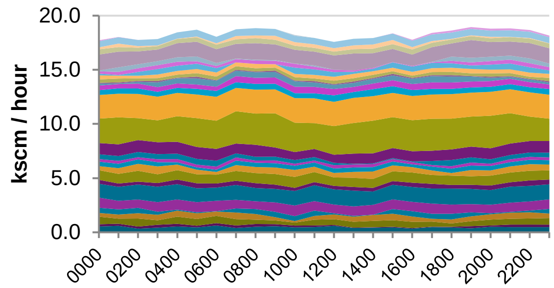
1. **Most industrial sites have relatively flat heat demand through the day.**
2. **Industrial heat pumps currently best cater to low-temperature process heat and we expect only modest improvements in terms of technology development to handle medium and high temperature process heat leading out to 2050.**
3. **The prevalence of CHP systems within the industrial sector.**

Gas demand – proxy for thermal demand

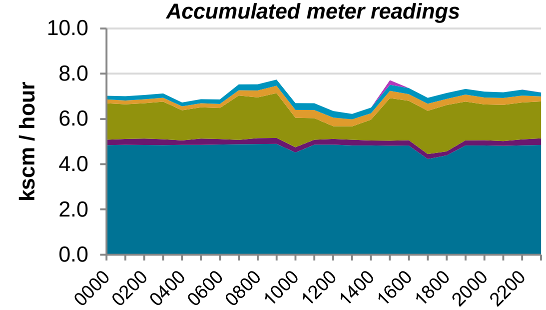
BREWERY & MALTING
(GAS DEMAND IN WINTER)
Accumulated meter readings



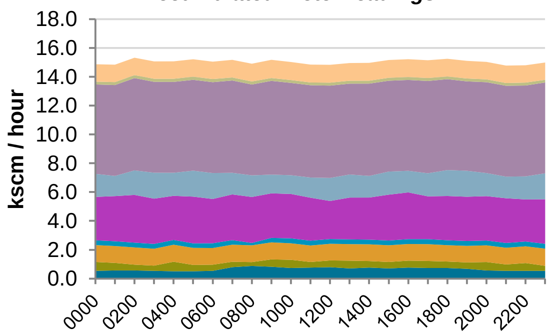
SPIRIT DISTILLING & COMPOUNDING
(GAS DEMAND IN WINTER)
Accumulated meter readings



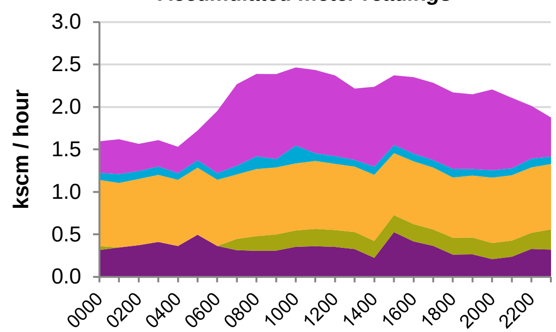
PAPER & PULP
(GAS DEMAND IN WINTER)
Accumulated meter readings



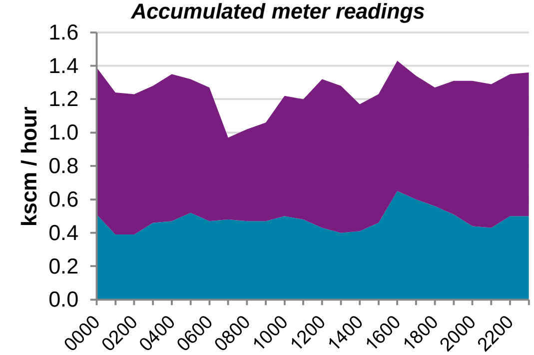
CHEMICAL & MISC. CHEMICAL PRODUCTS
(GAS DEMAND IN WINTER)
Accumulated meter readings



MISCELLANEOUS FOOD
(GAS DEMAND IN WINTER)
Accumulated meter readings



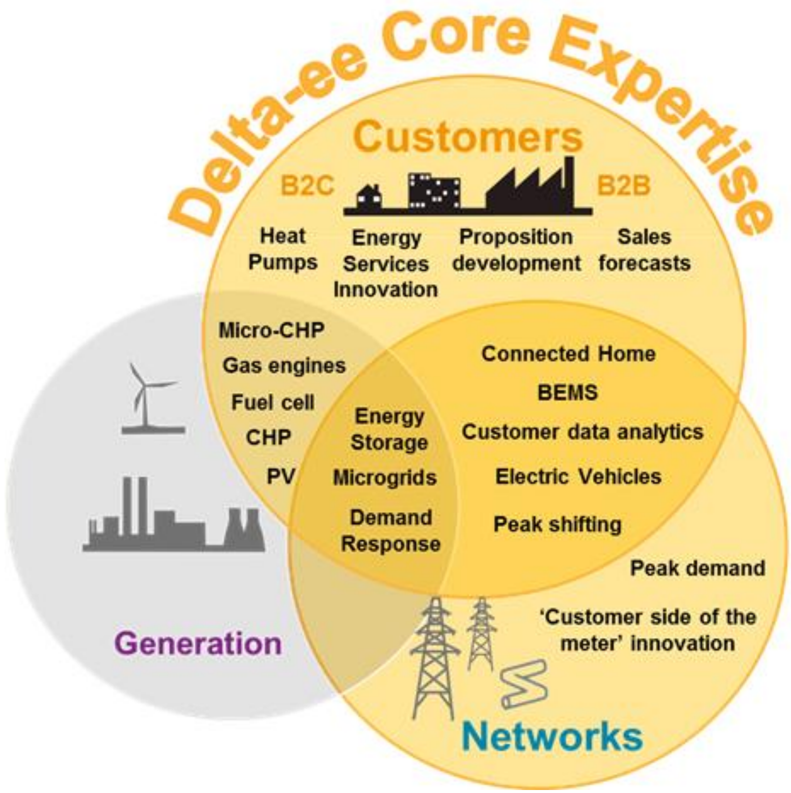
PREPARATION OF MILK AND MILK PRODUCTS
(GAS DEMAND IN WINTER)
Accumulated meter readings



Potential Reinforcement Requirements

- By 2050 and based on the loads illustrated in in previous slides, substantial reinforcements will 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.

Delta Energy & Environment



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