WESTERN POWER DISTRIBUTION
Serving the Midlands, South West and Wales
a nationalgrid company

2022 Low Carbon Heating Strategy

April 2022

westernpower.co.uk

Contents

Glossary ... **3**
1. Introduction ... **4**
1.1. Our approach ... 4
1.2. High level Government objectives ... 7
2. Low carbon heating methods ... **11**
2.1. Heat Pumps ... 11
2.1.1 WPD's approach to facilitate HP installation ... 12
2.1.2 Heat Pumps and Building design ... 12
2.1.3 Existing heat pumps and capacity ... 13
2.2 Thermal storage ... 14
2.3. District Heating or Heat Network systems ... 15
2.3.1 District heating networks and future projects ... 16
2.4. Electric Radiators with thermal storage ... 17
2.5. Combined Heat and Power (CHP) ... 18
2.6. Solar Thermal ... 20
2.7. Waste Heat Recovery ... 20
2.8. Hydrogen ... 21
3. Forecasting and Data ... **24**
3.1. Forecasting for the RIIO-ED1 Business Plan (2015-2023) ... 24
3.2. Developing Distribution Future Energy Scenarios (DFES) ... 26
3.3. Heat Pump Growth Factors ... 28
3.4. Investment allocated within RIIO-ED1 ... 28
3.5. Forecasting local growth and pinpointing upgrades ... 28
4. Planning and Capacity Availability ... **29**
4.1. WPD's expectation of Heat Pump installations ... 29
4.2. Estimating Connection cost and timescale ... 29
4.3. Simplifying the application processes ... 30
4.4. Planning and Design Changes ... 30
4.5. Technical Changes related to Heat Pumps ... 31
4.5.1. Thermal Capacity ... 31
4.5.2. Power Quality ... 31
5. Providing information to Customers ... **32**
5.1. Guidance and Advice Documents published ... 32
5.2. Guidance and Advice Documents planned ... 32
5.3. Capacity Indication for customers ... 32
5.4. Connections Surgeries ... 32
6. Stakeholder Engagement ... **33**
6.1. WPD's Approach to Stakeholder Engagement ... 33
6.2. Business Plan Strategic Stakeholder Engagement ... 33
6.3. Strategic Engagement with local authorities ... 33
6.4. Local Engagement with local authorities ... 33
6.5. Engagement for Housing Associations ... 33
6.6. Engagement for housing design ... 34
6.7. Engagement with UK Government ... 34
6.8. Engagement with Welsh Government ... 34
6.9. Engagement with Go Ultra Low Cities (GULC) ... 34
6.10. Engagement with Local Enterprise Partnerships (LEPs) and Electricity Supply Areas (ESAs) ... 34
6.11. Stakeholder Engagement Plans for 2022 ... 35
7. Plans to support Heat Pumps ... **36**
7.1. Profiling and Modelling ... 36
7.2. Releasing existing network capacity ... 37
7.3. New Homes ... 37
7.4. Existing Homes ... 38
7.5. Clustering ... 38
7.6. Mitigation of local network constraints ... 38
8. Smart Solutions and Flexibility ... **39**
8.1. WPD's approach ... 39
8.2. Domestic Flexibility ... 39
8.3. Commercial Flexibility ... 39
8.4. Whole System Flexibility ... 39
9. Projects to demonstrate Heat Pump connections ... **40**
9.1. Developing a balanced portfolio of projects ... 40
9.2. Completed Projects ... 40
9.1.1. Freedom ... 40
9.3. Current Projects ... 41
9.3.1. Parc Eirin Superfast Electricity Housing for the Future ... 41
9.4. Future Projects ... 41
9.4.1. Self assessment ... 41
10. Commitments of 2021 ... **42**
10.1. Realising benefits ... 42
10.2. 2021 - Parc Eirin Superfast Electricity Housing for the Future ... 42
10.3. 2021 – Design capacity assumptions ... 42
10.4. 2021 – Network capacity indication ... 42
11. Targeted Commitments in 2022 ... **43**
11.1. Realising benefits ... 43
11.2. Continued Monitoring of Parc Eirin Superfast Electricity Housing for the Future ... 43
11.3. Equinox ... 43
11.4. Smitn ... 43
Bibliography ... **44**

Glossary

Abbreviation	TERM
A	Ampere
ATR	Autothermal reforming
BAU	Business As Usual
BEIS	Department for Business, Energy & Industrial Strategy
CBA	Cost-benefit analysis
CCC	Committee for Climate Change
CHP	Combined heat and power
CSE	Centre for Sustainable Energy
CO_2	Carbon Dioxide
DSR	Demand Side Response
DNO	Distribution Network Operator
DSO	Distribution System Operator
EfW	Energy from Waste
ENA	Electricity Networks Association
EPC	Energy Performance Certificate
ES	Energy storage (battery)
EU	European Union
EV	Electric Vehicle
GHNF	Green Heat Network Fund Transition Scheme
GWh	Giga Watt hour
HNDU	Heat Networks Delivery Unit
HNIP	Heat Networks Investment Project
HP	Heat Pump
ICE	Internal Combustion Engine
kVA	Kilo Volt Ampere
kW	Kilo Watt
kWh	Kilo Watt hour
kWth	Kilo Watt thermal
LCNF	Low Carbon Network Fund
LCT's	Low Carbon Technologies
LV	240/400 Low Voltage
m	million
MV	Medium Voltage
MVA	Mega Volt Ampere
MW	Mega Watt
MWh	Mega Watt hour
PV	Photo Voltaic
RIIO-ED1	Revenue = Incentives + Innovation + Outputs – Electricity Distribution 1
RIIO-ED2	Revenue = Incentives + Innovation + Outputs – Electricity Distribution 2
SCADA	System control and data acquisition
TDH	Total Harmonic Distortion
UGC	Underground cable
UK	United Kingdom
UKPN	Unted Kingdom Power Networks
WHR	Waste Heat Recovery
WPD	Western Power Distribution

1. Introduction

1.1. Our approach

This document details how Western Power Distribution will help achieve the UK governments declared net zero by 2050 targets for the De-Carbonisation of Heating and ensures that future building owners are able to meet the requirements of de-carbonisation of heating and connect to the network in the manner convenient to them.

While people largely agree with the need to tackle climate change, the majority of owner occupiers do not realise that this will mean changes to their homes.

The document endeavours to lay the foundations for the de-carbonisation of heating, providing an insight to the various methods available and the possible impact this might have on the local grid.

It describes research, development and deployment activities carried out during the current RIIO-ED1 electricity distribution price control period and planned for the future.

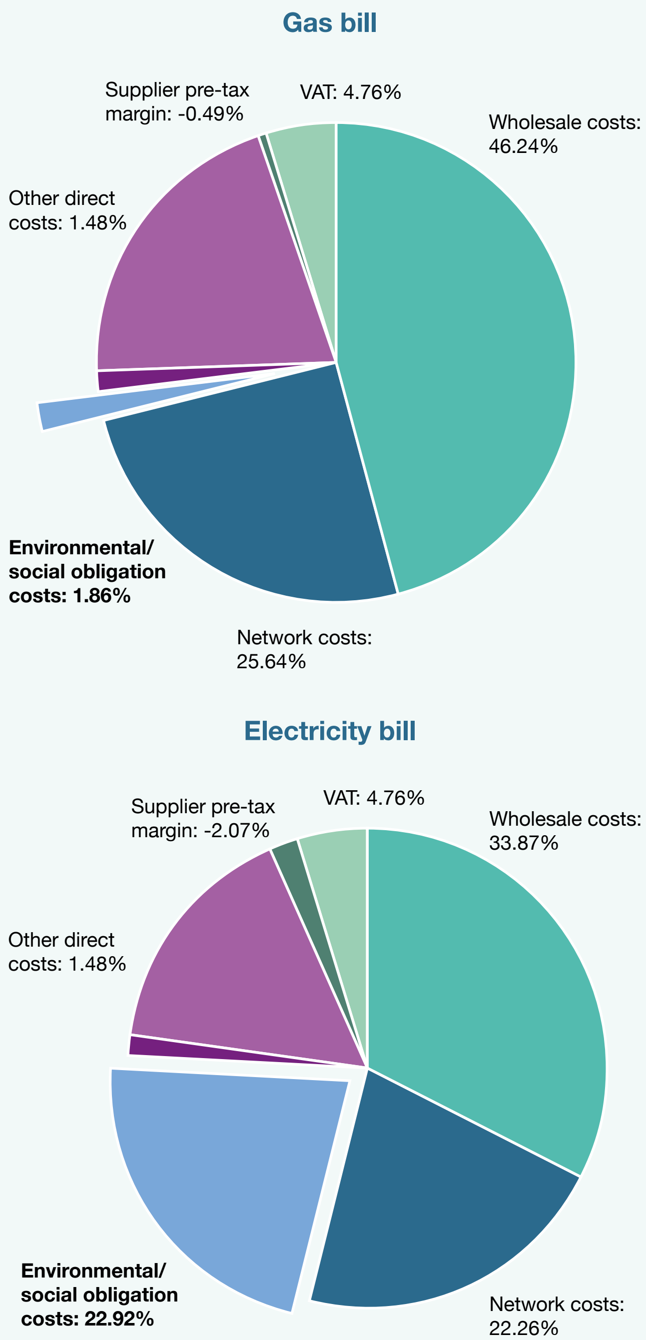
It also explains the rationale behind current innovation projects and business initiatives. Furthermore, it describes future activities including the transition of early-stage solutions into business as usual practice.

The document also presents WPD's vision for the decarbonisation of heating and outlines the various connections for a range of customer types. It provides details on the roadmap to achieve this vision and is supportive of an insulation first approach.

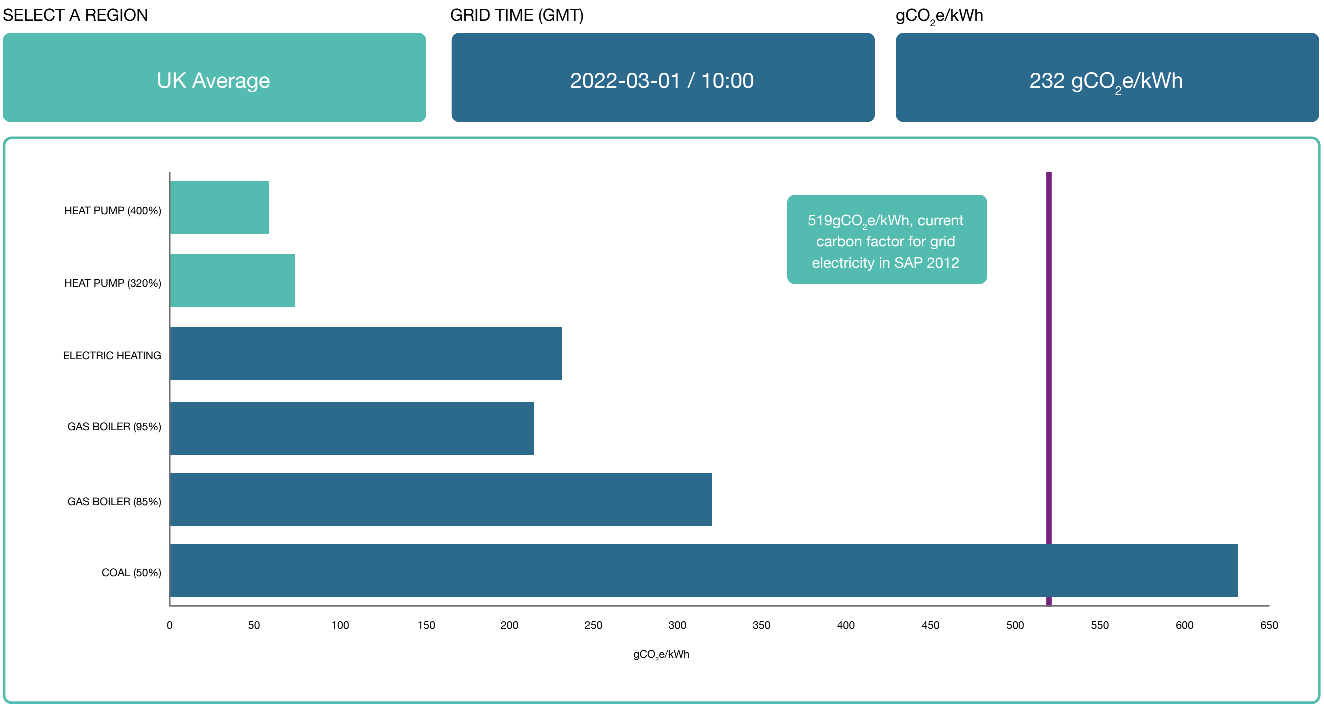
The cheapest energy for your building is the energy you don't have to use to heat the building. Especially when one looks at the current costing of energy in the UK, the infographic shown adjacent is from Ofgem (2021) and clearly shows the breakdown of the makeup of gas and electricity costs, some thought should be given by the government to swapping the environmental/social obligation cost between the two energy systems to encourage the conversion to low carbon heating.

The fact that UK government in the Spring 2022 budget has removed VAT for the next five years on energy efficiency measures such as solar panels, heat pumps and insulation means that this should encourage households to implement energy efficiency measures. But there is still no incentive in the pricing of electricity for the owner/occupier to transition from gas to electric heating. The current split in pricing is actually encouraging people to continue using fossil fuel.

Two aspects to affordability - operational costs



The other aspect which needs modification to encourage the transition to low carbon heating is the Standard Assessment Procedure. The data that feeds the calculations dates back to 2012. This for example gives electricity a carbon content of 519gms of CO_2 if this figure was updated to current values then the figure would drop down to about 230gms which will cause developers to use other non fossil fuel devices to heat their building. The graph below shows the UK average carbon content for electricity for 01/03/22 at 1000 hours.



The age of a property is the biggest single factor in the energy efficiency of the building. Building techniques and regulations have changed over time, alongside with wear and tear.

The UK has the oldest housing stock in Europe with 15% of buildings in England and 23% of buildings in Wales being built before 1900. Buildings in England and Wales were most commonly built between 1930 and 1982, 46% in England and 39% in Wales, and in England only 7% and 5% in Wales of buildings were built post 2012 or later[1].

Therefore for the de-carbonisation of heating to work efficiently in the UK, then it is essential that all the buildings where low carbon heating is installed, the building owners start from a fabric of the building first approach, i.e. undertake a detailed EPC review of the existing building so one knows where the problem areas are prior to upgrading the building. If the installation is a retrofit, then the upgrade to the fabric of the building should raise the EPC value to a minimum EPC C rating or higher.

Data from the BEIS funded Electrification of heat project of December 2021 clearly shows that there were small shortfalls (though within planned tolerances) in the number of installations for properties built pre-1945, with a slight excess in the 1945-1980 age bracket.

This is indicative of there being a greater challenge in successfully designing heat pump systems for older homes, however 163 installs were successfully completed in these older properties, clearly showing that such challenges are manageable in many cases.

If the building is a new build building, then that building should be designed for at least an EPC A rating from the offset, as going forward new buildings need to be 'energy efficient'. By improving housing insulation not only is energy consumption reduced but the capacity of the heating system can be reduced, bearing in mind the cheapest energy is the energy you don't use. The suitable sizing of electricity based systems will mean smaller costs. Having a well-insulated and ventilated building provides higher comfort levels and contributes to a healthier living environment. This approach would help the building occupier to keep fuel bills low, the designing of new build properties to have EPC A or higher will ultimately reduce the energy requirements of UK plc. Any retrofit work which incorporates the heating element should comply with PAS 2035 Whole house approach to retrofit.

This is best defined in the implementing Regulations of the Ecodesign Directive 2009/125/EC, which set minimum energy efficiency requirements.

Additional advice is available by visiting the Simple Energy website at **simpleenergyadvice.org.uk** where you can obtain independent advice as to things that one needs to consider.

The impact of CO_2 emissions is being mainly addressed through the UK governments The Future Buildings Standard. Heating and powering buildings currently accounts for 40% of the UK's total energy usage. The challenges involved in improving the energy efficiency of our buildings and reducing carbon emissions are significant.

To aid the transition the UK government has also published the following documents "The Ten Point Plan for a Green Industrial Revolution", their energy white paper "Powering our Net Zero Future", in addition "The Committee Point Plan for a Green Industrial Revolution", their energy white paper "Powering our Net Zero Future". In addition The Committee for Climate Change is "advising that the UK set its Sixth Carbon Budget (i.e. the legal limit for UK net emissions of greenhouse gases over the years 2033-37) to require a reduction in UK emissions of 78% by 2035 relative to 1990, a 63% reduction from 2019.

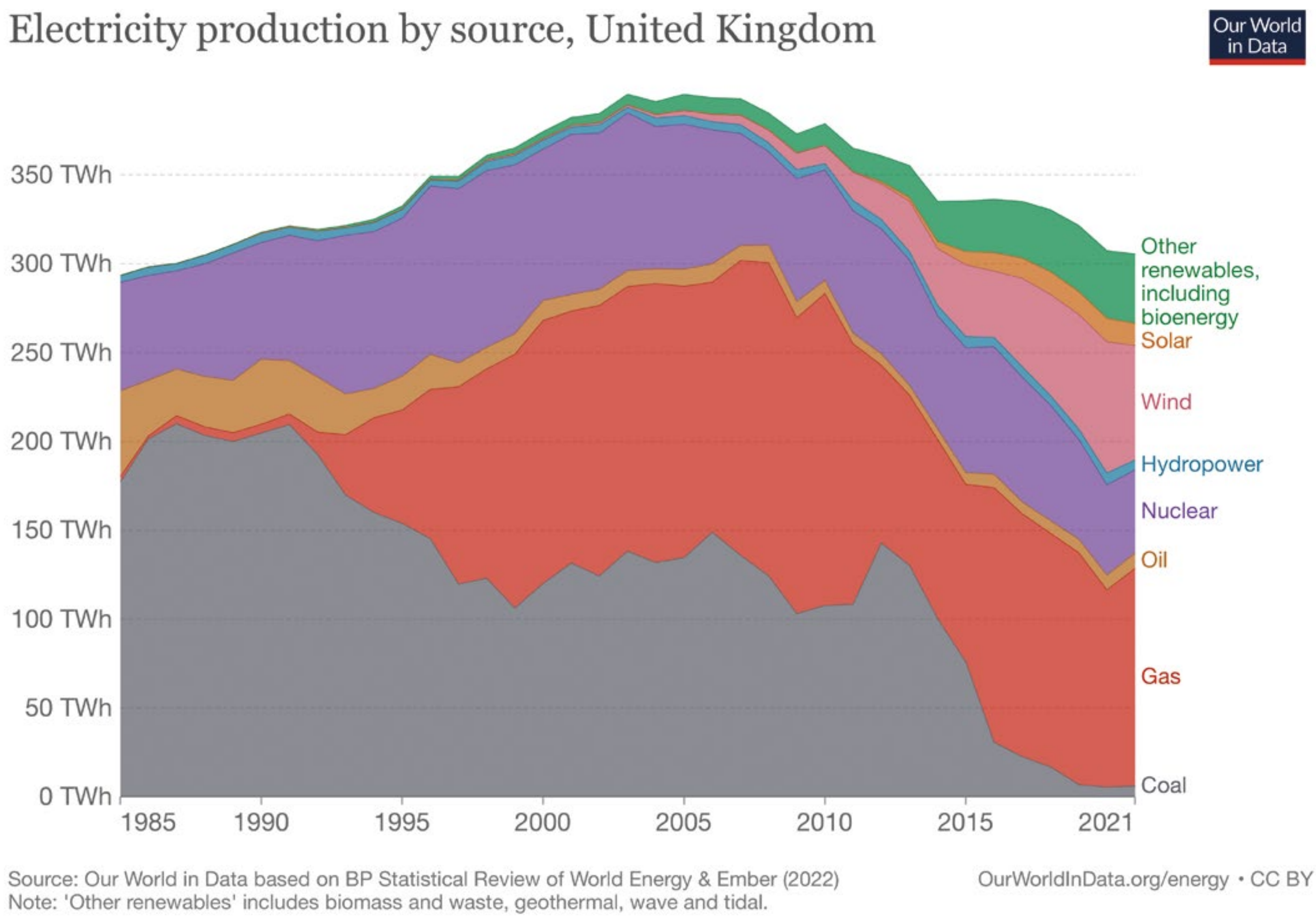
This will be a world-leading commitment, placing the UK decisively on the path to net zero by 2050 at the latest, with a trajectory that is consistent with the Paris Agreement"[2].

Tackling emissions from heating will need to be considered in the same way as we are already dealing with transport emissions.

During 2018 an estimated 38% of CO_2 emissions[3] in the UK were from the heating. It stands to reason that if the fabric of the building is improved then the energy consumed to keep the building warm or cool will be reduced which means there will be less dependence on the need for additional generation. The graph below clearly shows the reduction in consumption since the peak in about 2004/5, this trend needs to continue.

Achieving a climate neutral and circular economy requires the full mobilisation of industry. It takes many years to transform heating provision, with many domestic customers only replacing heating systems on failure or at the end of a 15 to 20 year lifespan. It is important that building owners are encouraged to be pro active so that when the time comes to replace their fossil fuel heating their first choice is to fit non fossil fuel heating as a replacement.

To reach the 2050 targets set in the Governments Clean Growth Strategy and the Future Homes Standard, WPD need to ensure that the availability of the electricity network helps make that societal change. The Department for Business, Energy & Industrial Strategy Heat Team require the networks to be ready ahead of need so that households and businesses don't continue with fossil fuel heating.



1.2. High Level Government Objectives

The UK government Future Homes Standard has already made inroads in reducing emissions in new homes. Previous revisions to Part L of the Building Regulations, regulated emissions from homes built today equate to less than half that of homes built 20 years ago. By making buildings more energy efficient and moving to cleaner sources of heat, there can be a further reduction of carbon emissions and keep energy costs down both now and in the future.

The Future Home Standard, to be introduced by 2025, will ensure new build homes are future-proofed with low carbon heating and world-leading levels of energy efficiency. The government intend to set the performance standard of the Future Homes Standard at a level which means that new homes will not be built with fossil fuel heating, such as a natural gas boiler. No further energy efficiency retrofit work will be necessary to enable them to become zero-carbon as the electricity grid continues to decarbonise. A low carbon heating system will be integral to the specification of the Future Homes Standard and the government anticipate that heat pumps will become the primary heating technology for new homes.[4] A useful reference can be found on the Governments Clean Growth website: -

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766109/decarbonising-heating.pdf

Taking the Government's Ten Point Plan for a Green Industrial Revolution, their Energy White Paper Powering our Net Zero Future, the Clean Growth Strategy and the Future Homes Standard all these documents set out the UK's objectives to reduce carbon emissions. The Energy White Paper states "Our success will rest on a decisive shift away from fossil fuels to using clean energy for heat and industrial processes, as much as for electricity generation."

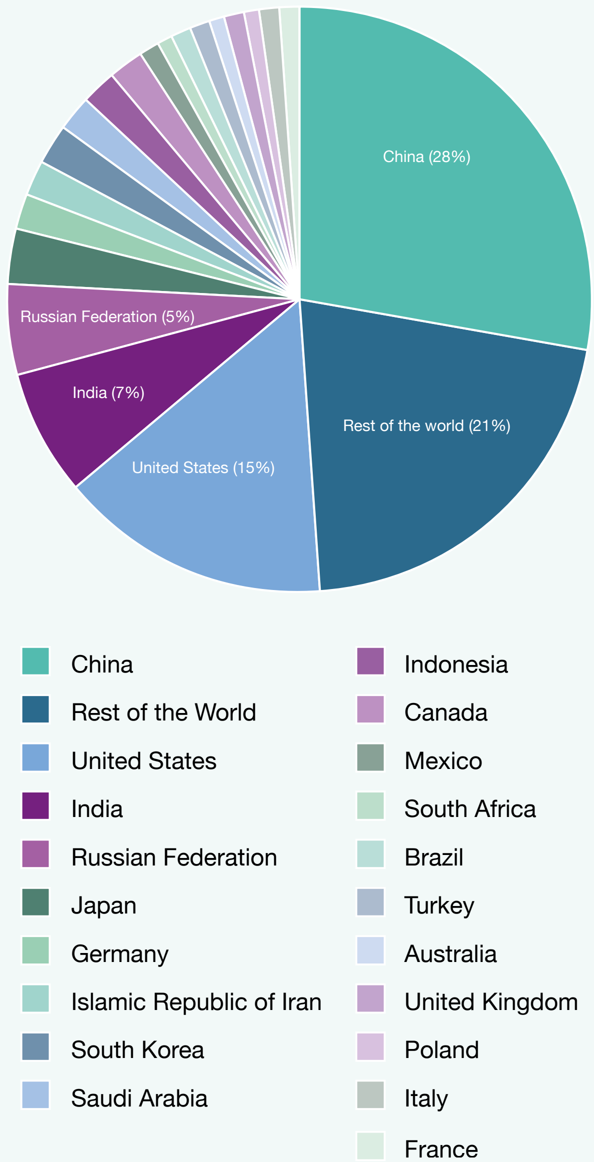
The British electricity networks need to be ready to accept this additional demand. WPD build networks with a 50 year asset life, so steps need to be taken now to ensure that the right networks are built for foreseeable future demands.

The graph shown adjacent shows the countries of the world that are producing 1% or greater of CO_2 emissions in 2020.

The graph was produced by the Union of Concerned Scientists and the data for the graph comes from Earth Systems Science Data 11.

The Stern Review, Economics of Climate Change (2006), states that the benefits of strong and early action far outweigh the economic costs of not acting.

The UK governments Heat and Buildings Strategy published in October 2021 shows that the future heating of buildings is likely to see a mix of low-carbon technologies used for the heating for buildings via hydronic air-to-water (air source) or ground-to-water (ground source) heat pumps and heat networks as a way to meet the low carbon budget.



2020 union of Concerned Scientists
Data: Earth Systems Science Data 11, 1783-1838, 2019

The Stern Review, Economics of Climate Change (2006), states that the benefits of strong and early action far outweigh the economic costs of not acting.

The UK governments Heat and Buildings Strategy published in October 2021 shows that the future heating of buildings is likely to see a mix of low-carbon technologies used for the heating for buildings via hydronic air-to-water (air source) or ground-to-water (ground source) heat pumps and heat networks as a way to meet the low carbon budget.

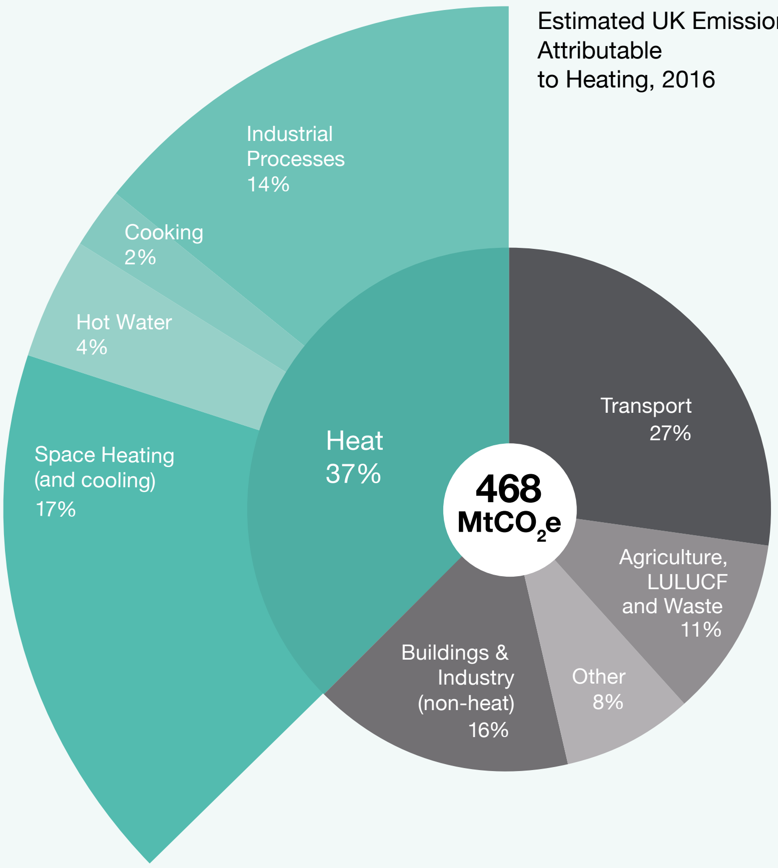
The Stern Review also points out that with the governments published heating strategy, then all interested parties can then act with 'no regrets'. This no regrets/low regrets is also echoed in the UK governments Heat and Buildings Strategy document.

Data produced by BEIS in November 2019, shown below, the green colouring clearly indicates the extent of heating CO_2 emissions has on the total UK CO_2 emissions, hence why action is required.

The governments Clean Growth Strategy identifies heat as the most difficult decarbonisation challenge facing the UK. It will be costly, involve large scale transformation and with that significant consumer impacts, and wide ranging changes to the energy systems and markets. Of the UK's 28 million households, there are approximately 17 million properties which are below the EPC b and C.

To cost-effectively decarbonise heat, most or all these 17 million buildings will need to be worked on to improve their respective EPC rating up to a minimum of C, between now and 2050. In 2017, the government set out the aspiration in the Clean Growth Strategy for as many homes in England as possible to be upgraded to EPC band C by 2035.

Estimated UK Emissions Attributable to Heating, 2016



The UK government is signalling its intention to phase out the installation of new natural gas boilers from 2035. Given the lifetime of a natural gas boiler is around 15 years, in order to reach net zero in a cost-effective consumer-friendly way, the aim is to phase out the installation of new natural gas boilers beyond 2035, once costs of low-carbon alternatives have reduced.

As a consequence the UK government is targeting growing the installation of electric heat pumps, from the current 30,000 per year to 600,000 per year by 2028, and converting the Off the Gas Grid customers to heat pumps during the 2020's.

Heat Pumps are becoming more commonplace on our houses, be they new-build or retro fit installations, especially as the UK government has set a target 600,000 heat pump installations per year.

The trend towards heat pumps is set to continue and increase as the UK adopts the governments Clean Growth Strategy and the Future Homes Standard.

Data produced by BEIS in November 2021 states that current heat pump installation rates in the UK were circa 34,896[5] per year, these installations are almost split evenly between retro fits and new build properties.

The government have stated that[6] and[2] they want the UK to remain a global leader in bringing down greenhouse gas emissions, and the major objective is to help the country rise to the challenge of cutting emissions to net zero by 2050.

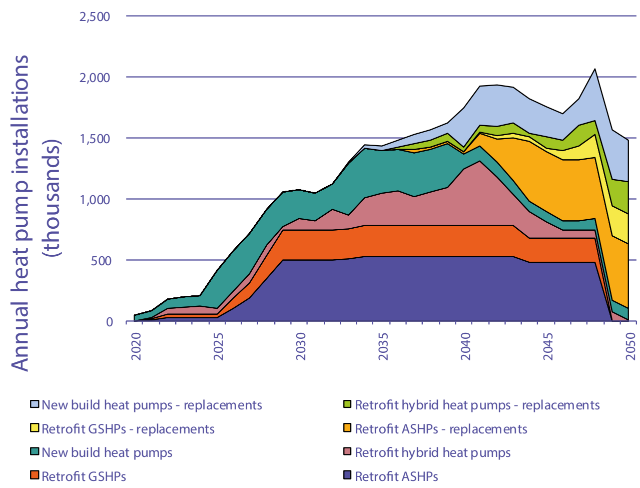
The adjacent graph shows where the Committee for Climate Change (CCC) shows the breakdown of yearly heat pump installations needed to reach the goals set. Whilst the majority of these heat pumps would be provided via the new build market there is also a focus on off-gas homes.

It is a BEIS prerequisite that during the 2020's any oil fired, solid fuel fired and LPG fired central heating which are off the gas grid and need to be replaced are to be converted to heat pumps with any remedial reinforcing of the electrical network being carried out ahead of need.

Figure 3.2 Buildings heat – high-level Sixth Carbon Budget policy package

Source: CCC

Figure B3.2 Annual heat pump deployment in homes



Source: CCC analysis, Element Energy for the CCC (2020) Development of trajectories for residential heat decarbonisation to inform the Sixth Carbon Budget

2. Low carbon heating methods

WPD are a Distribution Network Operator/Distribution System Operator and as such are agnostic as to what heating system is used by customers. The information in this section is an indication of the Low Carbon Heating that could be used in the de-carbonisation of heating in the UK and the sort of impact that would have on the electrical network.

Please note all price shown are based on electricity prices before the latest price increase.

2.1. Heat pumps

A heat pump is a device that uses a small amount of energy to move heat from one location to another. It is an energy efficient heating method, due to the coefficient of performance (COP) a heat pump has, depending on the time of year this could reach around 3.5, which means for 1kW of electric power in you get 3.5kW of thermal heat out. Heat Pumps breakdown into basically three distinct types Ground Source, Water Source or Air Source.

The term ‘Heat Pumps’ refers to a group of technologies that incorporate HVAC (heating, ventilation, and air conditioning) devices that provide thermal heat energy that is transferred from a source of heat or warmth, to a destination called a heat sink, effectively ‘pumping‘ warmth from one place to another.

Heat pumps move thermal energy in the opposite direction of natural heat flow by absorbing heat from a cold space and releasing it to a warmer one. The primary function of heat pumps is space heating through radiators, underfloor heating systems, or warm air convectors, heat pumps can also be used to heat water for use in the home or business. Most heating pumps have good climate control capabilities and can be used to provide space cooling by simply reversing the process of space heating. In many ways, a heat pump is functionally the same as conventional air conditioners. It’s basically an air conditioner that can reverse itself.

To achieve this heat transfer Fluorinated gases (F-gases) are used in the compressor, these gases are greenhouse gases but are not designed to be emitted from the appliance (although in some cases they will leak and need to be appropriately dealt with at the end of the appliance’s life). There is a ground swell from the manufacturers to using non F gas like R 290 (propane refrigerant) to run in the compressors, thus making them a “greener” option.

Using for example a detached house of 200m^2 which was built in 2010 in accordance to the relevant Building Regulations Standards, this house would have a space heating requirement of 11,000kWh per year. In addition to the space heating, there is the domestic hot water (DHW) to account for, assume four people living in the house, would equate to an additional 4,000kWh per year. A typical condensing gas boiler performing at 85% efficiency would achieve this at around £1,005 per year, - £734 for space heating and £271 for DHW. An oil-fired boiler with a similar efficiency would cost about £1,615 per year. These prices are volatile as they are based on world markets.

A correctly installed ground source heat pump only providing space heating would typically have a Coefficient of Performance (COP) of 4.3, so to produce 11,000kWh of heat, the ground source heat pump would need 2,558kWh of electricity at a typical cost of £349.

Adding the DHW demand, the heat pump would raise the water temperature to 40°C, electric heaters could then be used to raise the temperature of the DHW to the required storage temperature. This way the COP of 4.3 for the heating cycle maintained and the work rate of the electric heaters is reduced (at an effective COP of 1.0). The cost of DHW would cost typically about £395, reaching a total running cost of £744 per year - meaning a 26% reduction in annual running cost for the house.

For a typical air-source heat pump, which runs either air to air or air to water, can be typically rated with an ambient outdoor temperature >7 °C although this rating is affected by actual temperature of the air. Data from the Met Office shows that the average UK temperature from November to March (2015-2018) was 5.78°C, this will mean the COP will be about 2.8.

This translates to the heat pump needing about 3,928kWh of electricity for space heating costing about £510 plus another £460 for the DHW, thus ending up with a total of £970 per year. The reduction in air source heat pump running costs would be of only 3.5% in comparison to a gas boiler.

All electricity costs quoted are the not the new costs per kWh that electricity bills are currently showing.

Converting an existing LPG or Oil fired system to a Hybrid system is one method that can help by avoiding the high capital costs and delivering heat without creating capacity peaks on the electricity system is the hybrid heating and control technologies, these hybrid systems are an air source heat pump which is installed in parallel to the existing oil fired or LPG fired boiler, these systems can deliver low carbon heating solutions in homes that reduce CO_2 emissions but keep the costs down for the customer.

One further important point that needs to be considered is that any home that has been plumbed with 8mm OD microbore tubing cannot be converted to any form of heat pump, unless all the microbore piping is replaced, with all the additional work and complexity that would bring.

2.1.1 WPD's approach to facilitate HP installation

As an electricity system operator WPD's approach is to ensure that a suitable electrical system exists for all the heating requirements in all situations. The principle is simple, the heat pump infrastructure requires higher volumes of energy and it is WPD's job to provide the conduit for this energy.

With new build infrastructure the network is designed to cater for the necessary load so heat pump demands can be built into our initial network designs. WPD's plans will vary depending on the application and we detail various different options in this section.

With retrofit installations of heat pumps the overall demand on the network will increase, perhaps to a level that was higher than the original design assumptions. Mains cables may need to be uprated. A legacy design approach where service cables were looped and shared between two properties will need to be re-configured so that the house or building being installed with a heat pump will have its own unique service cable supply. Where this is the case and a domestic sized HP is to be connected the looped service will be removed at no cost to the customer.

It is expected that we will see high demands on the specific cables which supply local streets or to the service cables which feed individual properties and, especially where HPs are clustered, there is more chance of the network becoming constrained. WPD are already installing larger cable assets on new build substations and areas that have been identified where the proactive uprating of cable networks is appropriate.

Heat Pumps include electric motor pumps and can create power quality issues on some networks. To manage the assessment of Heat Pumps, the Electricity Network Association has created a Heat Pump database which defines the various criteria and also assess the heat pump to ensure it meets the requirements of BS EN 61000 for power quality, flicker, etc. criteria, this pre-assessment of the various HP models by the ENA streamlines the connection process thus making it easier for all including the DNOs. If a HP is offered which has not been pre-assessed into the database then WPD will carry out a complete assessment and the details of the new HP willbe included in the ENA database, this does make the turnaround assessment procedure longer due to the amount detailed work required.

2.1.2 Heat Pumps and Building design

Energy efficiency is assessed by Energy Performance Certificate (EPC) rating, where 'A' represents the best performing homes and 'G' the 'worst'. Homes with high EPC ratings will generally have high levels of insulation and efficient heating systems.

In broad terms, lower rated homes tend to be older, while higher rated homes tend to be newer due to the increased Building Regulation standards.

The new Future Homes Standard will see low carbon heating systems being integral to the specification of the Future Homes Standard and the government anticipate that heat pumps will become the primary heating technology for new homes.

The UK government wants to ensure that all parts of industry are ready to meet the Future Homes Standard from 2025. A 2021 interim uplift of the Future Homes Standard will deliver high quality homes that are in line with the government's broader housing commitments and encourage homes that are future proofed for the longer-term. These homes will be expected to produce 31% less CO_2 emissions compared to current standards.

But from 2025 the UK government want, new homes built to the Future Homes Standard to have carbon dioxide emissions at least 75% lower than those built to current Building Regulations standards[7].

With BEIS targeting off the gas grid homes for the fitting of HPs these properties are more likely to have solid walls than properties using mains gas, electric or communal heating. EPCs were introduced in 2010 and off-gas homes are not only more likely to have a low EPC rating, but also less likely to have been improved so will require a degree of remedial work prior to fitting of HPs.

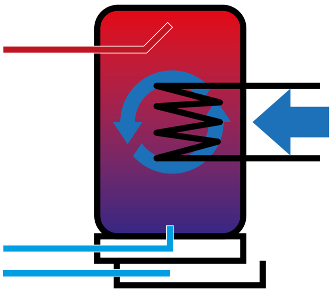
Since the 1970s houses with gas fired central heating systems could have a microbore pipework system for the radiators, this poses a problem if the houses are to be converted to air source heat pumps, as the air source heat pump cannot cope with the back pressure created by the microbore system. There is a work around which does not mean re-plumbing the building, provided the microbore system is 10mm outside diameter then a suitable buffer tank and circulation pump can be added into to the network to overcome the back pressure issues.

With heat pumps offering low grade heat compared to gas fired central heating it means the building housing the heat pump needs to have an EPC rating of C or above. If the house is designed with say an EPC of A the heat pump will not have to run 24/7 to maintain the heat in the home and the size of the heat pump will be smaller than a house with a low EPC rating.

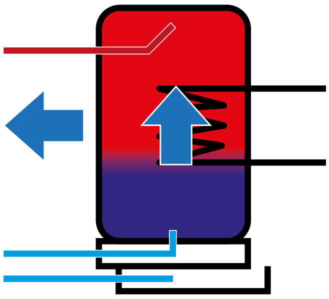
Houses with a low EPC rating will require a larger heat pump and the device is likely to be running most of the day. It is likely that tariff price signals will benefit customers who can avoid the evening peak load times on the electricity networ. It's in these scenarios that some form of heat battery such as a mixed storage tank would be required The storage tanks domestic hot water (DHW) storage and energy storage tanks are categorized and calculated according to their mixing characteristics during charging and discharging phases.

A mixed storage tank maintains its temperature layering while in discharge mode, hot water withdrawal and has a minimal mixing zone in this mode. In the loading phase or reheating phase, the storage tank is ideally mixed due to convection.

Figure 1 - Phases of a mixed storage system



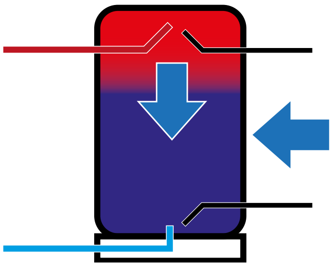
a)
Charging phase of a mixed storage system



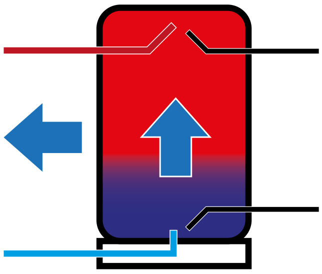
b)
Discharging phase of a mixed storage system

A charging storage tank is characterised as a tank which maintains its temperature layering both in charging and discharging mode.

Figure 2 - Phases of a charging storage system



a)
Charging phase of a charging storage system



b)
Discharging phase of a charging storage system

2.1.3 Existing heat pumps and capacity

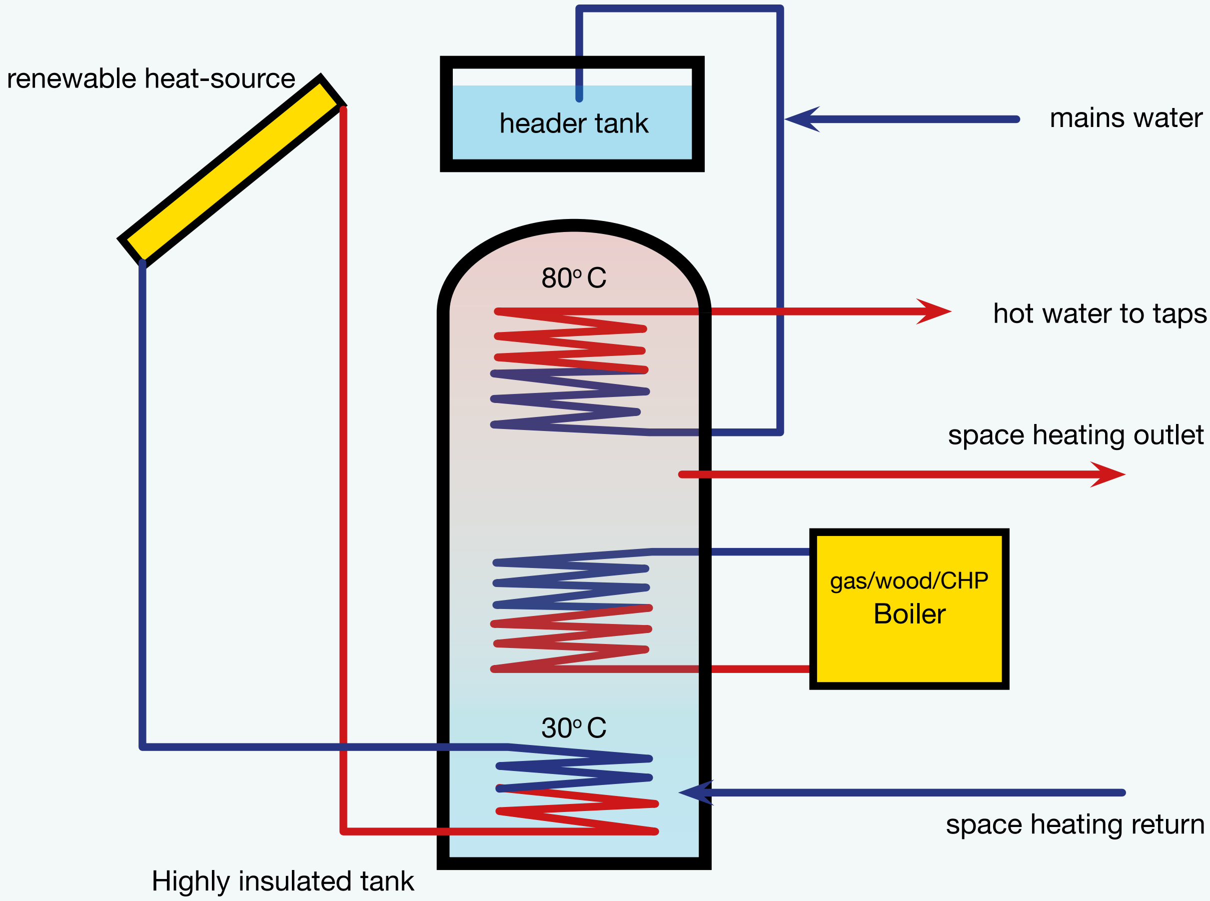
WPD already have experience understanding the effect of heat pumps on the network to support the early adopters of non-fossil fuel heat systems. The table below shows the number and capacity of heat pumps as reported in WPD's DFES annual reports for the four license areas as of March 2022. See below for the table.

Installation capacity	Number of installations	Total installed capacity (MW)
Up to 3.85kW	2,725	8.66577
Above 3.68kW	7,264	52.84131

2.2 Thermal storage

Thermal storage has been evolving for about 25 years. Thermal storage is the buffer associated with heat sources that provide heat certain times but there is an almost constant need for space heating. A typical example is a heat pump, it can provide SH and DHW but not at the same time and this is where the thermal store comes into its own.

A number of methodologies have been developed to store heat over the years, including rock stores and phase-change materials, but the most effective and pragmatic method has been in the use of water (water can retain around five times more heat than concrete). After a number of years of varying success, the market can now provide efficient water-based thermal stores. Thermal storage tanks appear to be similar in appearance to the conventional hot-water cylinder, but they are very different in their operation. A thermal store provides both space heating (radiators or underfloor) and mains pressure hot water.



A thermal storage water cylinder reverses the normal process whereby the boiler heats the water that is to be sent to the taps, this water being stored until required. By contrast, in a thermal storage system, domestic hot water (DHW) is provided via a heat exchanger. Cold water from the mains enters the coil at the top of the tank and is heated by the surrounding hot water before outputting to the taps. Hot water is therefore effectively provided on demand and at mains pressure.

The water that passes through the central heating system also passes through the cylinder. This water never changes, it simply flows around the vented or un-vented heating circuits before being re-heated through the thermal store.

A heat pump or boiler, whether supplied by gas, biomass or CHP, is usually the prime generator of heat to a thermal store. Water heated by the boiler passes into the tank and through a heat-exchanging coil and heats the water in the tank. Additional renewable heating technologies (e.g. solar collector or heat pump) can be included by adding a further coil to the bottom of the tank-where relatively low grade heat can be most efficiently employed in heating the coldest part of the tank.

2.3. District Heating or Heat Network systems

District heating or a Heat network is a system of insulated pipes covering a finite local area, for example the majority of Copenhagen's building heating is supplied via a district heating system, where instead of having an individual boiler for heating your building a district heating or heat network system provides the delivery of heat via highly insulated pipes from a centralised heat source.

The centralised heat source could be energy from waste, waste heat, or combined heat and power source to name a couple of energy sources.

As an electricity system operator WPD's approach is to ensure that a suitable electrical system exist for district heating networks in all situations. We have noted the Committee on Climate Change comments about the development of Heat Networks, as we see this technology develop we will developed specific guides.

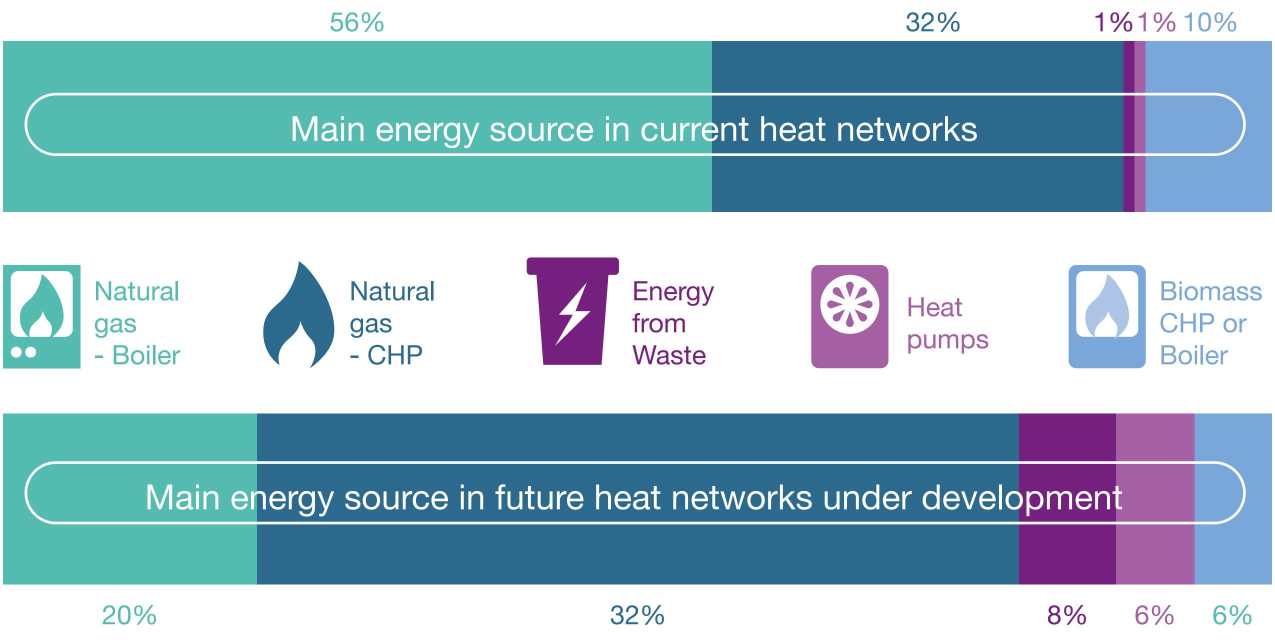
We predict that Heat Networks will be relatively easy for us to accommodate on our networks, with the input energy required for them being provided at one central point rather than individual homes.

Where Heat Networks include generation elements, this may also support the electricity network. These networks are likely to also offer balancing services to the wider grid.

WPD are beginning to see District heating, and are working with Bristol and Cardiff Councils to this effect, WPD are planning on monitoring the heat network to understand how heat networks will impact on the network with the objective of WPD being an enabler to the de-carbonisation of heat in all its forms.

In our forecasting, where a local authority has an existing heat network in place, or has identified one as part of its local area energy plan, WPD have down rated the expectation of heat pump uptake in those areas and uprated the expectation of Industrial & Commercial (I&C) energy profile demand.

An indication of how district heating systems can be "powered" is shown below where the current methods are shown and the future methods are shown as well, giving an indication of the de-carbonisation taking place.



2.3.1 District heating networks and future projects

Currently district heat networks provide about 2% of the overall UK heat demand across the domestic, public, industrial and commercial sectors, but a much higher share can be achieved. The UK government's research suggests that about 14-20% of the UK heat demand could be cost-effectively met by heat networks by 2030 and about 43% by 2050.

In recent years, new schemes have come to market all over the UK and support local economies, such as the Commonwealth Games Village in Glasgow, and ongoing projects in the cities of Leeds and Bristol aiming to connect new loads to local and low carbon energy sources. The latest figures reveal that around 17,000 heat networks supply nearly 500,000 consumers in the UK, up from an estimate of around 2,000 networks and 211,000 users in 2013.

In addition, 81 heat network projects are in the pipeline under the Government's Heat Network Development Unit (HNDU) and are seeking investment. The pipeline reflects a portion of the total projects that HNDU is currently working with. These projects are at different stages of development from heat mapping through to commercialisation.

Low carbon and renewable energy sources for heat networks can significantly lower carbon emissions from heat (between 50 to 100gCO_2 /kWh for a biomass network), compared to traditional solutions (above 200gCO_2 /kWh).

Within the WPD area the following list gives the many projects that currently either under construction or in the planning stage.

HNIP APPLICATIONS

- Bridgend Town Heat Network, is a CHP – Gas system, sponsored by Bridgend County Borough Council.
- Old Market Network, is a water source heat pumps system, sponsored by Bristol City Council.
- Temple, is a water source heat pumps system, sponsored by Bristol City Council.
- Bedminster, is a water source heat pumps system, sponsored by Bristol City Council.
- Redcliffe Heat Network, is a CHP – Gas system, sponsored by Bristol City Council.
- Cardiff, is a CHP Energy from Waste (EfW) system, sponsored by County Council of the City and County of Cardiff.
- Cranbrook Expansion, is a CHP EfW system, sponsored by East Devon District Council.

HNDU COMMERCIALISATION/DPD STAGE PROJECTS

Nil

HNDU TECHNO-ECONOMIC FEASIBILITY STAGE

- Ebbw Vale (Rassau) FES, is a Boiler – Biomass system, sponsored by Blaenau Gwent County Borough Council.
- The Works FES, is a Boiler – Biomass system, sponsored by Blaenau Gwent County Borough Council.
- City Centre Phase 2 FES, is a Water source heat pumps system, sponsored by the Bristol City Council.
- GIFHE(peak) FES, is a CHP – Gas system, sponsored by North East Lincolnshire Council.
- Plymouth Southern City Centre District Energy Scheme, is an Air-source heat pump system, sponsored by Plymouth City Council.
- West Bromwich FES, is a Waste heat – Other (without heat pump) system, sponsored by Sandwell Metropolitan Borough Council.
- Solihull Town Centre FES, is a CHP – Gas system, sponsored by Solihull Metropolitan Borough Council.
- Veolia Energy from Waste FES, is a CHP - EfW system, sponsored by Staffordshire County Council.

HNDU MAPPING AND MASTER PLANNING STAGE

- Tregaron MAP, is a Boiler – Biomass system, sponsored by Ceredigion County Council.
- Corby Town Centre MAP, is a CHP – Gas system, sponsored by North Northamptonshire Council.
- SERC EfW heat supply MAP, is a CHP – EfW system, sponsored by South Gloucestershire Council.

NON HNIP PROJECTS THAT ARE UNDER CONSTRUCTION

Deep Geothermal COM CST, is a geothermal system, sponsored by Stoke-on-Trent City Council.

PROJECTS NOT CURRENTLY BEING PURSUED BY LOCAL AUTHORITY SPONSOR

- Icknield Soho Loop & Smethwick Gas CHP/WSHP MAP, is a CHP – Gas system, sponsored by Birmingham City Council.
- Langley & Peddimore FES, is a CHP – Gas system, sponsored by Birmingham City Council.
- Chesterfield MAP, is a CHP – Gas system, sponsored by Derbyshire County Council.
- Matlock MAP, is a waste heat – Industrial (without heat pump) system, sponsored by Derbyshire County Council.
- Clay Cross MAP, is a CHP – EfW system, sponsored by Derbyshire County Council.
- Exeter City Centre DPD, is a CHP – Gas system, sponsored by Devon District Council.
- Cultural Quarter FES, is a CHP – Gas system, sponsored by Leicester City Council.
- Waterside FES, is a CHP – Gas system, sponsored by Leicester City Council.
- County Hall site at Glenfield FES, is a CHP – Gas system, sponsored by Leicester City Council.

2.4. Electric Radiators with thermal storage

This is a design of electric radiator, where the internal electrical elements are encased within non porous fireclay heat plates. When the element heats, it transfers the heat to the fireclay and then in turn to the radiant surface of the radiator. Once the core is hot, cold air is drawn from the floor and up through the flutes to create convection heat.

These radiators continuously generate and conserve heat within the core of the heater. Each heat plate has a typical power rating of 100 – 200 watts. When the electric heating system is switched on, the element gets hot, heating the storage plate within a matter of minutes. Once heated the heat plate will retain heat for well over 30 minutes, transferring heat to the metal casing and flutes of the Radiator.

These radiators often have a built in digital electronic room thermostat and 7 day programming system. Optionally they can be controlled remotely by radio frequency and by an App from any smart device. This continual dynamic re-heat process continues thereby maintaining the room temperature. The ability to sense temperature changes and react immediately is one of the great benefits of this type of heating.

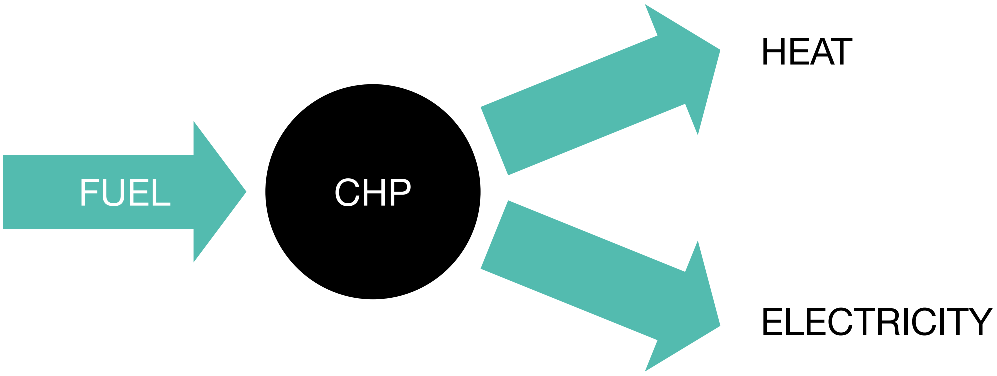
Because of the ability to heat up quickly the use of electricity is limited and the cost of using the radiators may be low provided the buildings insulation is good. These radiators heat the room to a comfortable even temperature and also keep the floor temperature within a few degrees of the ambient room temperature.

Using this form of heating will mean that for every kW of power used there will be a kW of thermal heat.

2.5. Combined Heat and Power (CHP)

CHP is a process in which both space heating plus domestic hot water heating and electricity are produced at the same time. Traditional CHP units have been operating at an industrial/community scale since the 1970s. Now since 2000, with rising energy prices, micro CHP designed for individual buildings has become economically viable.

Effectively the micro CHP unit replaces the conventional gas central heating boiler providing heat and hot water as usual, but additionally providing some of the building's electricity needs. The European Cogeneration Directive defines micro-CHP as all units with an electrical capacity of less than 50kW.



There are three types of micro CHP boiler: -

1) **The Stirling Engine CHP Boiler,** this is a type of boiler that is used mostly in domestic settings It is a type of external combustion engine, where the combustion engine is heated when the boiler is fired up to produce the hot water. This heats up the fully enclosed working gas within the Stirling engine, causing it to expand. The expansion of the working gas forces a piston to turn up and down between a copper coil, generating an electrical current, which can then be used in the home. The working gas usually used in a Stirling engine is helium, due to its strong heat transfer properties. The main limitation of this type of boiler is that it only produces electricity when you have the central heating on, so despite being a very efficient type of boiler, it does not produce an abundance of electricity. A key advantage is that the combustion process involved in a Stirling Engine CHP boiler is much quieter and more efficient than internal combustion engines.

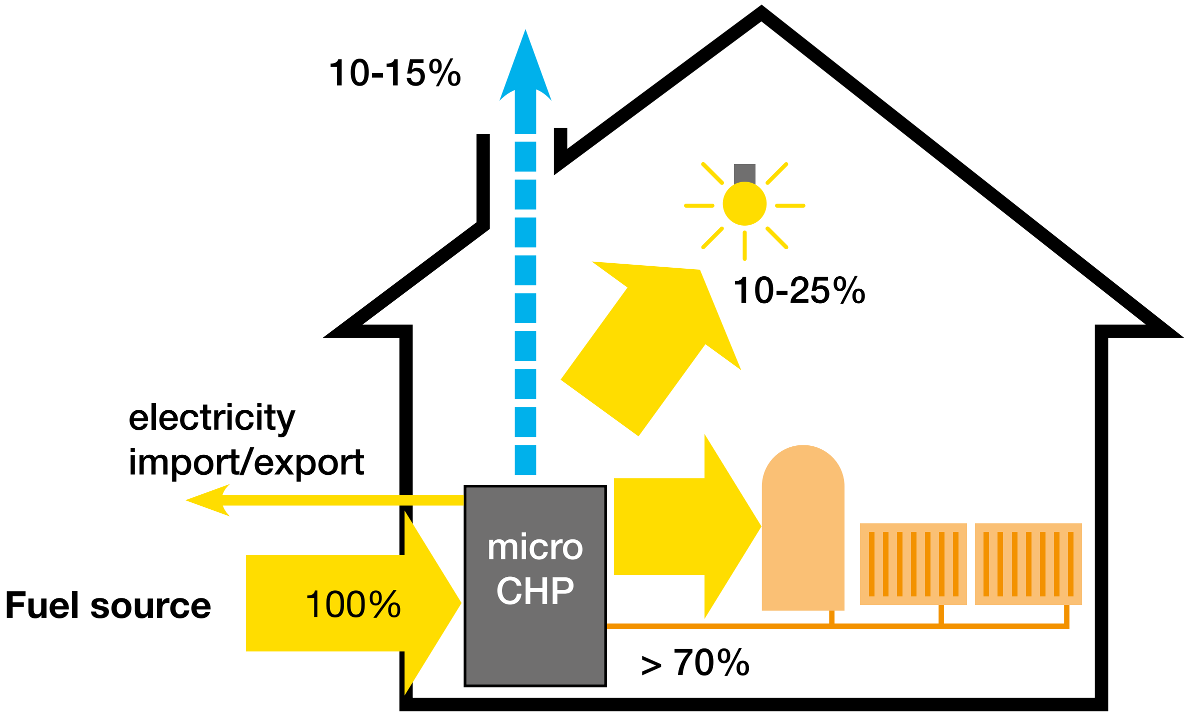
2) **The Internal Engine CHP Boiler,** this type of CHP boiler is commonly used in large buildings such as hospitals. It involves using a fuel source to drive a turbine, which is connected to the electricity generator. The waste heat from this combustion process is captured to produce hot water for the space heating and warm water. This is the most common form of CHP boiler found to date. However the process is noisy and you have far less control over the hot water generated, so fuel cell and the Stirling engine CHP boilers are often preferred.

3) **The Fuel Cell CHP Boiler,** this is a boilers use fuel cells which convert fuel and air directly into power and heat through a quiet, efficient, solid-state electro-chemical reaction. Fuel cells generate power significantly more efficiently than internal combustion and Stirling engine CHP boilers. This is because fuel cell CHPs convert chemical energy directly to an electrical current, maximising their efficiency. This type of CHP boiler is still in development so is not yet commercially available on a wide scale.

The main output of a micro-CHP system is heat, with some electricity generation, at a typical ratio of about 6:1 for domestic appliances. A typical domestic system will generate up to 1kW of electricity once warmed up. The amount of electricity generated over a year depends on how long the system is able to run. Domestic micro-CHP systems can be powered by mains gas or liquefied petroleum gas (LPG), plus there models are now powered by wood chip, bio mass or bio-liquids, including biodiesel. Although gas and LPG are fossil fuels rather than renewable energy sources, the technology is considered a low carbon technology because it can be more efficient than just burning a fossil fuel for heat and getting electricity from the grid. Micro-CHP systems are a similar size and shape to standard domestic boilers. They can be mounted on a wall or can stand on the floor.

Current developments in micro CHP technology are around the Stirling engine. These engines are external combustion engines, which allow continuous, controlled combustion resulting in very low pollutant emissions and high combustion efficiency. In comparison with ICE devices, Stirling engines have relatively long service intervals as well as lower running costs as well as being quieter – which makes them more suitable for domestic applications.

The cost of installing a CHP boiler is between £5000 to £7000, depending on the type of installation and home specification.



The main difference between a micro-CHP system and a standard boiler is that a micro-CHP system can generate electricity while heating water – a boiler cannot do this.

A Stirling engine micro CHP system would cost about £5k installed and would generate about 1kW of electricity, so if the electricity that is generated by the CHP could be used in the building then this will reduce the electricity consumption of the building thus reducing bills.

2.6. Solar Thermal

Solar thermal energy is well known as a valid technology for hot water preparation and space heating in residential buildings. Solar thermal energy is the conversion of the radiant energy from the sun into heat, which can then be used for such purposes for SH and DHW in buildings. For WPD the interest is about making a connection for the product as well as establishing how electricity demand might change as solar collection systems are added to the portfolio of heating solutions. Some systems are also able to combine photo voltaic system into the solar heating thus fully maximising the space taken up by the system. A solar thermal collector working on this principle consists of a sun facing surface which transfers part of the energy to a working fluid such as water or air. To reduce heat losses to the atmosphere and to improve its efficiency, one or two sheets of glass are usually placed over the absorber surface and insulation is placed behind the absorber. This simple solar thermal collector is called a flat plate collector, which can achieve temperatures of up to about 100°C.

Solar thermal systems have been developed to a mature and economically feasible standard of technology, ready to use also for colder climates and for special applications, wherever low temperature heat up to 100°C is needed. According to Mauthner and Weiss (2013), the worldwide installed capacity amounts to 234GWth corresponding to 335million m^2 of solar collectors (status by the end of 2011). The biggest markets are China followed by Europe, USA, and Canada. At present, however, the vast majority are small systems in private houses.

Solar district heating (SDH) plants are, on the contrary, a large scale application of solar thermal energy. Large fields of solar collectors form the solar thermal plant, which feeds the produced solar heat into block or DHW networks in urban quarters, smaller communities, or large cities. The collector fields are either installed on free ground or integrated into building roofs. Both types of solar collectors, glazed flat-plate and evacuated tube collectors, are used, and the collector field capacities range from 350kWth up to 50MWth for the largest (at present) systems installed. In combination with heat stores, the solar thermal plant contributes renewable and emission-free solar heat at shares of typically 10–50% of the total heat supply of the DHW system.

In particular, Denmark is currently creating a success story, when it comes to solar DHW. Between 2010 and 2014, 35 plants were built, representing a total capacity of 264MWth. Most of those plants are coupled with combined heat and power (CHP) plants and were realized without incentives. A total capacity of 328MWth is already built today in Denmark, and 250MWth more are already planned. A success factor for the development in Denmark is the flexibility of the entire heat and electricity production system in which the local energy providers, usually organized in cooperatives, can participate. The EU-funded demonstration project Sunstore (Février, 2013) on the Danish island, Aero, is a lighthouse example for such a system. The Danish District Heating Association aims at an installed capacity of 5.6GWth until the year by 2030.

At international level, the long-term potential of solar thermal energy is estimated to be 15% of the total DHW capacity.

Historically, solar DHW plants were introduced in the late 1970s by the interest to develop solar heating plants with seasonal storage. Sweden had a leading role in the early demonstrations, together with the Netherlands and Denmark. In the 1990s, projects in Germany and Austria followed. To-date 216 plants with more than 350kWth nominal power have been put into operation in Europe. Out of these, 82 plants have a nominal power of more than 1MWth. The total installed capacity amounts to 433MWth and the yearly increase in the year 2013 was actually 32% (Dalenbäck, 2014). Nevertheless, solar DHW plants represent only about 1% of the installed capacity of solar thermal systems, despite the fact that competitive heat prices lower than €50/MWh can be reached.

2.7. Waste Heat Recovery

Industrial waste heat is the energy that is generated in industrial processes which is not put into any practical use and is lost, wasted and dumped into the environment.

Recovering the waste heat can be conducted through various waste heat recovery technologies to provide valuable energy sources and reduce the overall energy consumption, ultimately the owner of this waste heat could offer the heat to district heat network where it could be used to provide a heating to district heat network.

With the growing trend of increases in fuel prices over the past decades as well the rising concern regarding global warming, engineering industries are challenged with the task of reducing greenhouse gas emissions and improving the efficiency of their sites.

Sources of waste heat mostly include heat loss transferred through conduction, convection and radiation from industrial products, equipment and processes and heat discharged from combustion processes.

Heat loss can be classified into high temperature, medium temperature and low temperature grades. High temperature WHR consists of recovering waste heat at temperatures greater than 400°C, the medium temperature range is 100–400°C and the low temperature range is for temperatures less than 100°C.

Usually most of the waste heat in the high temperature range comes from direct combustion processes, in the medium range from the exhaust of combustion units and in the low temperature range from parts, products and the equipment of process units.

It is estimated that the UK industrial sector consumes as much as 17% of the overall UK economy's energy consumption and generates about 32% of the UK's heat-related CO_2 emissions.

2.8. Hydrogen

Hydrogen can play a part in plans to reduce carbon emissions and has the benefit of being able to make low carbon use of the existing gas network. In WPD we trialled the Freedom project with Wales & West Utilities which showed how gas systems, with or without Hydrogen, can help customers reduce their carbon footprint.

As with other systems that are not directly linked to electrical energy at the home or point of use, our interest in Hydrogen is in the power that will be required to produce the gas. This more centralised power demand will change our network compared to one which delivers electrical energy to each customer.

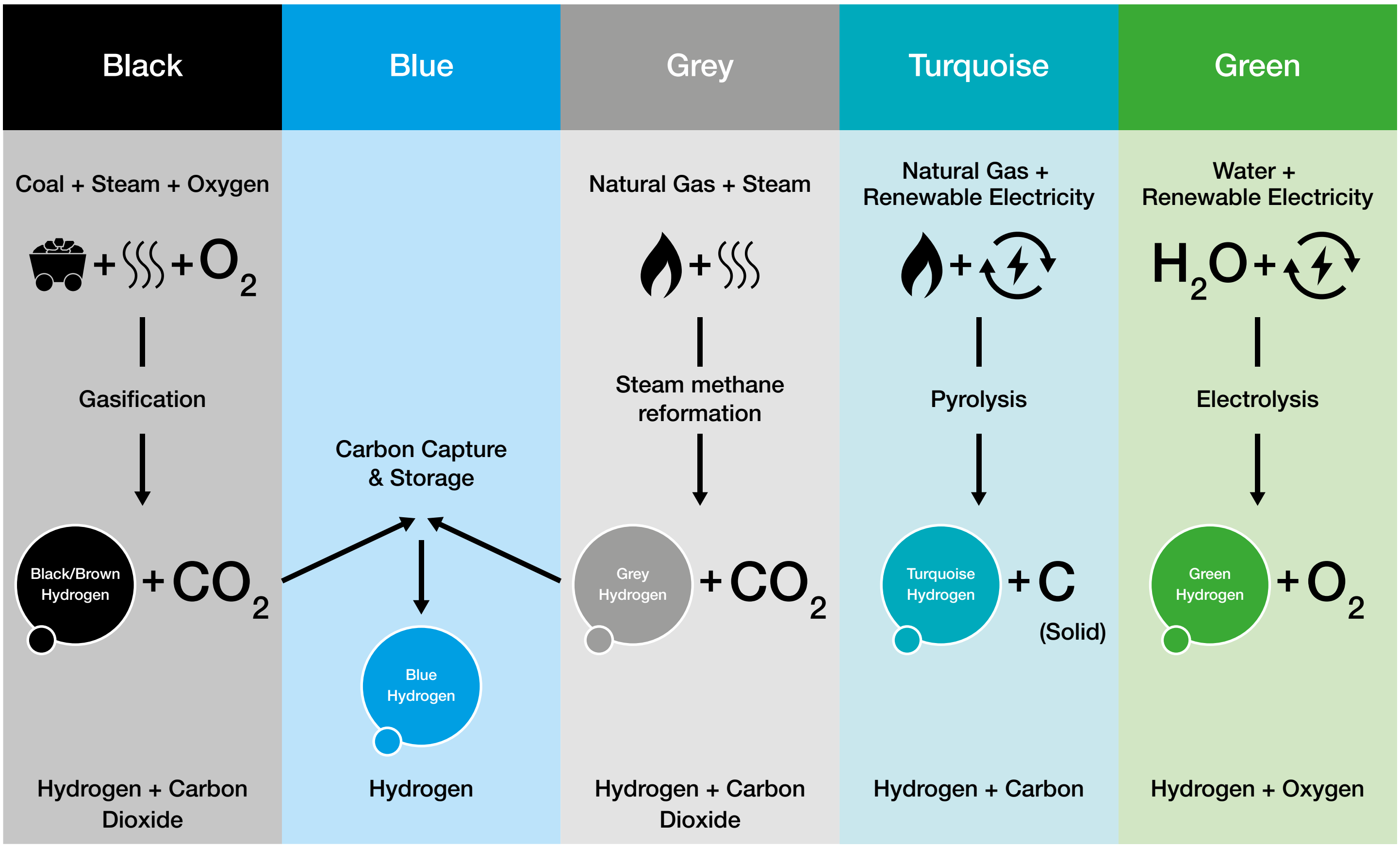
Whilst Hydrogen can help reduce carbon emissions there are other considerations that need to be explored. WPD do not have a preference toward any energy solution so long as a cost benefit analysis of all environmental aspects is considered.

For Hydrogen this is related to both the method of production and the environment that the gas burns in.

When hydrogen is combusted in pure oxygen the only product is water vapour (H_2O). As air is made up of about 78% nitrogen and some 21% oxygen, with hydrogen burning with a very hot flame the resultant reaction will produce nitrogen oxide (NO) as a by-product, this then reacts in the atmosphere to form nitrogen dioxide (NO_2).

Emphasis needs to be placed on the importance of developing of new emissions standards for hydrogen appliances in relation to pollutants thus mitigating the effects of the hydrogen combustion.

There are many 'colours' of hydrogen – each referring to how it is produced. Green hydrogen is the only variety produced in a climate-neutral manner. It could play a vital role in global efforts to reach net-zero emissions by 2050. Green hydrogen has been hailed as a clean energy source for the future. But the gas itself is invisible – so why are so many colourful descriptions used when referring to it?



It all comes down to the way it is produced. But it should be noted that when creating non green hydrogen the process is carbon intensive, there are many different reformers in industries, and autothermal reformer and steam methane reformer are the most common ones.

The key difference between steam reforming and autothermal reforming is that steam reforming uses the reaction of hydrocarbons with water, whereas autothermal reforming uses the reaction of methane with oxygen and carbon dioxide or steam to form syngas.

Reformers are devices useful in chemical synthesis of pure hydrogen gas from methane in the presence of a catalyst. This device uses three main reactions: steam reforming, autothermal reforming or partial oxidation.

White hydrogen

White hydrogen is a naturally occurring version that can occasionally be found underground, but there are few viable ways of extracting this - so experts instead look to generate it artificially.

Hydrogen can be produced from a range of resources including fossil fuels, nuclear energy, biomass and renewable energy sources. This can be done via a number of processes. Depending on production methods, hydrogen can be grey, blue or green – and sometimes even pink, yellow or turquoise – although naming conventions can vary across countries and over time. But green hydrogen is the only type produced in a climate-neutral manner, meaning it could play a vital role in global efforts to reduce emissions to net zero by 2050.

Green hydrogen

Green hydrogen – also referred to as “clean hydrogen” – is produced by using clean energy from surplus renewable energy sources, such as solar or wind power, to split fresh water into two hydrogen atoms and one oxygen atom through a process called electrolysis. The resulting gas can be burned or used as a carrier to provide energy. And, if generated using renewables, it can be a clean alternative to burning fossil fuels. The process does require large volumes of water and electrical energy.

Black, brown and grey hydrogen

Grey hydrogen is the most common form and is generated from natural gas, or methane, through a process called “steam reforming”. This process generates just a smaller amount of emissions than black or brown hydrogen, which uses black (bituminous) or brown (lignite) coal in the hydrogen-making process. Black or brown hydrogen is the most environmentally damaging as both the CO_2 and carbon monoxide generated during the process are not recaptured.

Blue hydrogen

Hydrogen is labelled blue whenever the carbon generated from steam reforming is captured and stored underground through industrial carbon capture and storage (CSS). Blue hydrogen is, therefore, sometimes referred to as carbon neutral as the emissions are not dispersed in the atmosphere. However, some argue that “low carbon” would be a more accurate description, as 10-20% of the generated carbon cannot be captured.

Other colours of hydrogen

Turquoise hydrogen refers to a way of creating the hydrogen through a process called methane pyrolysis, which generates solid carbon.

As such, there is no need for CCS and the carbon can be used in other applications, like tyre manufacturing or as soil improver. Its production is still in the experimental phase.

Then there is pink hydrogen. Like green hydrogen, it is created through electrolysis of water but the latter is powered by nuclear energy rather than renewables.

The extreme temperatures from nuclear reactors could also be used in other forms of hydrogen production by producing steam for more efficient electrolysis, for example.

Meanwhile yellow hydrogen is the term used for hydrogen made through electrolysis of water using solar power, although some use it to mean hydrogen generated through electrolysis of water using mixed sources depending on what is available.

Hydrogen can also be generated from biomass and, depending on the type of biomass and CCS technologies, can have lower net carbon emissions than black/brown or grey hydrogen.

A fuel for the future

The International Energy Agency (IEA) says that hydrogen could play an important role in our clean energy future.

But it notes that to make a real contribution to the energy transition, hydrogen will need to be used in sectors where it is almost absent – like transport, steel production and cement production.

Currently, clean hydrogen isn't scaling fast enough to deliver on its potential, in part due to challenges like COVID-19 and lower fossil fuel and CO_2 prices.

The World Economic Forum has launched the Accelerating Clean Hydrogen Initiative, as part of its Climate Action Platform, Shaping the Future of Energy, Materials and Infrastructure, to find ways to accelerate its adoption.

3. Forecasting and Data

3.1. Forecasting for the RIIO-ED1 Business Plan (2015-2023)

In WPD's RIIO-ED1 Business Plan, WPD used national forecasts to tailor scenarios for the four WPD license areas. In addition WPD worked with the Centre for Sustainable Energy (CSE) to deliver the "Who's on our wires" report. This added socio economic factors to the national growth forecasts for all Low Carbon Technologies. For example, the numbers of heat pumps were predicted to grow in areas where the housing stock suits early adoption.

This means that it is highly likely that Low Carbon Technologies (LCTs) will be clustered closely together leading to a compound effect on specific parts of the network. This work led to our targeted uprating of assets when other works take place over around 7% of our network, in locations where we could be confident of load growth. Since these scenarios were developed we have seen that BEIS are targeting Oil fired central heating and LPG fired central heating systems. These heating systems are usually found in rural areas away from the gas main which are feed via single phase overhead lines, this set up would produce a cluster of heat pumps in the village or hamlet.

Data obtained from the Citizens Advice[8] builds a picture of heating mix in the UK. Of the 27 million homes in Britain, over 22 million use mains gas as their main heating fuel which creates a UK average of 84% of all homes. In total, 3.7 million homes in Britain use non-mains gas fuels for their primary heating. Around 2.3 million homes are heated by electricity (8.6%), just over 1 million homes by heating oil (4.1%), 198,000 homes by solid fuel (0.8%) and 187,000 homes by LPG (0.7%).

The current population of heat pumps within the four WPD licence areas is matching the RIIO-ED1 business plan forecasts. All heat pumps by licence area for the year 2050 in our DFES 2021 projections (in numbers of heat pumps). This includes the following sub-technologies: -

- District heating
- Domestic - Hybrid
- Domestic - Hybrid + thermal storage
- Domestic - Non-hybrid ASHP
- Domestic - Non-hybrid ASHP + thermal storage
- Domestic - Non-hybrid GSHP
- Domestic - Non-hybrid GSHP + thermal storage

Licence Area	Steady Progression	System Transformation	Consumer Transformation	Leading the way
East Midlands	920,571	1,380,012	2,978,525	2,730,408
South Wales	385,505	518,969	1,084,943	936,560
South West	611,029	807,882	1,656,676	1,490,390
West Midlands	816,791	1,177,847	2,511,640	2,209,022
Grand Total	**2,733,896**	**3,884,710**	**8,231,784**	**7,366,380**

All electric heating by licence area for the year 2050 in our DFES 2021 projections (in numbers of heat pumps/heating techs). The volumes of direct electric heating and night storage heating which could arguably be described as low carbon depending upon the energy mix of the electricity supplied (additional technologies included compared to the overleaf are highlighted in teal): -

- Domestic - Non-hybrid ASHP + thermal storage
- Domestic - Non-hybrid GSHP
- District heating
- Domestic - Hybrid
- Domestic - Hybrid + thermal storage
- Domestic - Non-hybrid GSHP + thermal storage
- Direct electric heating
- Domestic - Non-hybrid ASHP
- Night storage heating

Licence Area	Steady Progression	System Transformation	Consumer Transformation	Leading the way
East Midlands	1,076,166	1,457,682	3,078,311	2,903,161
South Wales	430,604	539,963	1,110,996	990,672
South West	743,623	859,866	1,733,373	1,635,223
West Midlands	954,398	1,243,165	2,601,934	2,371,410
Grand Total	**3,204,791**	**4,100,676**	**8,524,614**	**7,900,466**

Note – the direct electric heating and night storage heating volumes decrease over time to 2050 as people switch to heat pumps if you were to look at them on an individual basis.

3.2. Developing Distribution Future Energy Scenarios (DFES)

Since 2016 WPD have been producing Distribution Future Energy Scenarios (DFES) at a license area level which predict the likely impact of HPs along with other new technologies.

The scenarios use a bottom up approach to provide future energy scenarios, at Electricity Supply Area (ESA) level, for the potential growth of distributed generation, electricity demand growth and electricity storage. These are then used to identify future constraints on the distribution network and develop strategic investment options to economically resolve those constraints, when triggered.

The analysis undertaken for Heat Pumps in the Distribution Future Energy Scenarios (DFES) study involves the following four stages: -

1

A baseline assessment.

Technology baselines are calculated from WPD's network connection database. This information is then reconciled with other market intelligence and external databases. In addition, further desktop research is undertaken to address inconsistencies. For Heat Pumps the main data sources are the domestic Renewable Heat Incentive (RHI) datasets and Energy Performance Certificate (EPC) database.

2

Resource assessment.

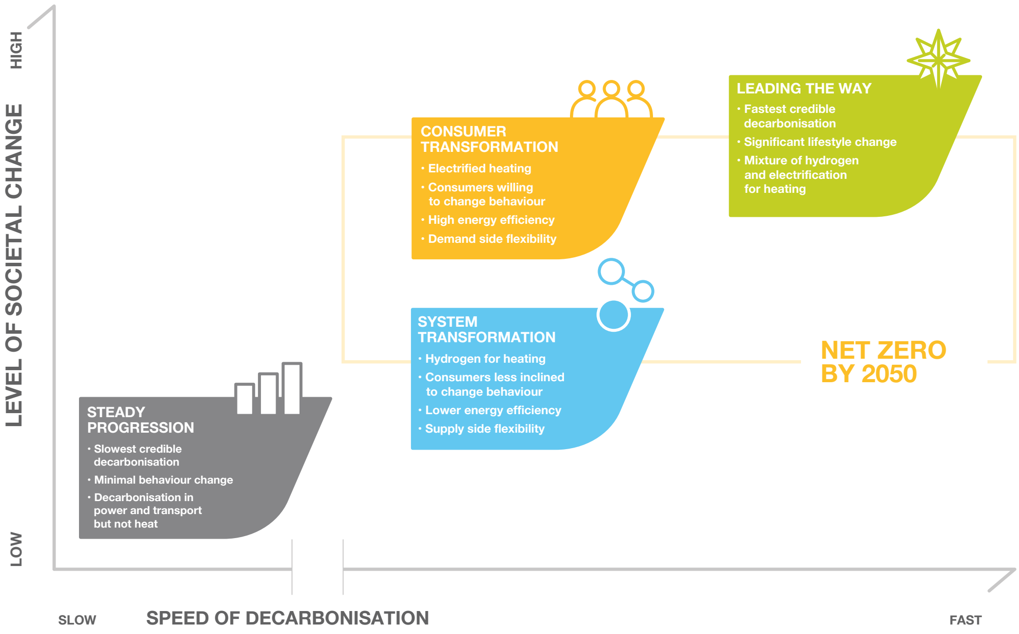
Locational data from a wide range of data sources and GIS analysis is used to understand the geographical distribution, local attributes, constraints and potential for Heat Pumps installations across the WPD network, assigned to each Primary substation. For Heat Pumps, the spatial allocation is based on characteristics of the housing stock and the existing heating technologies used in domestic properties. This is then combined with local stakeholder engagement to capture the most up to date regional heat strategies. Heat Pumps are then further broken down into two subcategories, electric and gas back up (hybrid systems), which both show different expected usage profiles which are accounted for in strategic network analysis by WPD.

3

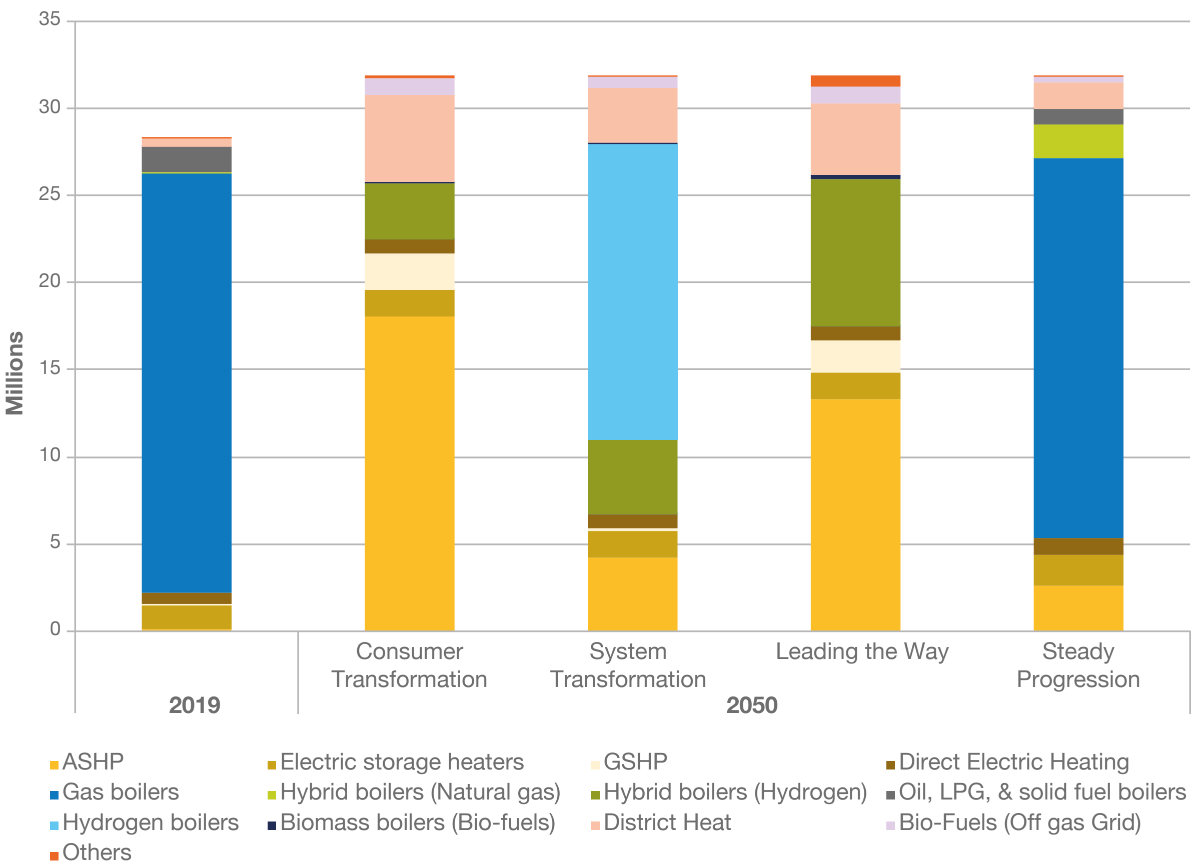
A scenario projection to 2050.

The DFES scenario framework follows that used in the National Grid Future Energy Scenarios (FES), therefore the near term Heat Pump deployment is extrapolated to create the projections at a Primary substation level in the medium and long term, incorporating local resource factors. These 2050 projections outlines the number of Heat Pumps expected to be installed across WPD, investigating different ways that the UK government targets for net zero greenhouse gas emissions by 2050 are reached.

In the latest report, WPD have aligned each of the scenarios with National Grid's 2020 FES, which has the following four scenarios: -



In the latest National Grid FES they have developed a new set of scenarios through extensive industry collaboration. These have net zero at their core and explore how the level of societal change and speed of decarbonisation could lead to a range of possible future pathways.



3.3. Heat Pump Growth Factors

National and local legislation will be key drivers of future heat pump growth in the licence area. The UK government has and is consulting on the Future Homes Standard, their work on a full technical specification for the Future Homes Standard has been accelerated and the government will consult on this in 2023.

The government also intend to introduce the necessary legislation in 2024, ahead of implementation in 2025. In December 2019 the UK government published the Consultation on changes to Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for new dwellings, this document states “the government intend to set the performance standard of the Future Homes Standard at a level which means that new homes will not be built with fossil fuel heating, such as a natural gas boiler.

A low carbon heating system will be integral to the new Future Homes Standard and the government anticipate that heat pumps will become the primary heating technology for new homes. As a consequence there is a need to ensure that all parts of industry are ready to meet the Future Homes Standard from 2025, which will be challenging to deliver in practice.

In 2021 the government will produce an interim uplift will deliver high-quality homes that are in line with the broader housing commitments and encourage homes that are future-proofed for the longer-term. These homes will be expected to produce 31% less CO_2 emissions compared to current standards.”

From a consumer perspective, the key hurdle will be price. Lower running costs are not yet balancing out the up-front costs, even with the current purchase subsidy. There is limited evidence relating to the actual whole life savings or resale value.

Despite the current barriers, the FES 2020 presents a much higher growth projection for heat pumps than FES 2019, reflecting that the UK government is committed to expanding the low carbon economy while hitting the carbon budgets. On 27 June 2019, the UK government set a legally binding target to achieve net zero greenhouse gas emissions from across the UK economy by 2050.

All scenarios in National Grids FES 2020 show the approximately 23 million gas fired central heating installations that currently burn natural gas for heating, that the levels of natural gas burned in all these properties halves by 2038 across all net zero scenarios.

3.4. Investment allocated within RIIO-ED1

Within WPD’s RIIO-ED1 submission £112m was approved for allocation intended for socialised reinforcement attributable to LCTs. Of this over £6.1m was directly related to Heat Pump installation.

3.5. Forecasting local growth and pinpointing upgrades

In addition to WPD’s DFES forecasting work, WPD are working with Sero and POBL Housing Association, to build approximately 250 new build homes which will be fitted with the complete suite of low carbon technology including Solar Panels, Battery Storage, EV charging and Heat Pumps. The houses will be fully monitored thereby enabling the generation of for example space heating and a domestic hot water profiles for each of the heat pumps across a day or a year.

WPD plan to use all the profiles to create a typical After Diversity Maximum Demand (ADMD) for EPC grade A houses. ADMD is used in the design of electrical distribution networks where demand is aggregated over a large number of customers. ADMD accounts for the smoothing of peak load a network is likely to experience. This new ADMD data will be used in drafting new design document for new housing estates and could then be used by Network Strategy when they undertake the four license area DFESs.

The tool will be developed to help highlight where proactive reinforcement can help prepare the local networks for LCT connections and specifically EV and HP connections. WPD will use this tool to support the business plan submissions for network upgrades.

4. Planning and Capacity Availability

4.1. WPD's expectation of Heat Pump installations

The size and type of HP varies with building. Smaller size HPs are expected to be seen in domestic situations where the house EPC value is A, B or C. Larger HPs will be seen at with buildings which have an EPC of D or lower.

Heat pumps up to 32A per phase to WPD's low voltage distribution system are likely to be accommodated on existing house services but larger installations of greater than 32A will often require a three phase service or other upgrades.

Heat Pump type and power output	Likely supply requirement	Likely installation location	Specific connection requirements	Network considerations
HP up to 16A ≈ 3.8kW	Single Phase	Domestic	None – connects via household plug/socket	None
HP up to 32A ≈ 12kW	Single Phase	Domestic	Dedicated household circuit	In some cases limited local reinforcement is required
HP greater than 32A Over 8kW	Three Phase	Domestic	Dedicated household circuit	Likely upgrade to service cable and local mains
HP greater than 32A (high capacity)	Three Phase	Large building	Three phase dedicated supply point	Requirement for three phase connection and likely local mains upgrade

4.2. Estimating Connection cost and timescale

The cost and complexity of the electricity network required to support new heat pump installations will vary with size. At a domestic level i.e. less than 32A per phase only minimal works will be required to accommodate the heat pump but for larger installations and small district heating systems new transformers and substations are likely. The cost and works timescale will vary with the complexity of the works as detailed below.

Heat Pump type and power output	Likely installation location	Approximate connection lead-time	Network considerations	Approximate customer connection cost
HP up to 16A ≈ 3.8kW	Domestic	Immediate	None	None
HP up to 32A ≈ 12kW	Domestic	Immediate in most cases	Usually none	Usually none
HP greater than 32A Over 8kW	Domestic	4 to 8 weeks	Likely upgrade to service cable and local mains	£1,000 to £3,000
HP greater than 32A	Large building	8 to 12 weeks	Street works and permissions	£3,500 to £12,000

It should be noted that in a retrofit hybrid heating situation it typically takes about three days to plumb in an air source heat pump into an existing gas or oil fired central heating system.

4.3. Simplifying the application processes

WPD use the latest paper copy version of ENA application form for the notification of both EV and Heat Pump applications. Since 2021 WPD have introduced a “Traffic Light System” for the connection of LCTs, for example with heat pumps WPD currently have 268 heat pumps that qualify for connect and notify, however, we have 548 heat pumps that fall into the Green or Amber category.

During 2022 WPD will introduce a new App. NIA funded iDentify App which has been developed by SPEN. This App will totally change the way applications will be made to WPD. The whole process will be electronic and should speed up the connection process for the Customer. It is envisaged that all the DNOs within the UK will adopt the App as the primary method application. Once signed into the App, the installer of any LCT infrastructure needs to follow the relevant application process for their particular LCT device which can be defined in two ways: -

1. **Where the connection of the LCT is LESS than or equal to 32A; or**
2. **Where the connection of the LCT is GREATER than 32A.**

The ENA are in the process of producing an App which will utilise work done by Scottish Power with their NIA project iDentify. This new ENA App will integrate with all the various platforms that currently exist and are currently used by installers, it is an objective of the ENA App to make the whole connection and installation process easier. The ENA App is due for completion in about 18 months time.

4.4. Planning and Design Changes

When WPD design and extend their network it is expected that assets should remain in service for around 50 years, it is imperative that a heat pump installation and any other LCTs are notified to us. Notification is a requirement of the customer/installer and helps WPD plan the network reinforcement more efficiently which results in lower bills for everyone.

This means that WPD always look to predict future changes and assess how WPD can reasonably accommodate the changes into the current plans and designs. WPD’s RIIO-ED1 plans looked at changes that could be made to support the adoption of LCTs.

Work which can future proof the network is key to remaining ahead of demands. On the WPD cable networks, the cost of excavation and reinstatement works are a large proportion of the overall costs so rather than potentially needing to overlay cables as LCT take-up increases, WPD increased the minimum cable size for all new underground cable installations.

Similarly, when working at substations, the plant cost of transformers meant that WPD increased the minimum ground mounted transformer sizes with only a marginal increase in installed cost. Both of these incentives partially, future-proof new networks at minimal increase in cost.

Connections which include PV, ES, HP and EV charging shall be designed with a network impedance that meets the WPD defined value at the point of common coupling (PCC), i.e. at the point where the customers system meets the WPD system.

Connections of PV, ES, HP and EV charging to existing houses where the houses are connected via a looped service cable can be connected and our Network Services teams will remove the looped service at a convenient date for all parties.

Where a connection supplies more than one LCT, no diversity shall be allowed unless load control is provided and verified by the relevant LCT installer to prevent the service and cut-out from being overloaded.

4.5. Technical Changes related to Heat Pumps

To permit the connection of heat pumps there are typically some technical aspects to overcome, including thermal capacity, power quality and harmonic emissions. All these issues are covered off in WPD's Standard Technique documents in the SD5G suite.

These Standard Technique documents describe WPD policy for processing the ENA EV and HP approved application form from customers, or their nominated installer, for the installation and connection of individual or multiple LCT's (Electric Vehicle Charge Points and/or Heat Pumps), where any items have a rating greater than 32A per phase, onto WPD's low voltage distribution system.

WPD use the information provided by the customer or installer to assess the suitability of the existing network to supply the Electric Vehicle charging or Heat Pump infrastructure.

Suitability will be based upon the network's susceptibility to voltage fluctuations, flicker and harmonic voltage distortion, as well as ensuring it is kept within the designated thermal and voltage limits.

4.5.1. Thermal Capacity

To assist with thermal capacity, i.e. the ability to carry more load within the low voltage network, since the start of RIIO-ED1 WPD have increased the minimum size of the low voltage mains cable to have a cross sectional area of 185mm^2, during RIIO-ED2 this will change to a minimum cable 300mm^2, WPD have also increased the minimum size of low voltage service cables to 25mm^2 Copper or 35mm^2 Aluminium concentric service cables.

The smallest rated ground mounted transformer has increased to 500kVA and the smallest rated pole mounted transformer to 25kVA single phase, during RIIO-ED2 the smallest pole mounted transformer will be 50kVA.

4.5.2. Power Quality

As Heat Pumps use power electronics which can cause interference and possible damage to the electricity network there is a need to ensure these installations comply with BS EN 61000 Part 3-2, Part 3-3, Part 3-11 and Part 3-12. As a result the ENA have created a Heat Pump and EV charger data base, where the heat pumps have been assessed for compliance to the relevant standards and the results recorded for all DNOs to use, this pre-assessment will take into account the effect of the harmonics and power quality.

Once the heat pump has been assessed by the ENA the DNO only requires to undertake a thermal or load assessment of the local network where the heat pump is to be connected, thus reducing the time the host DNO will require to assess the installation.

5. Providing information to Customers

5.1. Guidance and Advice Documents published

WPD have developed guidance document for local authorities and customers who are considering converting or installing heat pumps into their building/s and or properties.

WPD's "2021 Guide on Heat Pumps and DNO Engagement with Local Authorities or Building Owners" provides information specifically tailored to local authority or customers delivering heat pumps into building/s or housing. The guide covers some of the technical considerations related to heat pump installations as well as offering advice on how to make applications and discuss plans with us.

5.2. Guidance and Advice Documents planned

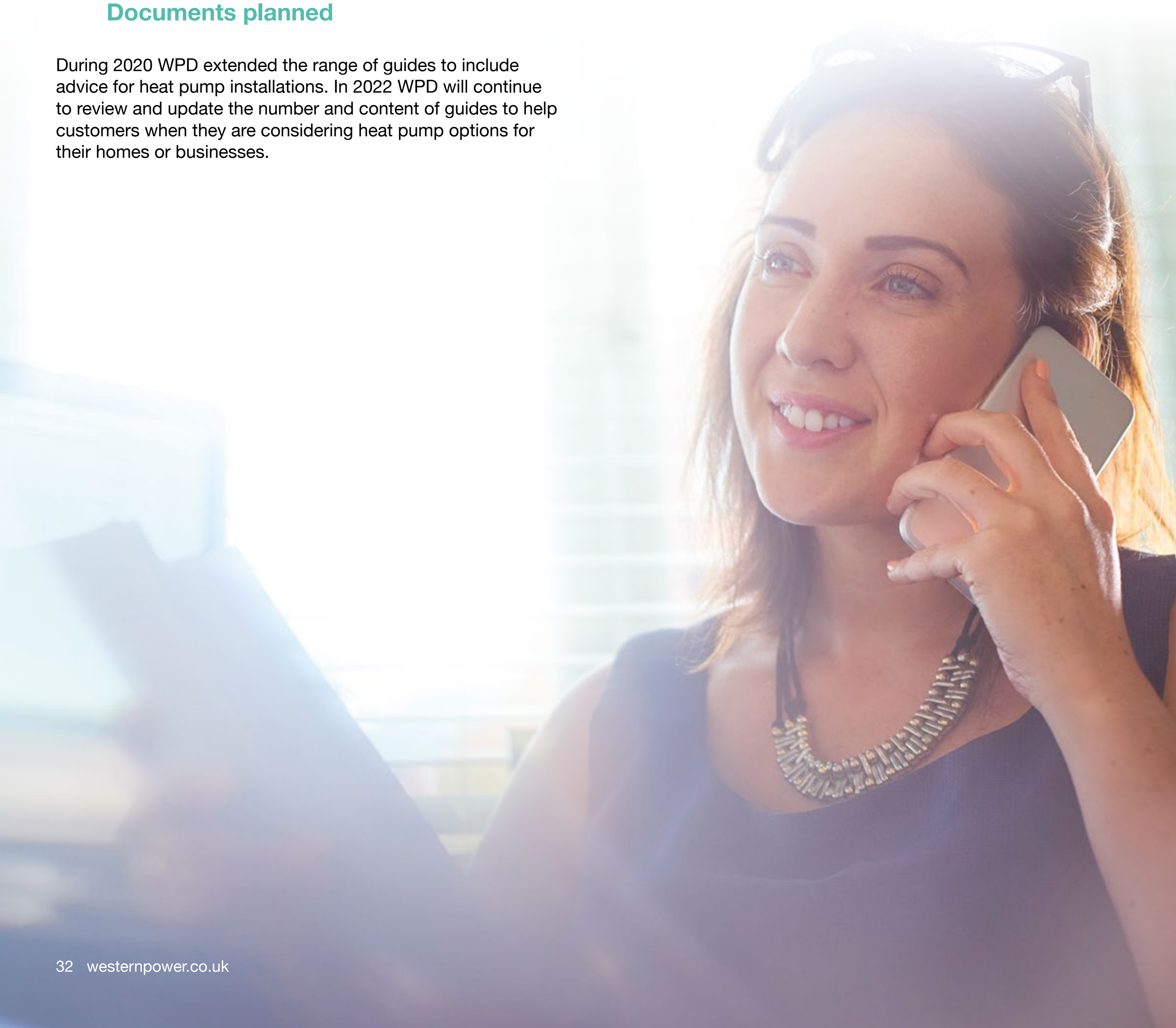
During 2020 WPD extended the range of guides to include advice for heat pump installations. In 2022 WPD will continue to review and update the number and content of guides to help customers when they are considering heat pump options for their homes or businesses.

5.3. Capacity Indication for customers

WPD has consolidated our network capacity map in to a single map with different layers so that a single source of visual data retrieval can be easily and readily achieved. This will further support customers being able to access our data to inform their new connection and operation decisions.

5.4. Connections Surgeries

Local authority and house builder customers have the opportunity to request one to one connection surgeries with our local planning teams. At a local level they will be able to discuss plans for low carbon heating or heat pump installations and how the electricity network can be adapted and uprated to accommodate their future plans.



6. Stakeholder Engagement

6.1. WPD's Approach to Stakeholder Engagement

WPD's approach to engagement depends on the requirements of individual stakeholders. In some cases a company level strategic engagement is needed and in other cases a more local engagement is required.

WPD provide front end services using locally based teams that are responsible for their local networks and the local customers connected to them. At this level a more informal engagement is the most efficient solution and complements the more formal strategic stakeholder engagement.

6.2. Business Plan Strategic Stakeholder Engagement

WPD have an excellent track record of stakeholder engagement across the range of topics contained within our business plans. Since 2010 WPD have included elements of LCT readiness. In the early years the focus was on pragmatic steps WPD could take to support what was a small population of heat pumps.

The engagement sessions helped form WPD's plans and have also informed innovation projects related to heat pumps. In 2021 the strategic stakeholder engagement included a specific topic on heat pump readiness.

6.3. Strategic Engagement with local authorities

Local Authorities are beginning to take the lead on installing and retro fitting heat pumps in buildings & housing association sites. This is particularly true in Wales where the Welsh government have declared a climate emergency and are actively driving the retro fitting of heat pumps to the Housing Associations housing stock. WPD will publish an updated 2022 heat pump guide for local authorities to help them with their plans.

6.4. Local Engagement with local authorities

WPD will be directly engaging all 130 local authorities in our area during 2022 on their local energy plans. Whilst this will cover all LCTs, heat pumps and decarbonisation of heat will be a major topic. A key aspect of this will be the crucial role WPD has to play in meeting the local energy needs of the communities we serve. This is set to increase further as local authorities set their own net zero targets and build energy plans.

WPD will be outline the current future energy scenario modelling, how it has been developed and the predicted technology volumes for your area. WPD also hope to understand Local Authority's plans for decarbonisation and any current local energy development plans which are in place. WPD want to ensure future energy requirements are accounted for within WPD's energy scenarios and future investment plans.

6.5. Engagement for Housing Associations

WPD have engaged with POBL Housing Association and Sero Homes with a new build of approximately 250 houses using single phase heat pumps and other LCT devices are being fitted to the houses, these will be full monitored for some two years so that learning can be gained on the heat pumps and the other LCT devices, the project will utilize the new service cables designs where three phase will be fed to each house with a view to help reduce the losses when compared to single phase supplied houses.

WPD are also involved in with the retrofit of net zero equipment in the Pobl Penderry housing estate in Swansea where some 700 houses are being updated in via the Optimised Retrofit Welsh government project, the project sets out to meet the net zero targets brought about by climate emergency which has been declared by the Welsh government.

6.6. Engagement for housing design

After a consultation period with multiple relevant parties WPD have changed their standard house service cable which supplies all properties. This is now a three phase 35mm^2 hybrid design of concentric cable which provides future proofing for the householder should they wish to upgrade to a three phase supply.

WPD have provided information for reports compiled by the Renewable Energy Association as a part of their works to lobby government and planners. WPD were pleased to share stakeholder engagement with them on this subject and are continuing discussions with relevant government departments.

WPD's Superfast Electricity project was developed in conjunction with Pobl Housing Association and Sero Homes, an innovative Welsh based developer/provider of Energy Positive homes.

6.7. Engagement with UK Government

WPD and various other parties are involved with BEIS in their Stakeholder engagement, this engagement has been brought about by the Governments Clean Growth Strategy and the Future Homes Strategy which details the de-carbonisation of heat and transport.

WPD are trying to ensure that to meet the challenges of the Clean Growth Strategy that new buildings should also accommodate the complete suite of PV, ES, HP and EV charging of LCT's thus providing a holistic approach.

WPD have engaged with the BSI and BEIS on the PAS suite of Smart Device Standards which will allow products to communicate with each other and be controlled to manage network demands.

The various projects undertaken with Sero Homes and Pobl will show the merit of having a common standard for smart devices within the home. As one of objectives of these projects will be to try to limit fuel poverty for the householders.

6.8. Engagement with Welsh Government

WPD's projects in conjunction with Pobl and Sero Homes to demonstrate Superfast Electricity have all been developed with the help of the Welsh Government. WPD were able to engage early with the Welsh Government and have followed their plans for decarbonisation alongside UK Government plans.

6.9. Engagement with Go Ultra Low Cities (GULC)

Three of the four Go Ultra Low cities, Nottinghamshire & Derby, Milton Keynes and Bristol, are within our operating area.

Bristol in particular have held numerous discussions about decarbonizing heat in their buildings. Using many of the specific delivery plans listed above, we will work with each city at a local level to help them deliver their targets.

6.10. Engagement with Local Enterprise Partnerships (LEPs) and Electricity Supply Areas (ESAs)

Ensuring WPD's future network investment plans are aligned to developments being planned at a local level is a key priority for WPD as a distribution business.

The four Electricity Supply Areas in WPD are local areas which match our higher level network feeding areas. We engage with customers in an each ESA to build our plans for high level network growth.

Every 6 months, under WPD's Strategic Investment Options work, workshops are undertaken with local stakeholders from a licence area to understand their pipeline of projects and ensure WPD are capturing the correct data to feed into the investment strategies.

WPD then build a bottom up vision of demand, generation and storage growth by absorbing the locally published plans and other market intelligence to enable WPD to study the network under future growth scenarios.

The data that accrues is also shared back with Local Enterprise Partnerships, local authorities and other stakeholders and has been used to inform local energy plans.

The aim is to ensure that the LEP's future energy requirements are accounted for within WPD's energy scenarios and future investment plans.

6.11. Stakeholder Engagement Plans for 2022

WPD will continue to engage with the UK Government through BEIS and their Clean Heat Team.

On 03/03/22 WPD held their first Low Carbon Heating Workshop at Aston Villa Football Ground this seminar was open to all from Local Authorities, Housing Associations, Developers or any other interested parties.

The workshop comprised presentations from senior personnel at WPD as well as representatives of other sectors including heat pump manufacturers, housing associations and the Welsh Government. Each presentation was followed by discussion sessions where the views of the attendees helped to shape WPD's future plans. Topics for discussion included:

- Connecting low carbon heat technologies to the WPD network.
- The development of heat pumps.
- Retrofitting existing properties to accommodate low carbon heat solutions.
- Alternative technologies including: District heating; Solar thermal; Electric boilers; Combined Heat and Power (CHP); and Waste heat recovery.

7. Plans to support Heat Pumps

7.1. Profiling and Modelling

As the UK sets out to meet the challenge of the Clean Growth Strategy, The Energy White Paper and the Future Homes Standard by de-carbonizing heating and transport, the change in heat generation technology from fossil fuel towards heat pumps will lead to altered electricity demand profiles of buildings and neighbourhoods.

As a consequence of the low grade heat produced by the heat pump and the move to energy efficient buildings with an EPC rating of A or higher, electricity demand profiles will change on the existing houses that have been converted to heat pumps and on the new build A rated homes.

This will mean that all existing profiles DNO's currently use will need changing, so the heat pump profiles from the project work WPD are involved with in Tonyrefail will generate profiles for space heating (SH) and a domestic hot water (DHW) of the houses.

Each house will generate two profiles, SH and DHW, these will apply to each of the heat pumps used on the projects, which over time, WPD can then use all the profiles to create a typical ADMD for EPC grade A houses.

Consistent, interlinked demand profiles of electric usage are important for the electric network operators and their planners, to correctly design electricity network. It is envisaged that WPD will generate retrofit heat pump profiles with the Optimised Retrofit project thus creating SH and DHW profiles for retrofitted homes which will have a lower EPC rated houses when compared to new builds. This information will be beneficial for the design of existing network estates which are being upgraded.

For the design and simulation of energy concepts for residential buildings and areas, simple methods to generate consistent demand profiles for electricity, space heating and domestic hot water demand (DHW) are needed.

Time-dependent characteristics of residential energy demand depend strongly on user behaviour which needs to be accounted for in models. The diversity of the load profiles must be respected to avoid aggregation of peaks and capture occurring smoothing effects.

Typically heat pumps are selected for the respective homes on the basis of thermal demand for space heating and domestic hot water. By using standardised load profiles for space heating approach an average load profile is derived from measurements, usually linked with outdoor temperature and scaled to a specific annual energy demand.

Since the method is based on a vast number of datasets which are averaged, resulting profiles can be seen as valid.

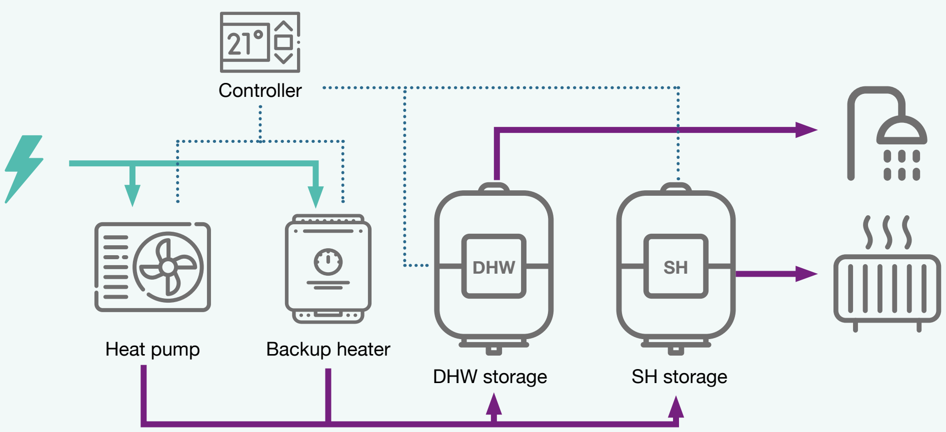
The drawback of using standardised load profiles is that those profiles represent a large number of buildings or occupants and thus show usually low variation.

They only partly reflect individualities in the building due to different physical building properties or the inclusion of solar gains. The challenge with the profile is to correctly reflect user behaviour, which will significantly influence the building energy performance but this would need to be tied into the EPC rating of the particular building. The methods for DHW consumption modelling are similar to those applied for space heating demand.

Heat pump operational data in the UK is limited as the projects that have been carried out have had low numbers of heat pumps which makes the data statistically insignificant.

WPD have a wealth of experience in designing housing networks that consist of houses with poor EPC ratings and recognise the need to evolve our design methodologies to include new use cases which take into account high EPC ratings of the buildings.

WPD will use this experience to ensure that heat pumps can be accommodated in the most efficient and economical way.



Heat pump system

- Thermal Energy
- Electric Energy
- Control line

Variations in:

- Sizing of storage and heat pumps
- Heat distribution system temperatures
- Source temperatures
- HP efficiencies

Where existing network architecture is not best suited to permit heat pumps WPD will take steps to mitigate this and, if upgrades are required, use innovative solutions to allow faster and efficient connections.

For example, in line with BEIS thinking, WPD are considering oil fired, solid fuel and LPG fired central heating systems are usually installed in rural settings, these areas are invariably supplied by small cross sectional area, single phase overhead lines (OHL) when these outlying areas change to heat pump and electric vehicles that the single phase OHL's are upgraded to three phase OHL's this would allow the village to convert to heat pumps and electric vehicle charging and not produce out of balance loading of the phases or be limited to a finite size of single phase pole mounted transformer.

7.2. Releasing existing network capacity

WPD's low voltage network already includes a finite volume of available capacity. When WPD establish local transformers for new developments the Planners choose between three pre-set transformer capacities.

Likewise with new developments when WPD establish new LV Mains circuits the Planners are currently restricted to $185mm^2$ and $300mm^2$ Wavecon cable sizes.

This means that there is often capacity available between the designed demand of the network and the size of transformer and LV Mains cable which feeds it.

WPD also expect that the backbone 33kV network and transformers will be able to accommodate a finite level of heat pump activity.

7.3. New Homes

The production of the Future Homes Standard brings consultation on requirements for new homes.

WPD have already seen an interest from some developers and local authorities to add a readiness for future charging requirements and heat pump installations.

WPD already design and install LV mains networks which include a level of diversity, which allows for the fact that all customers do not use all of their installed demand at the same time.

This means that our LV mains networks are able to flex to the demands placed on them and only require reinforcement when a proportion of customers have increased their demands.

The service cable, which runs from the street to an individual property, cannot make use of this diversity as it needs to provide the whole supply for that specific customer.

WPD have already identified that increased LCT demands could require larger capacity service cables and are trailing these in the Superfast Electricity project.

In addition WPD have held a consultation during 2020 on upgrading the standard single phase service cable to three phase thus preventing the need to dig up the gardens at some point in the future to upgrade the service cable because of increasing demand.

The outcome of this consultation has seen WPD change their standard service cable design to three phase hybrid cable.

7.4. Existing Homes

A large section of WPD's existing networks were designed for 1950s, 1960s and 1970s where the electricity usage assumptions at the time of installation were lower than the current standards[9]. Whilst most new homes connected from the early 1990s will have a service provision which is not looped and can accommodate a normal domestic demand, the additional demand of a Heat Pump and other LCT installations will need to be assessed.

WPD appreciate that the capacity of a house service/cut-out is the last thing on a customer's mind when they choose a heat pump so WPD are working with the ENA LCT Group to make this assessment and acceptance as simple as possible.

The ENA LCT Group have two projects which are on-going and relevant, the first one is an App for smart phones which will make the connections of LCT's much easier and by taking a simple photograph of the cut-out by the customer identifies to the host DNO whether the device is fit for purpose. The second project the ENA LCT group are currently running a project in ascertaining the absolute values of the various cut-outs and service cables combinations which will allow customers/installers a simple way of identifying the capacity of a service cable; the project will tie in the application which can be used across the UK and for any DNO network.

Where a customer wants to install new Low Carbon Technology to their property there is a need to check that their property is not connected via a service loop. If the property is serviced via a looped service then WPD will remove the looped services and small sized service cables will be replaced at no cost to the customer.

7.5. Clustering

WPD's low voltage networks rely on a level of diversity between connections. Heat Pumps can provide a period for load shifting depending on the thermal mass of the building. As heat pumps should be installed in houses which have an EPC rating of C or above, it is envisaged that if heat pumps were installed in lossy houses with a low EPC rating it is unlikely that there will be diversity to be applied.

In addition to the forecasting work WPD have done and are doing, notifications of installed heat pumps are being used to identify hotspots and clusters of heat pumps and other LCT's.

Unfortunately not all LCT installations are reported to the host DNO. WPD are using this clustering information to direct the proactive reinforcement of networks.

7.6. Mitigation of local network constraints

There may be isolated locations where a cluster of new heat pumps will exceed the capacity of the WPD local network. It is envisaged that many of these sites will be identified with the clustering modelling. Where clusters are not identified and WPD have not anticipated the change in demand it could result in blown fuses and customers being inconvenienced.

Delivering an upgraded network from scratch will take a specific duration and, whilst these works are being planned and executed, it is not acceptable for our customers to continue being inconvenienced by supply interruptions.

Where Heat Pump design allows for flexibility through energy store systems, this could form the first line response to local overload situations. It is possible WPD would make use of equipment developed for EVs in the Connect and Manage project. This equipment would only be used for as a last resort, and for a finite period while the network was upgraded.

WPD local teams have shown themselves to be the industry leaders in response to supply interruptions and this technology will allow them to provide this same high level of service where LCT's create a specific problem.

8. Smart Solutions and Flexibility

8.1. WPD's approach

Meeting the Clean Growth Strategy, The Ten Point Plan for a Green Industrial Revolution and the Energy White Paper decarbonisation of heating targets, heat pumps (HP's) are recognised as a technology that meet the requirements and as such there is a 600,000 heat pump installation per year target set for the new build housing sector. Heat pump technology provides great opportunities for reducing heating related greenhouse gas emissions, but the wide-spread retrofit deployment on existing houses could also create new challenges in the electricity distribution sector.

Operating heat pumps in a "smart" way, as part of a wider smart grid, would help to address some of these challenges. In particular the potential demand peaks from heat pumps in a largely decarbonised future building stock could turn out to be a significant future challenge, both in terms of available generation and the capacities of the electrical network. This could well lead to an increasing need for demand side response (DSR) in the electricity system, as intermittent renewable generation meets increased demand from the heat pumps.

In an average winter, large parts of the housing stock should be able to provide flexibility in the case of a DSR event, without any upgrades to the thermal properties of the building or the heat pump being required. But it is likely that if a 1-in-20 winter occurred then significant improvements of both the thermal mass and the insulation are likely to be required in many UK buildings in order to achieve sufficient levels of flexibility.

Flexibility is already an established network management tool for WPD, developed under the Flexible Power brand name. Where constraints are identified WPD could look at a range of solutions to rectify them, including smart and flexible solutions. Flexible Power has traditionally looked to larger customers to provide the flexibility responses, so we would predict that HP flexibility would be provided to us via aggregators.

We also predict that customers would be encouraged away from times of peak electricity usage through time of use tariffs developed by electricity suppliers.

8.2. Domestic Flexibility

In order for heat pumps to be able to realise their full potential for demand-response, there are a number of challenges which need to be overcome. According to the Centre for Ageing Better, 21% of all homes in the UK were built before 1919, 38% were built before 1946, and only 7% after 2000, making the UK housing stock the oldest in the EU[10]. UK building stock needs to be made more suitable for heat pumps (and their flexible operation) in that the buildings need to be brought up to the current level of insulation standards. The introduction of a simple heat store for the space heating would provide the ability to not run the HP at peak times introducing some flexibility into the existing housing market.

8.3. Commercial Flexibility

The majority of the UK commercial building stock also being pre 1970s this commercial building stock needs to be made more suitable for heat pumps (and their flexible operation) in that the buildings need to be brought up to the current level of insulation standards, and the introduction of a simple heat store for the space heating will provide the ability to introduce flexibility into this section of the existing commercial market. With commercial buildings using heat pumps for space heating and hot water tanks suitably sized heat stores and hot water tanks are a fundamental aspect of "flexibility" and key to aligning the generation of zero carbon energy with the use of the energy without burdening the UK bill payer with vast investments in system wide electrical storage or over provisioning of generation capacity and network.

8.4. Whole System Flexibility

Flexible heat pumps, storage heating and hot water tanks are a fundamental aspect of "flexibility" and key to aligning the generation of zero carbon energy with the use of the energy without burdening the UK bill payer with vast investments in system wide electrical storage or over provisioning of generation capacity and network.

Some heat pumps systems that have a reliance on inflexible direct heating (boost) elements on low temperature days. The use of the boost element has the potential to significantly drive up the power demand on the network, when the network generation requirements are already at the very point where they most stressed.

9. Projects to demonstrate Heat Pump connections

9.1. Developing a balanced portfolio of projects

WPD's projects are developed through the Innovation Strategy. WPD always look for projects which cover the three main themes of Assets, Customers and Operations.

WPD ensure the projects retain this balance by the regular review of the Innovation Strategy which is supported by more general Stakeholder Engagement.

WPD use the Local Authority Stakeholder Engagement sessions to ensure our projects are providing the right blend of technical and flexible solutions.

9.2. Completed Projects

9.1.1. Freedom

The Freedom Project has concluded following a two year programme, installing 75 PassivSystems smart hybrid heating systems in Bridgend, South Wales that ran over the 2017/2018 heating season.

Western Power Distribution (WPD), Wales & West Utilities (WWU) and PassivSystems, have been working closely to turn the concept of low carbon domestic heating into a reality. Using an air-source heat pump and high-efficiency gas boiler hybrid system in 75 residential properties, the project clearly demonstrated the value that an integrated approach to deploying low- carbon smart technologies can deliver.

Project learning indicates that a hybrid approach to decarbonising our heating that is combined with green gas growth could lead to the total decarbonisation of domestic heat. The Freedom Project set out to investigate the role of multi-vector solutions in the form of a hybrid heating system.

The combination of a conventional gas boiler and an air source heat pump (ASHP) with PassivSystems optimised smart controls has addressed these issues and presents a cost-effective decarbonisation pathway, where reinforcements to the electricity grid can be avoided by utilising the existing energy storage capability of the gas grid at times of peak demand and when renewable power generation output is not delivering.

The project has addressed all aspects of the energy trilemma, with a specific focus on heat and the potential for hybrids to be transformational in delivering solutions that will shape future energy market dynamics.

As a result of the work delivered in the Freedom Project, hybrid heating systems have demonstrated that they are a complementary solution across the various futures of heat pathways, providing the opportunity for partial electrification combined with hydrogen in major cities and other decarbonised gas elsewhere.

The findings of the project will contribute to the challenge of reducing carbon emissions at the lowest cost impact for domestic consumers by delivering increased heating system efficiencies and a reduced unit cost from the energy supplier for energy consumed by the hybrid heating system.

To address the objectives of the Freedom Project, WPD, WWU and its project partners developed and improved their energy systems modelling to consider and optimise the operation of hybrid heating systems served by a combination of electricity and gas.

The optimal split between the two energy sources is intrinsically determined by finding the lowest-cost choice to meet the heating demand while also considering the costs in other parts of the system, such as seasonal storage, interconnection and reinforcement. This cost-optimal split will generally vary from one hourly interval to another and will be driven by the assumed price of gas as well as the endogenously driven cost of generating electricity in a given hour.

The global recognition of the challenges of climate change, in particular the ambitious reductions in carbon emissions proposed by the UK Government. In 2018, heating and powering homes accounted for 22% of all greenhouse gas emissions in the UK. The UK has already made considerable progress in this sector by reducing total emissions by 43% since 1990, despite there being approximately a quarter more homes. It is the UK government's objective that from 2025, new homes built to the Future Homes Standard will have carbon dioxide emissions at least 75% lower than those built to current Building Regulations standards. Significant progress is being made in decarbonising electricity generation and seeking low-carbon gas alternatives.

However, in the UK, the current existing domestic heating remains largely unaffected by attempts to lower-carbon outputs, aside from the considerable progress made through increased boiler efficiency. Gas boilers are the predominant technology for the provision of domestic space heating and hot water in the UK with a market penetration of some 80% of homes. In order to meet ambitious carbon reduction targets, our high dependency on fossil gas heating will need to reduce, with the adoption of hydrogen mixed with the natural gas and the installation of hybrid heating systems offering the flexible solution to make best use of renewable gas and electricity.

9.3. Current Projects

9.3.1. Parc Eirin Superfast Electricity Housing for the Future

WPD is looking to new and innovative areas, to this end WPD are working with Pobl and Sero Homes where currently in Tonyrefail, South Wales circa 250 new build homes are being built, each house is fitted with PV, ES, HP, EV charging, smart white goods each device is connected to a PLC these homes will be supplied via three phase service cables and dark fibre to each house.

WPD will be fully monitoring the estate, including the heat pumps so that demand profiles will be generated to show thermal demand and show different characteristics regarding daily and yearly patterns compared to the present day, the demand profiles of the space heating and DHW are important for the planners, to correctly design energy grid and supply concepts for buildings and neighbourhoods.

It should be pointed out that due to the unforeseen circumstances brought about by Covid 19 lockdowns the amount of work completed on this project has slowed down and as a consequence this has had a delaying effect on the project.

9.4. Future Projects

9.4.1. Self assessment

When a customer chooses a Heat Pump or Electric Vehicle their next task is to consider is whether the cut-out and service cable are looped or suitable for LCT connection.

Through the Energy Networks Association this project is being developed in conjunction with the other DNO’s to provide a centralised way of providing us with pertinent information about their service which will allow us to quickly assess if it is suitable to accept a heat pump or EV charger.

10. Commitments of 2021

10.1. Realising benefits

Work completed in projects only becomes fully valuable once the findings transition into business as usual. With respect to heat pumps and new build housing estates WPD have already made changes to the technical design and as a consequence minimum cable designs are now adopted.

In addition with existing houses fitted with looped LV service cables these are to be removed and replaced by individual service cables. As the various projects that are currently underway it is likely there will be more changes that will be made as a result of information gathered from the projects.

The sections below detail different projects WPD undertook in 2021.

10.2. 2021 - Parc Eirin Superfast Electricity Housing for the Future

The Superfast electricity Housing for the future – Tonyrefail project houses will see the houses fitted with heat pumps, as there is currently very little useful data on the impact heat pumps will have on an electrical network, this project will be used to define a typical profile for the space heating of the house and a second profile for the heating of the domestic hot water.

Both of these two discrete profiles will be obtained from the 238 houses and the data will then enable new ADMD values to be created for heat pumps that can then be added to the current ADMD number that WPD use for planning of new estates, this new data will enhance the calculations to carried out in future housing estate designs.

Currently there are about 40 homes which are occupied WPD using the Smart meter data and correlating that data with the GridKey data we have slowly been getting a better understanding of what is happening on the estate. Currently there are about four BEV's on the site.

10.3. 2021 – Design capacity assumptions

For many years WPD have used a set of After Diversity Maximum Demand (ADMD) figures to design the backbone network that supports housing developments. It has allowed for the efficient and economic connection of traditional gas and electrically heated homes.

The impact of LCTs will change this design model. WPD will use data from our innovation projects to calculate a new ADMD which includes allowances for Heat Pumps, EV charging and other LCT's.

Using the data from a couple of new build estates within WPD we have been able to gather data from HPs and EV charging which have allowed WPD to generate a faster method of allowing Customers to connect LCT's to the network, the new Approvals system follows a traffic light process, as of February 22 there are some 268 heat pumps that qualify for connect and notify, however, WPD have 548 heat pumps that are Green or Amber category.

Currently WPD readily accept the installation of 204% more than the ENA process permits or 280 more devices than the ENA process permits.

10.4. 2021 – Network capacity indication

During 2021 WPD wants to consolidate the network capacity map in to a single map with different layers so that a single source of visual data retrieval can be easily and readily achieved. This will further support customers being able to access our data to inform their new connection and operation decisions.

This consolidation has now been carried out on WPD's website. The consolidated map has a capacity heat map which covers the whole company area and provides data at the Primary substation level or at the Distribution substation level showing the capacity available to support low carbon heating or the connection of other Low Carbon Technologies from a Primary or Distribution transformer level.

11. Targeted Commitments in 2022

11.1. Realising benefits

Work completed in projects only becomes fully valuable once the findings transition into business as usual. With respect to heat pumps and new build housing estates WPD have already made changes to the technical design and as a consequence minimum cable designs are now adopted. In addition with existing houses fitted with looped LV service cables these are to be removed and replaced by individual service cables.

As the various projects that are currently underway it is likely there will be more changes that will be made as a result of information gathered from the projects.

The sections below detail changes WPD expect to make in 2022.

11.2. Continued Monitoring of Parc Eirin Superfast Electricity Housing for the Future

Currently there are about 40 homes which are occupied in Parc Eirin, WPD using the Smart meter data and correlating that data with the GridKey data we have slowly been getting, is giving WPD a better understanding of what is happening on the estate.

Currently there are about four BEVs on the site. As the new homes get built and the new residents move in to their new homes WPD will continue to monitor the site and grow the learning.

11.3. Equinox

Equinox (which stands for Equitable Novel Flexibility Exchange) seeks to investigate how much flexibility can a portfolio of heat pumps offer the wider system and how can Network Companies and Energy Suppliers work together to offer a fair price to heat pump owners for this flexibility.

The NIC project EQUINOX is a joint venture with WPD, Guidehouse, SERO Homes, Scottish Power Energy Networks, West Midlands Combined Authority, Welsh Government, Passiv Systems and Octopus Energy which will run from March 2022 to December 2025 during this time it is looking to develop novel commercial arrangements, processes, and supporting technologies that unlock flexibility from portfolios of domestic heating assets, while meeting the needs of all consumers, including the fuel poor and vulnerable.

11.4. Smitn

This project relates to the innovation priority area of data. It aims to extract additional value from our smart meter data by creating a validated LV network against which algorithms using smart meter data can be tested.

It also contributes to the priority area of digitalisation by investigating how the quality of our data can be improved which is a pre-requisite for digitalisation.

There are proposed applications for smart meter data that could potentially benefit DNOS such as improving load estimates for planning, phase identification and identifying unregistered low carbon technologies.

Testing the accuracy of algorithms using smart meter data to determine items such as phase connectivity requires a known result to compare the predicted values to, however our LV records are sometimes incomplete and unvalidated.

This project solves the problem by first providing fully validated test networks so that algorithms can be evaluated accurately then by evaluating several use cases for smart meter data.

The project also tests a new method to identify customer's LV feeder from outside their premises.

11.5 Smart Meter early information – future home heating

WPD have used an estate of about 100 homes to understand the different design outcomes of our old and new modeling software and IDNO rules. We then checked the results against the aggregated Smart Meter data at a substation level. The action for 2022 will be to fully consider the impacts and amend WPD LV design policy accordingly.

Bibliography

1 Page 1 of Office for National Statistics report – Age of property is the biggest single factor in energy efficiency of homes.

2 Page 7 of CCC Policies for the Sixth Carbon Budget and Net Zero dated December 2020.

3 Page 3 of BEIS 2018 UK Greenhouse gas emissions provisional figures March 2019.

4 Page 4 of The Future Homes Standard: 2019 Consultation on changes to Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for new dwellings.

5 Page 3 of Data provide by Dr Emily White of BEIS in email to author dated 16/12/20.

6 Page 5 of the UK Low Carbon Transition Plan, national strategy for climate and strategy.

7 Page 8 of The Future Homes Standard: 2019 Consultation on changes to Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for new dwellings.

8 Page 2 Off-gas consumers: Updated information on households without mains gas heating June 2018.

9 Information provided by Oli Spink from the DFES Two Degrees scenario for all DNO areas.

10 Page 1 More than 1m over 55s living in hazardous homes Home Care Insight study finds. Access/Intelligence/Studies by Sarah Clarke 09/05/2019 https://www.homecareinsight.co.uk/more-than-1-million-over-55s-living-in-hazardous-homes-study-finds/

WESTERN POWER DISTRIBUTION

Serving the Midlands, South West and Wales

a national**grid** company

Western Power Distribution (East Midlands) plc, No2366923
Western Power Distribution (West Midlands) plc, No3600574
Western Power Distribution (South West) plc, No2366894
Western Power Distribution (South Wales) plc, No2366985

Registered in England and Wales
Registered Office: Avonbank, Feeder Road, Bristol BS2 0TB

www.westernpower.co.uk

@wpduk