Plymouth 4 & 5DHC Roadmap

Part 1. UK Context

March 2019

About HeatNet NWE

This document has been developed as part of the HeatNet NWE project, which is part-funded through the Interreg NWE programme and aims to increase the uptake of 4DHC networks across North-West Europe. As part of this project, the partners are developing the HeatNet Model, which will help the public sector to begin implementing 4DHC networks, and the Transition Roadmaps, which will outline the partners' experience in developing six district heating pilots across North-West Europe. The HeatNet Guide to Financing is also currently being developed and will give a broad overview of the various sources available to finance district heating schemes.

For further information on these reports and on the HeatNet NWE project, please visit www.nweurope.eu/heatnet.

A roadmap to achieve 5th generation heat networks in the UK

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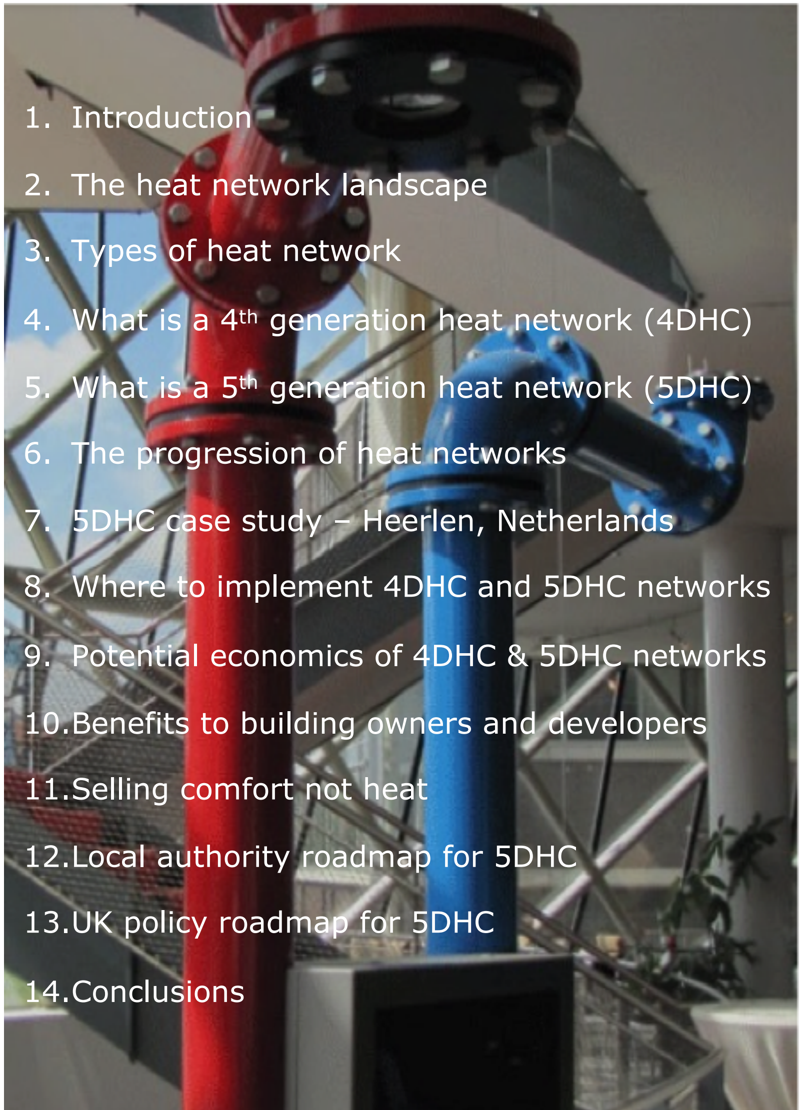
Summary



Picture courtesy of Minewater BV

Space heating and hot water account for over

20%

of the UK's greenhouse gas emissions and this is mainly burning gas in boilers

Heat networks and heat pumps will be a key part of decarbonising heat in the UK

Lower temperature 4th and 5th generation heat networks offer a way to deploy heat pumps to achieve this

4DHC is a good solution where the demands are mainly heating, but it is a 4-pipe solution and has to be designed to the worst common denominator buildings

5DHC is a different shape, with decentralised heat pumps on an ultra low temperature network

Allowing energy exchange between buildings

The temperature and timing for building connection is often a major reason for not connecting to district heating

5DHC allows a more 'plug and play' approach that can address these issues

5DHC is a good solution where there is a significant mix of cooling and heating demands, allowing prosuming across the heat network itself

5DHC schemes provide the greatest IRR and CO_2 savings, even when compared with local ASHP options

Overall, 4DHC and 5DHC have significant potential to reduce carbon emissions and provide greater flexibility to building owners/developers aiming to connect

Introduction

This roadmap is an output from HeatNet, an EU Interreg project to address the challenge of reducing CO_2 emissions. The HeatNet 4DHC project aimed to identify the potential for 4th generation District Heating and Cooling (4DHC) in Plymouth, along with the medium and long term opportunities in a wider UK context.

This roadmap looks at the what, why, and where of 4th and 5th generation DHC. This is one of two complementary Roadmaps (Plymouth & UK). These roadmaps provide a next steps pathway, in both a practical and a policy way to encourage 4DHC and 5DHC.

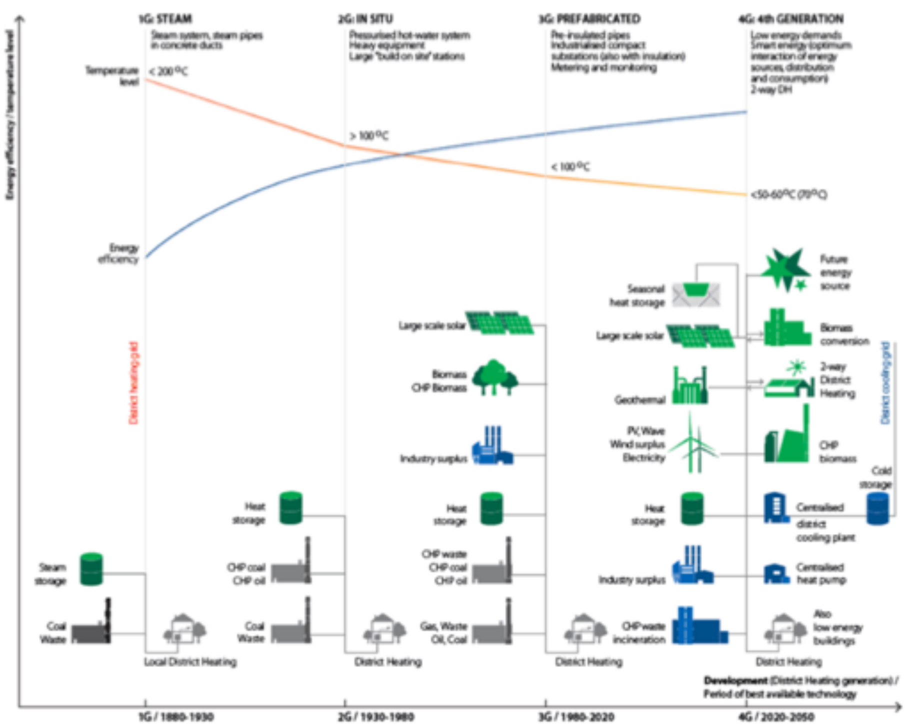
One of the key questions is ‘what do we mean by 4DHC, how would we define it, and what would it actually look like’. The ultimate goal being the implementation of a scheme in Plymouth and the development of a roadmap which could help North West Europe move towards greater propagation of 4DHC systems.

Initially, the team led by Plymouth City Council took a working definition of 4DHC based on that from Lund et al, as shown opposite.

The Lund definition is widely recognised through the diagram shown opposite, setting out a progression from 1st to 4th generation. However, we believe this definition needs further clarification on the actual practicalities of topology, temperatures, opportunities etc and this roadmap provides more clarity on categorisation and definitions of 3DHC and 4DHC. This thinking has also given rise to an early definition of a 5th generation (5DHC) approach.

The Lund definition of 4th generation DHC:

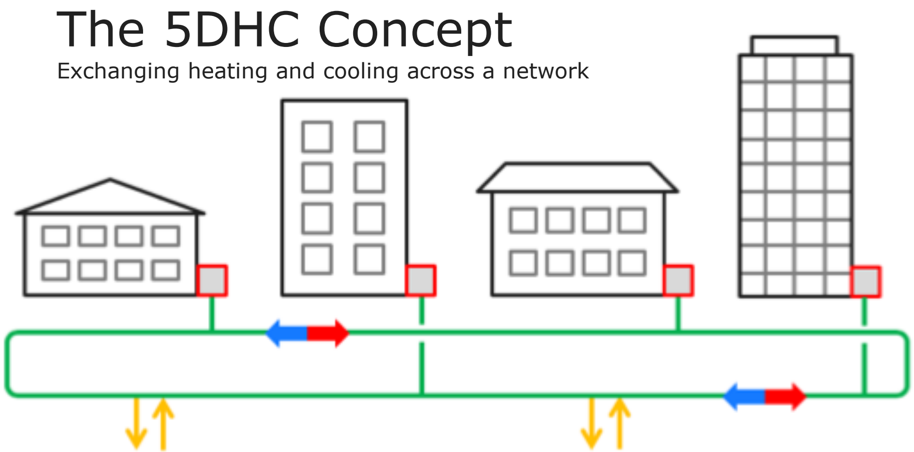
- *supply low-temperature (between 30-70ºC but generally 45-55ºC) district heating for space heating, domestic hot water and cooling to existing buildings, energy-renovated existing buildings and new low-energy buildings*
- *distribute heat and cooling in networks with low grid losses*
- *recycle heat from low-temperature and waste sources and integrate renewable heat sources such as solar and geothermal heat*
- *be an integrated part of smart energy systems (i.e. integrated smart electricity, gas, fluid and thermal grids)*
- *ensure suitable planning, cost and motivation structures in relation to the operation as well as to strategic investments related to the transformation into future sustainable energy systems.*



The heat network landscape

One of the main challenges for the UK over the next 30 years is how to decarbonise heat. Heat accounts for over a third of the UK's greenhouse gas emissions and the government has committed to reducing annual greenhouse gas emissions by at least 80% by 2050. A key part in the strategy is to encouraging the deployment of heat networks as a low carbon heating and cooling solution. In particular the UK government has introduced a £320M Heat Network Investment Programme to support this.

Heat networks are a key solution in high energy density areas. Also cooling demand is rising rapidly, partially as a results of warmer weather due to climate change. The UK electricity grid carbon factors have halved in recent years and further decarbonisation is making heat pumps a low carbon approach.



Unfortunately, UK district heating is often characterised and driven by the 80/70ºC nature of heating system design that has been part of the industry for many years. In some quarters there is still considerable resistance to moving away from these relatively high system/radiator temperatures. Much of the district heating in the UK could be regarded as stuck somewhere between 2DHC and 3DHC based on the Lund categories shown above. Initiatives like the CIBSE/ADE CP1 Heat Network Code of Practice and the Heat Trust Scheme are now beginning to change this thinking by providing investors/consumers improved standards and greater confidence around heat networks.

Current UK DH is often 2nd to 3rd generation supplying ~85ºC to meet the needs of existing buildings. Cooling is typically provided by separate systems, often local chillers rather than a district cooling system. Much of the UK DH sector is CHP based as the high value of electricity and relatively low cost of gas often makes it an economic solution. However, decarbonisation of the electricity grid means CHP is increasingly hard to justify based on carbon savings.

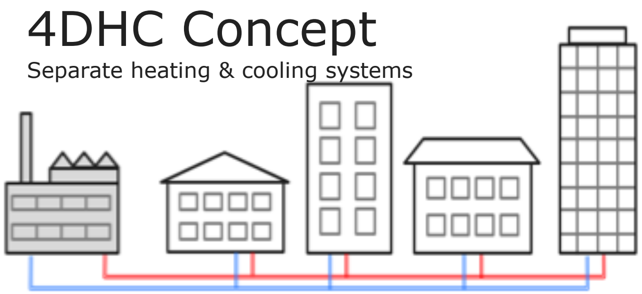
What do the future solutions look like? Decarbonisation of the grid is driving the electrification of heat. Many new buildings are also being designed around lower temperature heating systems, making heat pumps a more likely solution than gas based systems. The future for district heating is therefore likely to be lower temperatures and using heat pumps. What will these 4th and 5th generation heat networks look like and what are the benefits?

Heat networks and heat pumps will be a key part of decarbonising heat in the UK. Lower temperature networks offer a way to deploy heat pumps to achieve future reductions in carbon emissions.

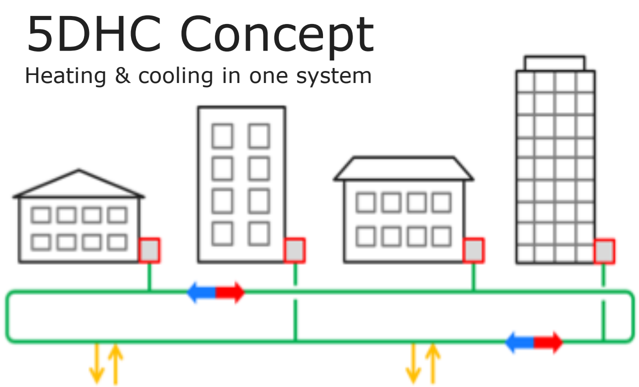
Types of heat network

3rd Generation DHC - Traditional centralised topology (shape) with an energy centre supplying heat outwards to buildings. Supplying at around 90-60ºC and return temperatures at around 50-40ºC, 3DHC would generally consist of well insulated, pre-insulated pipework with significant centralised thermal storage. 3DHC can supply DHW directly, but cooling would be a separate system. No interchange of heat between buildings is possible.

4th Generation DHC - Traditional centralised topology with energy an centre supplying heat outwards to buildings. Supplying at around 55-45ºC with a wider ΔT and return temperatures at around 25-15ºC, 4DHC would generally consist of highly insulated, pre-insulated pipework that is more likely to be plastic, with very large centralised thermal storage. 4DHC will usually need supplementary boosting to supply DHW, and cooling would be a separate system. No interchange of heat between buildings is possible.



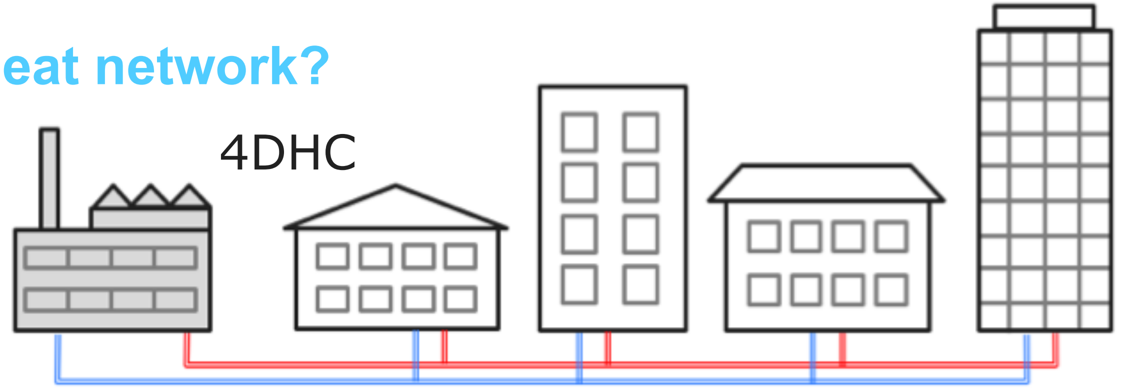
5th Generation DHC - Is a non-traditional topology with decentralised plant (usually heat pumps) supplying heat along ultra-low temperature headers in a spine/backbone (ambient loops may be possible in smaller systems). Supply at <45ºC, the ΔT is less relevant with return temperatures around 25-15ºC. 5DHC often consists of un-insulated plastic pipework with very low heat losses and longer pipe runs. 5DHC usually includes seasonal thermal storage to balance the spine temperatures and perhaps some short term localised thermal storage. 5DHC will always need supplementary boosting to supply DHW temperatures. 5DHC has built-in cooling supply and can interchange heating/cooling between buildings.



5DHC provides a single integrated 'plug-and-play' heating and cooling system allowing buildings to be 'prosumers' across the network.

What is a 4th generation heat network?

Topology – 4DHC is fundamentally the same topology/structure as a 3DHC design with a single energy centre and pre-insulated pipework supplying heat outwards to the demands. However, 4DHC differs significantly in having lower operating temperatures than 3DHC.

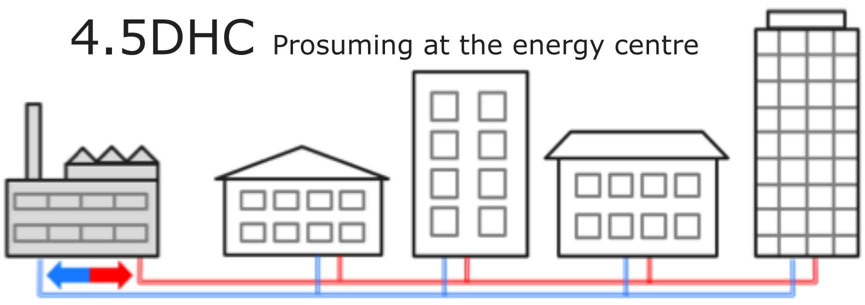


Operating temperatures – Generally 4DHC would supply at 55-45ºC which may then require a temperature boost in order to supply DHW. 4DHC would normally have wider ΔT's of 30ºC or greater. Return water temperatures may be designed to be as low as 25-15ºC. 4DHC systems could perhaps be weather compensated in Summer to reduce heat losses, providing the DHW boost can meet demand. However, this temperature reduction is less likely in 4DHC, the more that weather compensation is attempted, the more hot water boost is necessary to reach DHW temperatures.

Pipework – 4DHC would normally be highly insulated, pre-insulated pipework. However, the whole system could be run in cheaper plastic pre-insulated pipework which is also easier to install than steel (plastic pipework has reduced lifetime above ~70ºC).

Storage – 4DHC would generally have very large amounts of thermal storage capacity to smooth the demand and aid plant efficiency. Like 3DHC, this would be insulated hot water storage vessels. However, as temperatures are reduced, the storage capacity reduces so the tanks get larger, potentially presenting even greater location, aesthetics and planning issues.

Cooling – cooling would almost certainly be provided via a separate system. This means a 4-pipe system to achieve full 4DHC. It is notable that there is no interchange of energy between heating and cooling demands which is a key part of the Lund definition. So although the 4DHC approach meets the Lund requirements for a gradual reduction in temperature, it clearly does not distribute heat and cooling in networks with low grid losses. This is a key reason why a 5th generation category is necessary, where this energy exchange can occur across the network.



4DHC is a good solution where the demands are mainly heating, but 4DHC (with cooling) is a 4-pipe solution and has to be designed to the lowest common denominator buildings i.e. at the highest heating temperatures

A 4.5DHC option is possible to allow an exchange of heating and cooling at the energy centre

Advantages and disadvantages of 4th generation heat networks

Advantages include:

- Reduced operating costs and carbon emissions
- Lower heat losses due to lower operating temperatures
- Potentially longer pipe runs due to lower heat losses and cheaper pipework
- Greater plant efficiency due to improved heat transfer
- More opportunity for heat pumps, resulting in higher efficiencies at lower temperatures
- More opportunity to use low temperature waste/renewable heat sources

Disadvantages include:

- Larger pipework required to transfer the same amount of heat
- Greater pumping costs due to increased water volumes
- Requires some means of boosting temperature to supply DHW
- Larger storage volumes for the same amount of heat i.e. lower storage heat density
- No opportunity for energy exchange between buildings across the network, although exchange can occur at the energy centre i.e. 4.5DHC

4DHC Technologies include:

- High CoP heat pumps for new buildings operating at the 4DHC reduced temperatures
- High temperature (ammonia) heat pumps to supply existing buildings where 80/70ºC is still required
- Solar Hot Water temperatures become more compatible, with greater heat recovery potential as temperatures reduce
- CHP is generally a high temperature supply option and therefore less likely to play a part in 4DHC
- Condensing gas boilers could still be used as a top-up heat generator, but burning gas to provide heat at ~85% efficiency is less of a fit in a low carbon 4DHC strategy
- Biomass is highly unlikely to play a part in 4DHC, often requiring a continuous high temperature base load demand
- Cooling would still be provided by electric vapour compression chillers via a separate system.

4DHC Heat Sources include:

- Ground, Groundwater & Surface water would all play a greater part as heat sources in 4DHC, mainly due to lower temperatures providing higher heat pump CoPs
- Sewage treatment works and sewers could provide lower temperature heat sources for 4DHC heat recovery
- Industrial waste streams similarly provide greater opportunity for heat recovery
- Buildings with local large cooling demands (e.g. data centres) could provide a significant opportunity for local simultaneous heating & cooling using a single heat pump in one location i.e. 4.5DHC

What is a 5th generation heat network?

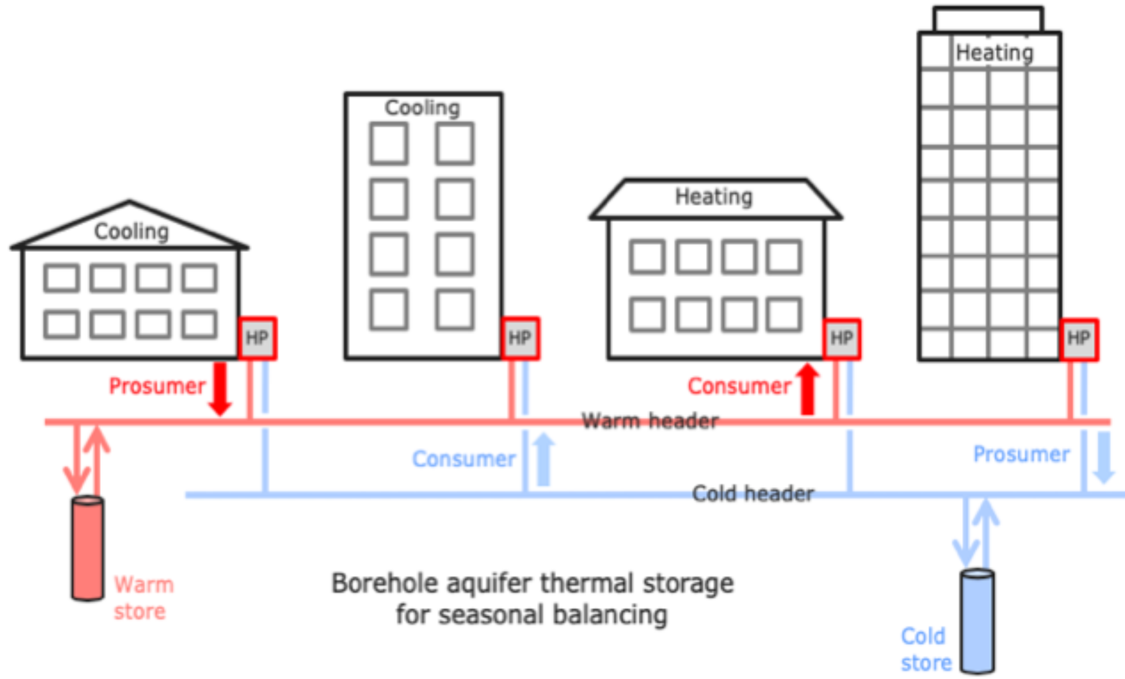
Topology – 5DHC is fundamentally a different shape/structure using a common two-pipe header system (spine) operating at even lower temperatures than 4DHC. The low temperature headers act as a heat source for multiple decentralised energy centres that take-out and feed-in heat.

This approach also requires a means of balancing the heat in the headers, when all buildings are in heating mode for instance. In Heerlen (see later), mine water is used to balance the 'backbone' but other balancing mechanisms are possible. Fundamental to 5DHC is the use of large long-term thermal storage as part of the balancing mechanism. 5DHC is the supply of heat along a spine with interchange of heating cooling between buildings and a balancing mechanism including seasonal thermal storage.

Essentially, the spine and long term thermal store become the heat source/sink for decentralised inputs and outputs of heat.

The scheme shown opposite uses borehole and aquifer thermal storage to balance the system with buildings acting as prosumers of heating/cooling. Boreholes can be built-out gradually alongside the buildings, as and when developments occur.

5DHC is a good solution where there is a significant mix of cooling and heating demands, allowing prosuming across the heat network itself.



5DHC schemes allows flexibility in terms of temperature and timing for building connections – a 'plug and play' approach.

Although we have retained the term 5th generation (5DHC) to allow easy differentiation and discussion, it is clear that 5DHC should be viewed as a different type of DHC altogether. Whilst 5DHC appears to be the next logical step, it has quite different shape, structure and approach to 3DHC and 4DHC.

Low temperature 'ambient loops' are possible if the loop has enough capacity to serve extremes. However, they are unlikely to operate well in larger schemes, as a loop makes it much harder to control heat and balance the system hydraulics than a header system. i.e. the last building on the loop could be starved of heating/cooling.

Other characteristics of 5th generation heat networks

Operating temperatures – Generally 5DHC would supply at less than 45ºC (often closer to 20ºC or less). 5DHC would not necessarily have wide ΔT's with 20ºC being sufficient, although wider ΔT's allow more heat to be carried in the same pipe. Return water temperatures may therefore be designed to be around 25-15ºC. 5DHC will always require a temperature boost in order to supply DHW but only the DHW volumes need to be boosted and this can be achieved locally. This might be achieved by individual booster heat pumps or a more centralised DHW system throughout each buildings.

Pipework – Because operating temperatures are so low, there is less need for pipe insulation as losses are very low anyway. The whole system could be run in cheaper plastic un-insulated pipework with significant capital cost reductions. The very low heat losses and reduced pipework costs can therefore lead to much longer pipework runs, potentially reaching buildings that would not normally be connectable.

Storage – 5DHC would generally have very large amounts of seasonal thermal storage capacity in order to balance heat in the spine. This could be aquifer or mine water storage or large purpose built underground stores. Some smaller short term thermal storage would be necessary in each decentralised plant room to smooth demand and enhance plant operation.

Cooling – Cooling would be provided from the same spine system. This means a 2-pipe system to achieve full 5DHC rather than a 4-pipe 4DHC system. This allows interchange of energy between heating and cooling demands in different buildings, meeting that particular part of the Lund definition.

Prosumer buildings - 5DHC is therefore a means to distribute heat and cooling in low temperature networks with low grid losses. Indeed, a key part of 5DHC design is to identify balanced loads where heating and cooling demands essentially cancel each other out. This fundamentally changes the way we think about heating/cooling supply in buildings. Buildings in heating mode then become 'prosumers' to supply cooling in other buildings, and vice versa. The idea of buildings as prosumers brings a requirement to balance demands across heat mapping, design and operation of heat networks, and changes the way we think about buildings.

This energy exchange is not a new idea, it was used in individual buildings on older Versatemp heat pump systems and is still used today in VRF systems. Small ground loop systems have also been developed to achieve this energy exchange, particularly in supermarkets. However, this energy exchange has not been achieved in the UK across large heat networks with energy exchange from one building to another.

Advantages, disadvantages of 5th generation heat networks

Advantages include:

- Even lower operating costs and carbon emissions than 4DHC
- Supplies both heating and cooling without the need for a separate cooling system
- Allows the interchange of heating and cooling between buildings, making buildings into prosumers
- Buildings take-out and feed-in heat making the system design less load dependent than a 3DHC or 4DHC topology
- Buildings can be added more easily without major changes to the spine/network. This could be viewed as a 'plug and play' onto a LAN. This can minimise timing issues that are often the downfall of more traditional heat networks
- Pipework heat losses can become almost irrelevant and insulation is often not required on the main heat network
- Cheaper pipework with low losses gives rise to potentially longer pipe runs covering wider areas, perhaps reaching buildings that would not normally be connectable
- Even greater plant efficiency, particularly heat pumps having very high CoPs
- More opportunity to recover waste/renewable heat sources such as solar water heating into the heat network
- Much greater opportunity for seasonal thermal storage which is not a feature of traditional heat networks

Disadvantages include:

- A 5DHC spine would require larger pipework to transfer the same energy. However, this can be minimised by balancing heating and cooling demands
- There are likely to be greater pumping costs due to the larger amounts of water being circulated
- 5DHC definitely requires some means of boosting temperature to supply DHW

5DHC Technologies include:

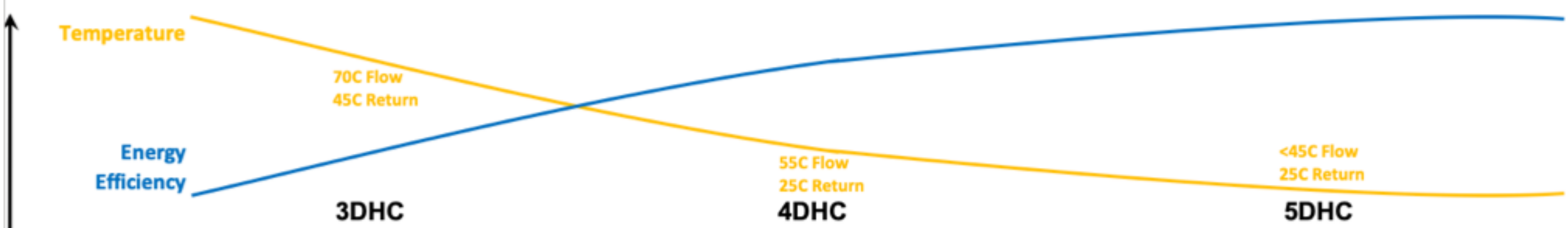
- Even higher CoP heat pumps, operating at the 5DHC reduced temperatures
- High temperature (ammonia) heat pumps to supply existing buildings where 80/70ºC is still required
- Solar Hot Water temperatures become even more compatible, with greater heat recovery potential as temperatures reduce
- CHP and biomass boilers are generally high temperature supply options and therefore unlikely to play a part in 5DHC
- Condensing gas boilers are much less likely to fit into a low carbon 5DHC strategy
- Electric vapour compression chillers should not be required on 5DHC networks

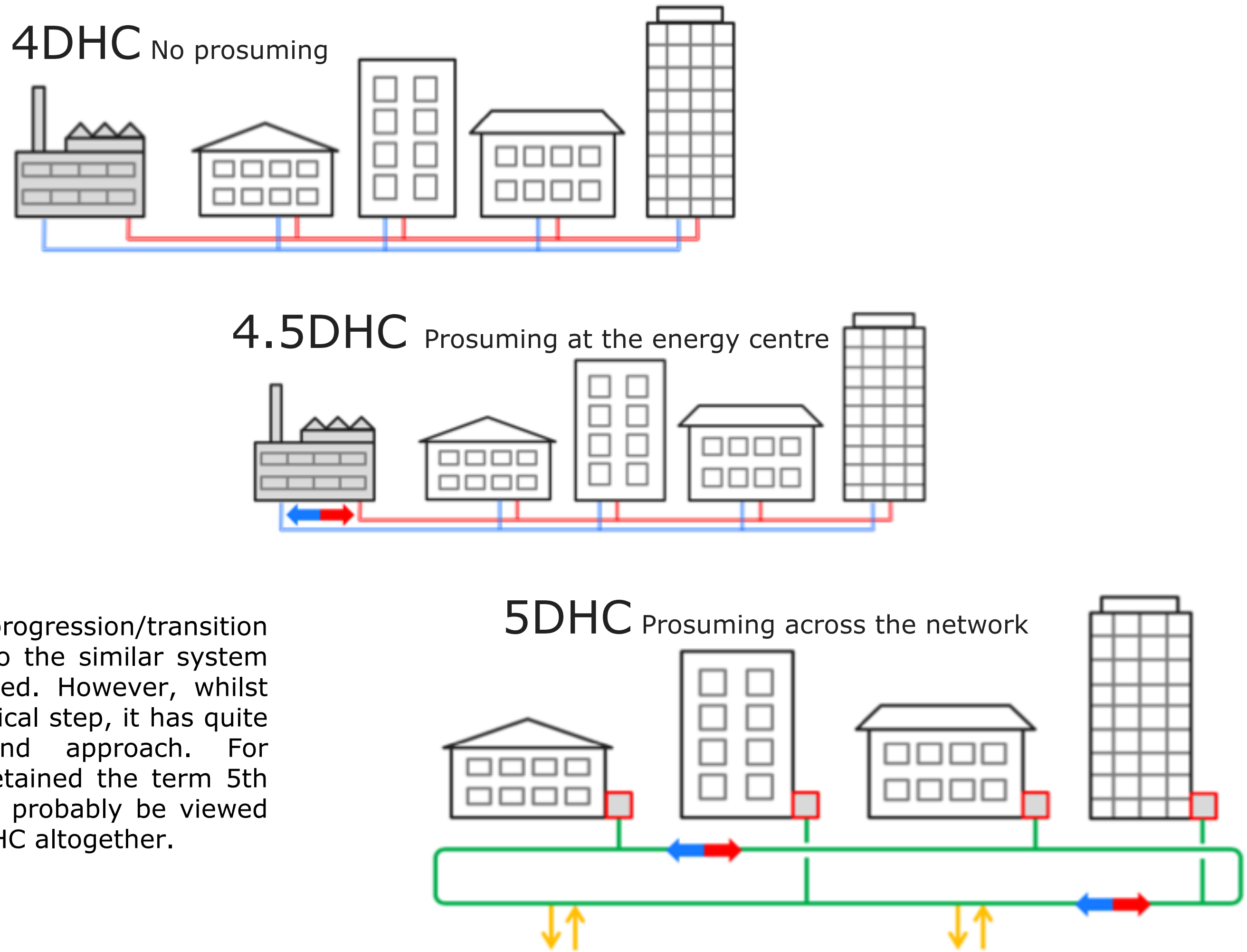
5DHC Heat Sources include:

- Ground, Groundwater & Surface water would all play an even greater part as heat sources in 5DHC
- Sewage treatment works and sewers would also provide heat sources for 5DHC heat recovery
- Industrial waste streams similarly provide even greater opportunity for heat recovery
- In general, the ultra low temperatures in 5DHC open up wider range of sources for heat recovery

The progression of heat networks

(This acknowledges and builds on work by Lund et al)





It is clear from that there is a progression/transition path from 3DHC to 4DHC due to the similar system architectures (topologies) involved. However, whilst 5DHC appears to be the next logical step, it has quite different shape, structure and approach. For discussion purposes, we have retained the term 5th generation (5DHC) but it should probably be viewed as an entirely different type of DHC altogether.

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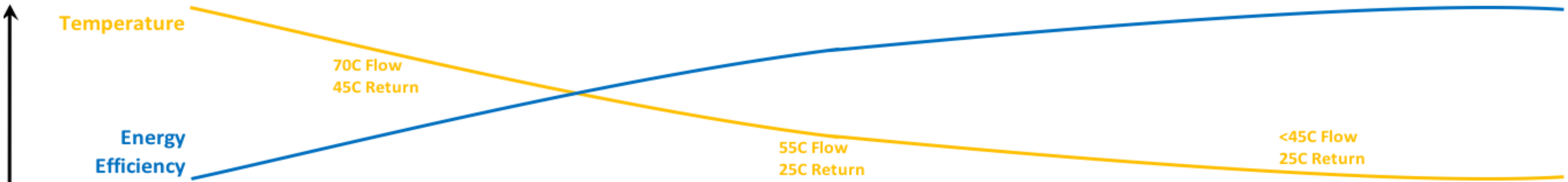
The progression of heat networks

(This acknowledges and builds on work by Lund et al)



	3DHC	4DHC	5DHC
DEFINITION			
Topology	- Traditional - Single Energy Centre supplying heat outwards	- Traditional - Single Energy Centre supplying heat outwards	**VERY DIFFERENT APPROACH** - NOT traditional DH design or central energy centre - Decentralised plant supplying spine/clusters/buildings - Supplying heat along a spine/backbone - Low temperature headers (not an ambient loop)
Temperature	- Supply at 70-60C [60C min to supply DHW] - Wide ΔT - Return temperatures 50-40ºC - Weather compensated to 60ºC	- Supply at 55-45C - Wider ΔT - Return temperatures 25-15C - Not weather compensated	- Supply at <45C - ΔT Less relevant - Return temperatures 25-15C - Not weather compensated
Pipework	- Well insulated, pre-insulated pipework	- Highly insulated, pre-insulated pipework - Plastic pipework	- Un-insulated pipework? Very low losses, longer runs? - Plastic un-insulated pipework
Storage	- Significant thermal storage	- Very large thermal storage	- Seasonal thermal storage - Some short term thermal storage
DHW	- Can supply DHW directly	- Will need supplementary boost to supply DHW	- Will need supplementary boost to supply DHW
Cooling	- Cooling would be a separate system	- Cooling would be a separate system	- Built-in cooling in a 2-pipe system
Heat interchange	- No interchange of heat between buildings	- No interchange of heat between buildings	- Interchange of heating/cooling with balancing mechanism - Buildings are then prosumers
ADVANTAGES		- Reduced operating costs and carbon emissions - Lower heat losses - Longer pipe runs? - Greater plant efficiency - More opportunity for heat pumps - More opportunity to use waste/renewable heat sources - More opportunity for simultaneous Heating & cooling?	- Even lower operating costs and carbon emissions - Supplies both heating & cooling - No need for separate cooling system - Interchange of heating & cooling - heat recovery between buildings - Buildings pick-off/inject, so less load dependent? - Can add buildings more easily - Heat losses become almost irrelevant - Longer pipe runs covering wider areas - Even greater plant efficiency, particularly Heat Pumps - More opportunity to use waste/renewable heat sources
DISADVANTAGES		- Larger pipework - Greater pumping costs - Requires DHW boost - Less storage density - No opportunity for energy exchange between buildings across the network	- Larger pipework - Greater pumping costs - Requires DHW boost - Less storage density
APPLICATIONS		**Mainly a new-build technology but with specific solutions for existing buildings where necessary** - New build (relatively easy) - Deep retrofit (straightforward) - Existing Buildings & Retrofit Lite - Boost to 80/70ºC with high temperature HPs - Slightly more opportunity for simultaneous Heating & cooling (conventional HPs)?	**More flexible/connectable plug and play LAN approach with built-in cooling and interchange of energy between buildings** - New build (easy) - Deep retrofit (easy) - Retrofit Lite (relatively easy) - Boost with conventional temperature HPs - Existing buildings (straightforward) - Boost with high temperature HPs - Built-in simultaneous Heating & Cooling (using conventional HPs) - Seasonal storage using boreholes

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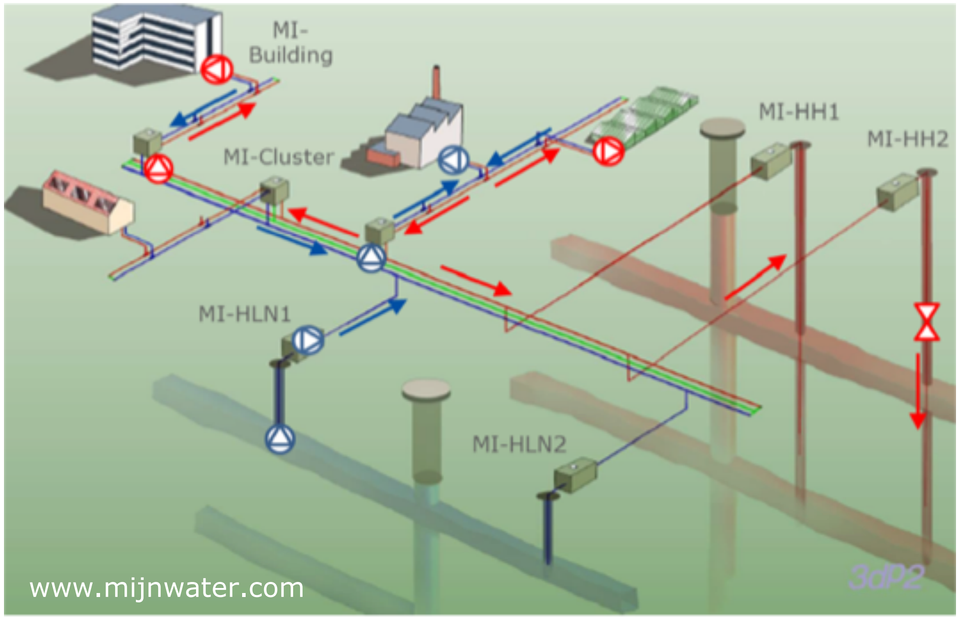
5th generation case study – Heerlen, Netherlands



The Minewater project in Heerlen, Netherlands is a working 5th generation DHC scheme. The scheme uses decentralised heat pumps and is based around mine water from a warm mine and a cold mine with a spine (backbone) as shown opposite.

Phase 2 of the scheme (Minewater 2.0) allowed the operators to take full control of the distributed heat pump plant rooms storage and controls. This allowed a lot more operational plant optimisation including energy exchange across the spine (prosuming) between buildings. This turned the approach into a heating/cooling supply scheme and promoted exchange of energy.

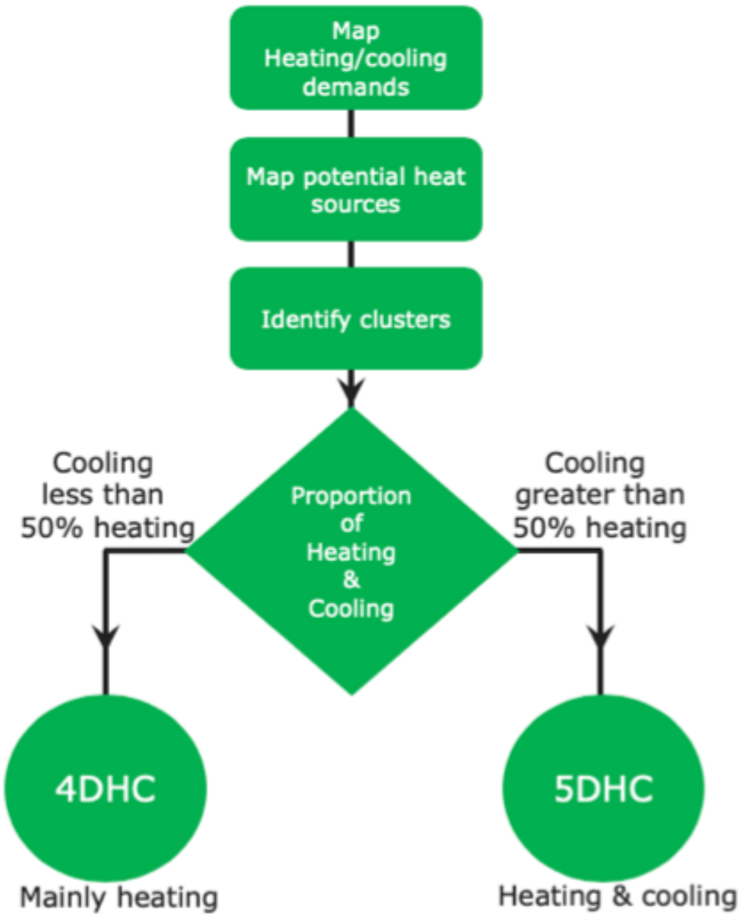
Minewater 3.0 is now introducing demand side response controls, gradually making the scheme a smart grid that interacts with the electricity market.

- The approach is based on balanced heating and cooling loads to exchange energy (prosume) as much as possible. The backbone is not an ‘ambient loop’ but is two main warm/and cold headers with a common return. This allows better hydraulics and avoids buildings on the end of a single pipe loop being starved of heating or cooling.
- Ultra low temperature networks like this need a means of balancing the spine temperatures when they get too hot or cold. In this case the minewater itself provides the seasonal storage balancing mechanism but other approaches are possible e.g. borehole aquifer storage. All mine wells are bi-directional to act as heat dumps/sources.
- Interchange of heating/cooling takes place on the backbone and buildings are seen as both demands (consumers) and suppliers (prosumers) with the overall spine and plant rooms controlled by the scheme operator.
- Local short term storage/buffers in cluster/building plant rooms smooth the operation of decentralised heat pumps. Local temperature boosting provides DHW using small heat pumps in the buildings.
- Pipework extends long distances compared to a 3rd generation heat network due to the low heat losses (flow is insulated) and plastic pipework is used were possible.
- A key part of the approach is to introduce energy efficiency measures including insulation to bring buildings down to Heerlen temperatures. Rather than dismissing existing buildings as too high temperature, the approach is to ‘insulate them down to the Heerlen scheme.
- Heerlen began through local authority ownership and is unlikely to have come about otherwise. The diminishing availability of natural gas has also been as a driver, and this issue is used in promoting the heat network approach.

Where to implement 4th and 5th generation heat networks

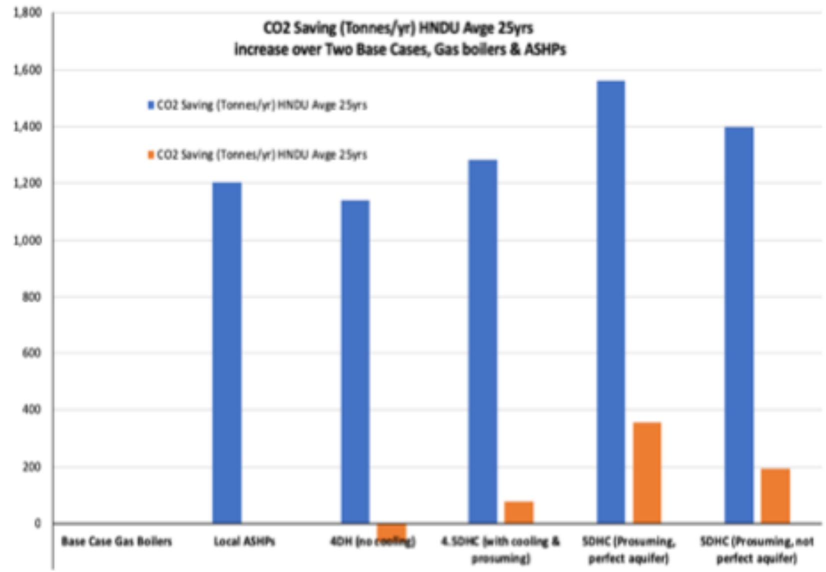
A move to lower temperature 4DHC would provide a change to the types of building that would be most applicable

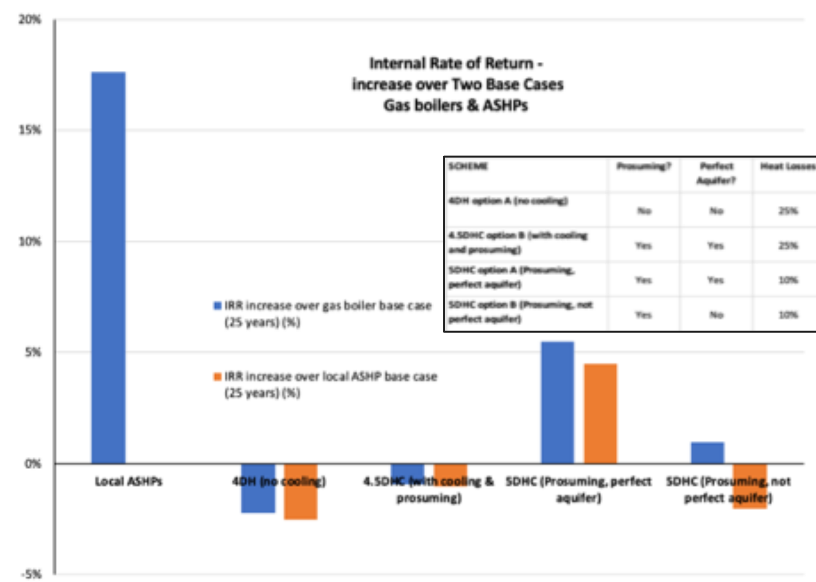
- New build developments would be a relatively easy fit with 4/5DHC as buildings can be specifically designed with appropriate low temperature heating systems
- Similarly, deep-retrofit buildings can be designed to match 4/5DHC temperatures
- Both of the above would still require systems to boost DHW temperatures at an individual dwelling level or at a more centralised building level
- Existing buildings and buildings undergoing retrofit-lite would probably still require higher temperatures, say 80/70ºC and are therefore more of a challenge for 4/5DHC
- However, higher temperature heat pumps could be used to boost to 80/70ºC in order to supply higher temperature heating systems in particular buildings
- 4DHC is a good solution where the demands are mainly heating, but 4DHC is a 4-pipe solution and has to be designed to the lowest common denominator buildings i.e. at the highest heating temperatures
- 5DHC is a good solution where the demands are both heating and cooling
- 5DHC temperatures bring even wider sources and heat recovery opportunities into play
- This does change the way heat mapping and feasibility is carried out, see opposite



Further work is necessary around the ideal distribution of heat pumps. When/if to cluster buildings – say three offices on one plant room OR say 100 individual homes. What is the ideal distribution/spacing/location of heat pumps?

Potential economics of 4th and 5th generation heat networks





SCHEME	Prosuming?	Perfect Aquifer?	Heat Losses	Cooling Network
4DH option A (no cooling)	No	No	25%	No
4.5DHC option B (with cooling and prosuming)	Yes	Yes	25%	Yes
5DHC option A (Prosuming, perfect aquifer)	Yes	Yes	10%	No
5DHC option B (Prosuming, not perfect aquifer)	Yes	No	10%	No

Based on the scheme being proposed in Plymouth, techno-economic modelling was carried out to compare 4DHC and 5DHC with both a gas boiler counterfactual (shown in blue) and a local ASHP counterfactual (shown in orange). Whilst this is very scheme specific, it does provide a useful indication of the potential economic balance between these systems.

- None of the schemes are economic without RHI or HNIP given the current electricity and gas prices. The taxation of these fuels unfairly favours gas use
- 5DHC(A) has the largest CO_2 savings (top graph) because of the low network losses and elimination of gas usage
- The 4DHC options require gas boiler top-up and have larger losses, these are negative factors for carbon emissions
- 4DH(A) increases carbon emissions over the local ASHP counterfactual due to network heat losses
- The only option with a positive IRR (bottom graph) is the 5DHC(A) scheme with RHI, although this is still below the standard public sector hurdle rate
- 5DHC has a capex advantage by not having to put in as large a heating and cooling network but instead has the borehole and water pipes. However, this capex benefit is largely lost because of the high capital cost of local DHW booster heat pumps

  5DHC options win because they have more heat pump capacity which inflates the RHI without compromising the capital costs. Decentralised 5DHC heat pumps are significantly cheaper per kWth than 4DHC heat pumps
- Lower 5DHC temperatures and the lack of a primary network mean there is a significant difference in heat losses, 25% for 4DHC versus 10% for 5DHC.

5DHC schemes provide the greatest IRR and CO_2 savings, even when compared with local ASHP options

Benefits to building owners and developers

	BAU	3DHC	4DHC	5DHC
PLANNING	Increasingly difficult to obtain planning permission	Planning permission should be straightforward	Planning permission should be even easier	Planning permission should be easier
TIMING	Development can go ahead at any time	Heat network requires careful timing	Heat network requires careful timing	Plug & play allows development can go ahead at any time
BUILDING REGULATIONS	Other measures required to achieve Part L	Lower Part L requirements	Even lower Part L requirements	Even lower Part L requirements
AIR QUALITY	Local air quality issues from gas boilers	Improved air quality compared to gas boilers	Improved air quality compared to gas boilers	Improved air quality compared to gas boilers
CAPITAL COSTS	Capital costs for traditional plant	Avoided capital costs of plant	Avoided capital costs of plant	Avoided capital costs of plant
ENERGY CENTRE	Space required for local plant rooms	Space required for centralised energy centre	Space required for centralised energy centre	Space required for plant rooms but centralised energy centre avoided
GAS SUPPLY	Annual gas safety check compliance	No gas safety check	No gas safety check	No gas safety check
FLUES	Individual flues required for boilers	No flues required	No flues required	No flues required
ELECTRICAL SUPPLY	Significant supply capacity for e.g. ASHP	Reduced electrical supply compared to distributed ASHPs	Reduced electrical supply compared to distributed ASHPs	Reduced electrical supply compared to 4DHC heat pumps
COOLING	Separate plant for cooling requiring space & capital costs	Separate plant for cooling requiring space & capital costs	Separate plant for cooling requiring space & capital costs	Built-in cooling with no additional capital requirements
RUNNING COSTS	Full costs	Reduced running costs & cost of heat	Even lower running costs & cost of heat	Even lower running costs & cost of heat
CARBON EMISSIONS	Higher carbon emissions	Lower carbon emissions	Even lower carbon emissions	Even lower carbon emissions
MAINTENANCE	Full O&M liabilities/ costs	No maintenance liabilities	No maintenance liabilities	No maintenance liabilities
REPLACEMENT COSTS	Capital costs for replacement plant	Avoided capital costs of plant	Avoided capital costs of plant	Avoided capital costs of plant

It is clear that new-build and deep-retrofit scenarios are the easiest applications of 4DHC and 5DHC. Developers are therefore key to introducing 4DHC/5DHC. This table sets out some possible developer incentives to move to 4DHC and 5DHC heat networks compared to a business as usual approach using gas boilers.

The temperature and timing for building connection is often a major reason not to connect to DHN. 5DHC allows a more 'plug and play' approach that can address these developer issues.

Selling comfort not heat

Traditional business models - In traditional and even 4th generation district heating the scheme operator is only responsible for heat reaching the building. Their responsibility ends at the building thermal sub-station or perhaps at a dwelling Heat Interface Unit. Many scheme operators are left frustrated that the poor design and operation of the internal building systems have a detrimental effect on their DHN performance. In particular, poor DHN return temperatures can often be traced back to problems that are outside the DHN operators remit e.g. high temperature heating systems, poorly insulated secondary pipework, poor heating control, poor HIU set-up etc.

5DHC taking overall control - A key part of a more decentralised 5DHC approach is that the scheme operator needs to take control of the distributed plant rooms to allow full scheme optimisation and encourage prosuming across the network. The operator can then optimise heat pump performance through good control and maintenance. Whilst also promoting greater exchange of energy between buildings. The more prosuming between buildings the lower the overall overall operating costs (and carbon savings) that can be passed onto consumers.

Buildings as prosumers – An essential part of 5DHC is therefore that the scheme operator must take full responsibility for the whole scheme including the decentralised heat pump plant rooms in order to allow management of the buildings as prosumers and balancing of the 5DHC headers/boreholes. Without this, prosuming is less likely and the benefits of 5DHC begin to fall away.

A new business model – 5DHC therefore changes the lines of responsibility for the operator and consumer. This opens up opportunities for new ways of selling heating and cooling. This might be better described as ‘selling comfort not heat’. Consumers could then be offered a temperature based service without having to worry about maintenance and replacement. Although these new business models are possible with 4DHC, they are less likely. Whereas a comfort based service is almost built-in to the 5DHC approach. This is potentially a huge step forward for new business models to come forward around heat networks.

A solution for cooling – there is a significant increase in cooling demand, with changes in climate and consumer expectation being big drivers. How is this cooling going to be supplied in the long term? 5DHC offers a way forward as it is a single system to supply/exchange both heating and cooling.

The consumer would simply pay for a comfort level with less to worry about around replacement and maintenance.

The operator can take full control of the whole scheme, optimise the system and bring greater cost/carbon benefits through a comfort based offer.

Local Authority roadmap for 5th generation heat networks

2020

- Include Low Temperature Building Zones in Supplementary Planning Guidance (SPG) to develop 4DHC and 5DHC areas/corridors that offer preferential planning approval – give clear signals that these areas will grow
- SPG to include DHN connection future proofing of all new and refurbished buildings (based on Buro Happold connection templates)
- SPG to insist on following CIBSE/ADE Heat Networks Code of Practice CP1.2
- Early adoption of 'no new homes should connect to the gas grid' and should instead rely on low-carbon heating systems such as heat pumps
- Local grants and S106 agreements to help buildings move to 60/40ºC
- Greater enforcement of Building Regulations Part L
- Discourage resistive heating through less preferential planning approval with greater scrutiny
- Publish a local 'connections guide' covering policy, technical and legal DHN guidance

2025

- Extend the Low Temperature Building Zones to cover all new buildings, offer preferential planning approval to buildings able to act as prosumers
- Early adoption of 150g/kWh with even lower overall building carbon targets
- No new non-domestic buildings should connect to the gas grid, and should instead rely on low-carbon heating systems such as heat pumps
- Continue grants and preferential planning approval to help buildings move to 60/40C
- Even more rigorous planning scrutiny/hurdles for proposed resistive heating buildings

2030

- Local Authorities should becomes a single LTBZ where all new buildings must be less than 60/40ºC
- Early adoption of 100g/kWh with even lower overall building carbon targets
- SPG to include even greater encouragement of 5DHC and prosuming buildings

A NEW LOW TEMPERATURE BUILDING ZONE

- All new and refurbished buildings to be less than 60ºC
- Grants to help existing buildings to move to 60ºC

THE PLYMOUTH RULE

UK Policy roadmap for 5th generation heat networks

2020

- Introduce SAP10 (and SBEM) 233g/kWh with lower overall building carbon targets
- Include improved Design Heat Loss Factors for 4DHC and 5DHC in SAP/SBEM
- Signal 150g/kWh and insist on all DHN following CIBSE/ADE Heat Networks Code of Practice CP1.2 from 2025
- Early adoption/signals 'no new homes should connect to the gas grid' and should instead rely on low-carbon heating systems such as heat pumps
- Grants to help buildings move to 60/40ºC and encourage presuming buildings
- Retain the RHI for heat pumps and encourage prosuming buildings
- Develop standard SPG text and connection guidance to assist Local Authorities
- Grants to help Local Authorities set up 'heat delivery bodies'

2025

- Introduce SAP11 (and SBEM) 150g/kWh with even lower overall building carbon targets and enhanced DHLFs
- Set up a HEAT REGULATOR and include 4/5DHC in their remit
- By 2025 at the latest, no new homes or non-domestic buildings should connect to the gas grid, and should instead rely on low-carbon heating systems such as heat pumps
- Signal 2030 phase out of new-build and replacement gas boilers
- Make resistive heating a much harder option in Building Regulations
- Continue grants to help buildings move to 60/40ºC and encourage prosuming buildings
- Continue/review the RHI for heat pumps and further encouragement for prosuming buildings

2030

- Introduce SAP12 (and SBEM) 100g/kWh with even lower overall building carbon targets
- Begin phase-out of new-build and replacement gas boilers
- Begin phase-out of resistive space heating
- Continue grants to help buildings move to 60/40ºC and encourage presuming buildings
- Continue, but review, the RHI for heat pumps and further encouragement for prosuming

Conclusions

- This study has defined 4th and 5th generation heat networks more clearly (Typologies) and set out where these types of heat network might best be used (Applications). The work has also identified the advantages and disadvantages of the various 4DHC and 5DHC approaches
- 5DHC using decentralised heat pumps is best where there is a heating and cooling demand, 4DHC is a better solution where the demand is mainly heating
- 5DHC has even greater potential in new-build because of the lower temperatures involved. But higher supply temperature heat pumps can be used to serve existing buildings
- Both heating and cooling can be provided from the same 5DHC system using a 2-pipe system to achieve full 5DHC rather than a 4-pipe 4DHC system. 5DHC has lower pipe costs, potentially covering longer distances
- Buildings on a 5DHC scheme become ‘prosumers’ that exchange heating and cooling across an ultra low temperature network
- 5DHC offers a plug-and-play approach giving timing and temperature flexibility on same system, whereas 4DHC has to be designed to the worst common denominator building temperature
- Heat losses are one of the big differences between 4DHC and 5DHC, a key advantage of 5DHC, but both 4DHC and 5DHC require temperature boosting to supply DHW
- Balancing aquifer thermal storage is necessary in 5DHC, but boreholes can be built-out gradually alongside the buildings, as and when developments occur
- Modelling indicates that 5DHC schemes provide the greatest IRR and CO_2 savings, even when compared with local ASHP options. Further modelling is needed to better understand these systems.
- 5DHC could allow operators to ‘sell comfort not heat’ which is potentially a huge step forward for new business models to come forward around heat networks
- Possible local authority and UK policy roadmaps have been suggested to encourage 4th and 5th generation heat networks. These sit alongside a more specific roadmap to reach a specific 5DHC scheme in Plymouth.

Overall, 4DHC and 5DHC have significant potential to reduce carbon emissions and provide greater flexibility to building owners/developers aiming to connect

The HeatNet project

HeatNet is an EU Interreg project to address the challenge of reducing CO_2 emissions across North West Europe by creating an integrated transnational approach to the supply of renewable and low carbon heat to residential and commercial buildings.

This particular project in Plymouth forms one of the 6 pilot studies in the UK, Ireland, Belgium, France, and the Netherlands that HeatNet have funded. The project focussed on identifying potential 4th generation district heating and cooling schemes in Plymouth.

Plymouth City Council (PCC) appointed a main consultant (Buro Happold) to conduct an extensive project focussed on introducing 4DHC across the whole Plymouth area. PCC also appointed a 'Concepts Team' comprising Building Energy Solutions, Carbon Descent and Genius Energy Lab to work in parallel and directly with the main consultant in order to use the Plymouth outcomes to develop UK wide learning and guidance on 4DHC for the whole sector. The Concepts Team aimed to develop/standardise the widest possible ideas, concepts and approaches to introducing 4DHC/5DHC.

The Plymouth HeatNet project had 5 stages:

Stage 1 - Research and evaluation on 4DHC opportunities

Stage 2 - Heat Mapping

Stage 3 - Outline Design

Stage 4 - Techno-economic Analysis

Stage 5 - Transition Roadmap

Interreg
North-West Europe
HeatNet NWE

This report presents the Concepts Team outputs as a road map for 4DHC across Plymouth, other local authorities and the UK as a whole.

Just prior to publication of this roadmap, the Heatnet team became aware of a very significant piece of work on 5DHC:

5th generation district heating and cooling systems: A review of existing cases in Europe (Buffa S et al) (Renewable and Sustainable Energy Reviews) (February 2019)

This is an important and comprehensive parallel study and it is encouraging that it appears to be very much in line with our own independent findings. However, given the timing we were not able to take account of the work in any detail.

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5. Annex XI final report - Transformation Roadmap from High to Low Temperature District Heating Systems (Werner et al)

6. Guidelines for Low-Temperature District Heating (Full-scale demonstration of low temperature district heating in existing buildings, EUDP, (2014)

7. 5th generation district heating and cooling systems: A review of existing cases in Europe (Buffa S et al) (Renewable and Sustainable Energy Reviews) (February 2019)

The HEATNET partners in Plymouth

Building Energy Solutions
Energy Management, Research & Training Consultancy

BUROHAPPOLD ENGINEERING

carbondescent
Delivering a Sustainable Future

GeniusEnergyLab

PLYMOUTH CITY COUNCIL

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Plymouth 4 & 5DHC Roadmap

Part 2. Plymouth Proposals

March 2019

About HeatNet NWE

This document has been developed as part of the HeatNet NWE project, which is part-funded through the Interreg NWE programme and aims to increase the uptake of 4DHC networks across North-West Europe. As part of this project, the partners are developing the HeatNet Model, which will help the public sector to begin implementing 4DHC networks, and the Transition Roadmaps, which will outline the partners' experience in developing six district heating pilots across North-West Europe. The HeatNet Guide to Financing is also currently being developed and will give a broad overview of the various sources available to finance district heating schemes.

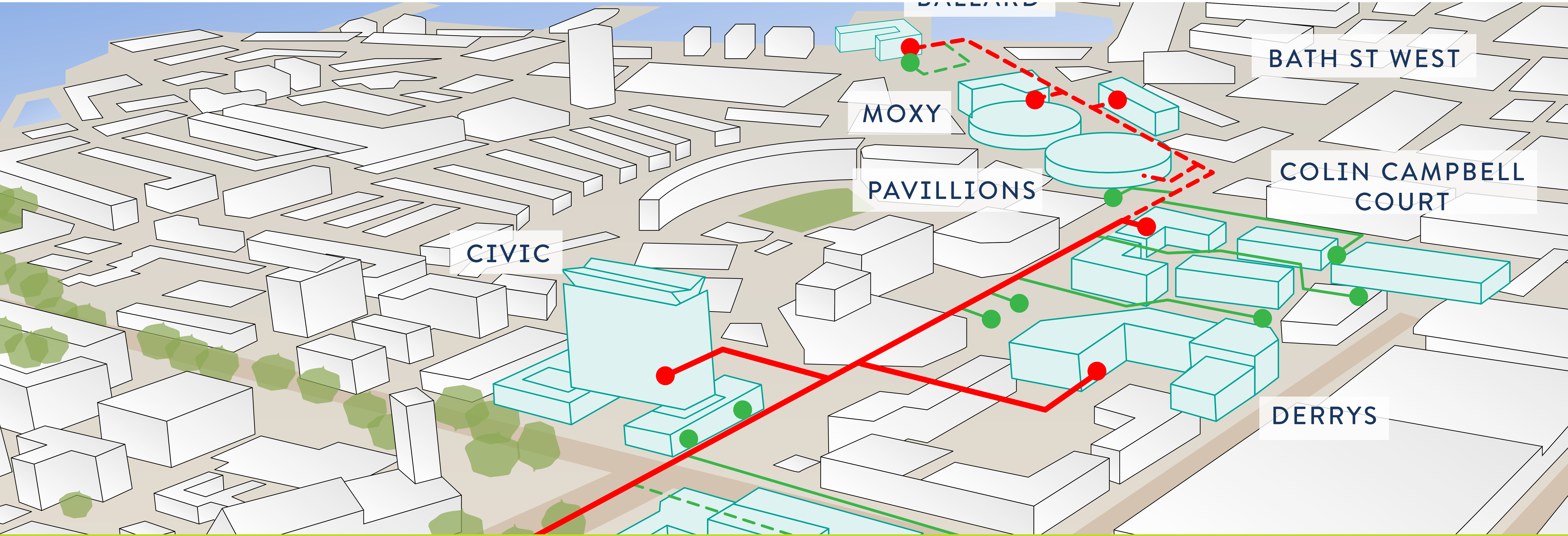
For further information on these reports and on the HeatNet NWE project, please visit www.nweurope.eu/heatnet.

BUROHAPPOLD ENGINEERING

Interreg North-West Europe HeatNet NWE

European Regional Development Fund

040974 PLYMOUTH HEATNET



STAGE 5 - PLYMOUTH ROADMAP

REVISION 03

29 MARCH 2019

Revision	Description	Issued by	Date	Checked
00	Draft Issue	AP	30/11/2018	JE
01	Draft incorporating minor changes and comment responses	AP		
02	Final Issue	AP	01/03/2019	JE
03	Final issue with minor changes	AP	29/03/2019	JE

Stage 5 Roadmap

Author	Aaron Powell
Date	29/03/2019
Approval	Justin Etherington
Signature	
Date	29/03/2019

CONTENTS

GLOSSARY

Term	Definition
ASHP	Air source heat pump
BEIS	Department of Business, Energy, and Industrial Strategy
Capex	Capital expenditure
CHP	Combined Heat and Power
BEIS	Department for Business, Energy & Industrial Strategy (previously DECC)
DEN	District Energy Network
DH	District Heating
DHN	District Heating Network
DHW	Domestic hot water
EfW	Energy From Waste
GSHP	Ground source heat pumps
HP	Heat Pump
HIU	Heat interface unit
HNDU	Heat Networks Delivery Unit
HNIP	Heat Networks Investment Project
LTDH	Low Temperature District Heating
LTHW	Low temperature hot water
RHI	Renewable Heat Incentive
PCC	Plymouth City Council
GWSHP	Ground water source heat pump
SWSHP	Surface water source heat pump

Unit	Definition
kW	Kilowatt (peak load unit)
kWe	Kilowatt (peak load unit) - electrical
kWh	Kilowatt hours (energy unit)
kWth	Kilowatt (peak load unit) - thermal
MW	Megawatt (peak load unit)
MWh	Megawatt hours (energy unit)

1 SUMMARY OF PROJECT TO DATE AND PURPOSE OF REPORT

BuroHappold have been commissioned by Plymouth City Council (PCC) to create a 4th generation district heating and cooling roadmap for Plymouth. This study has been funded by the European Regional Development Fund of the European Union, as PCC is in receipt of funding from the Interreg NWE Programme 2014-2020 for the HeatNet NWE project. HeatNet explores the feasibility and implementation of fourth generation district heating approaches in Plymouth until 31st December 2019.The aim of the HeatNet project overall is as follows:

HeatNet will address the challenge of reducing CO2 emissions in North West Europe by creating an integrated transnational NWE approach to the supply of renewable and low carbon heat (incl. waste heat) to residential and commercial buildings. District Heating and Cooling facilitates energy efficiency, less CO2 emissions and a greener economy.

The project aims to develop and test 6 local district heating and cooling networks (DHC) in UK, Ireland, Belgium, France, and the Netherlands.

The project contains two teams:

- Main consultant – producing a Plymouth focussed study and roadmap.
- Concept team – producing a concept roadmap aimed at the UK as a whole, also working alongside the Main consultant to provide review input.

The project has been split into five stages, the details of which are in the following sections.

Stage 1 - Research and evaluation on District Heating and Cooling opportunities

The project team and concept team visited the Mijnwater project in Heerlen to analyse and learn from their Fourth Generation District Heating and Cooling (4DHC) operational project. In recognition of what Heerlen have achieved, The teams defined a new system architecture 'Fifth Generation District Heating and Cooling' (5DHC) which is radically different from 4DHC.

4DHC

A system with centralised heat raising plant, utilising low primary network temperatures, potentially with a booster at the connection for higher Domestic Hot Water (DHW) temperatures. Lower primary network temperatures enable efficient use of electrical heat raising plant e.g. heat pumps. See Figure 1.1. Benefits of this approach include; removal of gas connections, reduced heat plant room size, compliance with current building regulations, potential compliance with future building regulations if electrically led, transferred risk of heat supply.

5DHC

A system with no centralised plant which utilises an energy sharing spine at variable, but very low, temperatures to deliver heating and cooling. It is possible to connect multiple heat sources to the spine. Connections have a heat pump plant room connected to the spine and they take heat from or reject heat into the spine. In this way energy can be shared between buildings. Also can benefit from seasonal storage. See Figure 1.2. Benefits of this approach include; removal of gas connection, compliance with current and future building regulations (full electrification), transferred risk of heat supply.

Deployment of DHC will depend on local characteristics as shown in Figure 1.3.

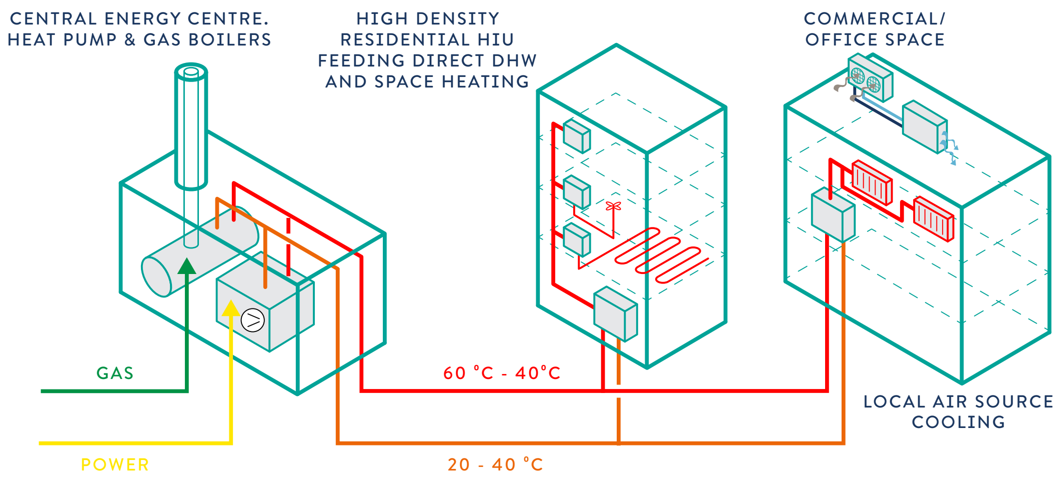


Figure 1.1: 4DHC

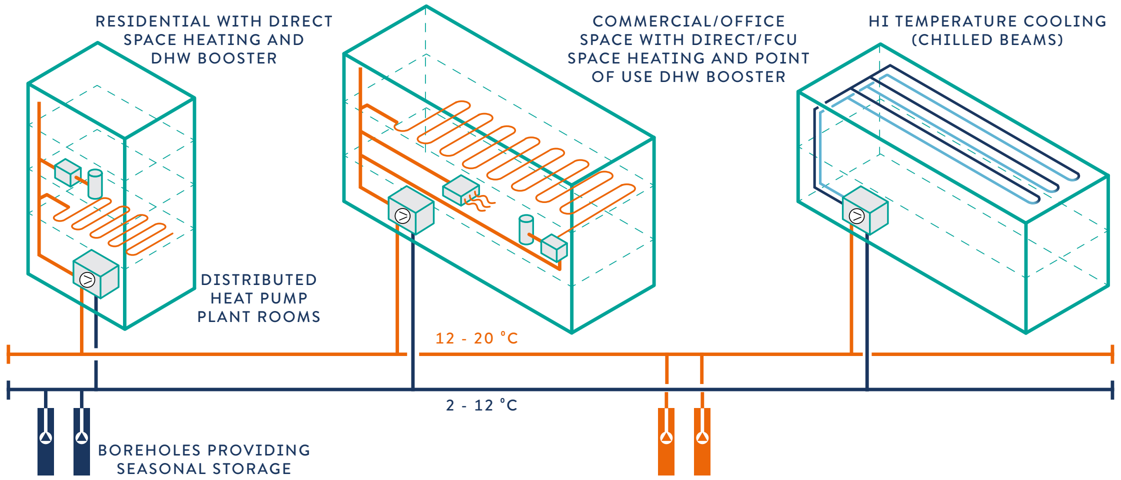


Figure 1.2: 5DHC

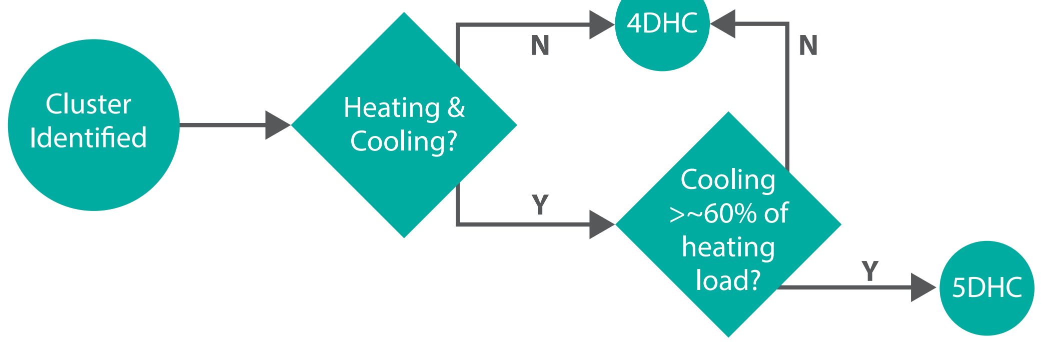


Figure 1.3: 4DHC vs 5DHC Decision Tree

SUMMARY OF PROJECT TO DATE AND PURPOSE OF REPORT

Stage 2 - Heat Mapping

The main consultant team mapped heat, coolth, power loads, and heat sources for Plymouth. There are multiple heat source opportunities in Plymouth which have potential for large scale heating including: Energy from Waste (EfW), Sea Water Source Heat Pump (WSHP), Ground WSHP, Data centre heat recovery, Incinerator heat recovery. From this there are seven clusters which could benefit from the sources, with 3 able to benefit from a cooling synergy potentially enabling 5DHC.

Stage 3 - Outline Design

The main consultant then developed an outline design and capex costing of 6 scenarios utilising clusters at the Civic Centre and Millbay. These clusters covered:

- 4DHC at the Civic cluster with distributed and centralised cooling systems
- 5DHC at the Civic cluster with seasonal thermal storage and without
- 5DHC at the Civic& Millbay cluster with seasonal thermal storage and without.

The main heat sources are open loop ground source heating at the Civic Centre cluster, with some sea water source heating from the Millbay cluster.

Stage 4 - Techno-economic Analysis

Then main consultant techno-economically modelled the scenarios designed at outline design stage. In general this found that:

- A district cooling network outperforms local air source cooling in the 4DHC scenarios.
- 5DHC generally outperforms 4DHC.
- Extending the 5DHC Civic Centre cluster to full Millbay cluster does not provide benefit.
- In order for a viable scheme to be realised there must be RHI or an RHI equivalent.

Stage 5 - Transition Roadmap

The main consultant then developed a Plymouth focussed roadmap which sets out how the city can begin to transition to a 4DHC city, which is the focus of this report, with the Roadmaps given in Sections 7 and 8.

The Concept team has produced a roadmap report which looks at the potential to apply these approached to U.K. with a view to beginning the transition nationwide. This will be a more strategic document, and complementary to the Plymouth roadmap (which focusses on Plymouth specific opportunities) and therefore the two can be read in conjunction. For example, a city (not Plymouth) may read the UK roadmap and then turn to the Plymouth Roadmap for an example of the specific steps that are being taken to propagate 4DHC.

1.1 PURPOSE OF THIS REPORT

The report will identify and review the current opportunities in Plymouth (both prior to and during this project).

The report will then propose a roadmap which tackles the main challenges to implementation of a scheme. These challenges will be identified both from a policy and from an implementation perspective. The roadmap will suggest short, medium, and long term actions that the stakeholders in a scheme must take to achieve widespread DH and DHC solutions in Plymouth.

The final section of the report will take the most promising 5DHC cluster identified and provide a tailored roadmap of next steps to the implementation of the scheme.

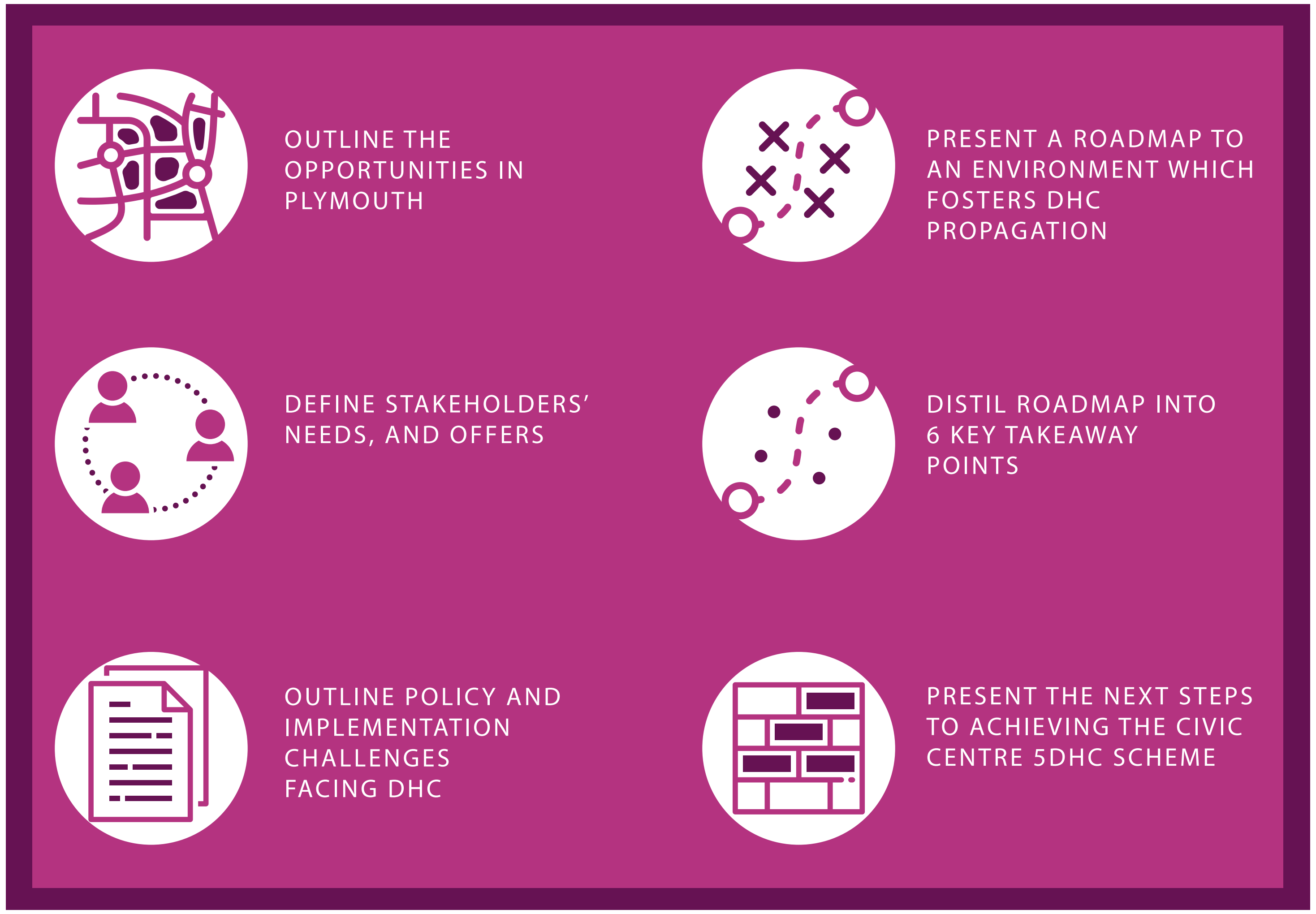


Figure 1.4: Purpose of the Report

2 INTRODUCTION

2.1 THE IMPORTANCE OF HEAT NETWORKS IN THE ENERGY TRANSITION

In October 2018 the Intergovernmental panel on climate change released a report on climate change which highlighted the speed of the transition away from fossil fuels required for the world to reach the 1.5 °C maximum warming limit.

The report found that we must be carbon neutral within 15 years to achieve the target.

With emissions due to gas heating responsible for ~20% of the UK emissions (kgCO_2e, calculated using data from DUKES 5.3 and BEIS Final UK greenhouse gas emissions national statistics 1990-2016), and the majority of these emissions coming from systems such as that seen in Figure 2.3 rapid progress needs to be made in decarbonising this sector. Currently the route to this is through electrification using heat pumps. As a local authority it is the responsibility of Plymouth City Council (PCC) to support this transition. Heat networks offer one way of implementing rapid electrification across multiple buildings, as well as improving security of energy supply, reducing fuel poverty.

The overall short term ambition of Plymouth City Council is to deliver a district heating and/or cooling system within the City. PCC have been working for a number of years across a number of studies to try and realise this goal, and the majority of these studies have been with the support of the UK Heat Networks Delivery Unit (HNDU) within the Business Energy and Industrial Strategy (BEIS) department of the UK government, and have been focussed on a 'traditional' archetype such as that in Figure 2.2.

This project has investigated the potential for 5DHC which integrates heating and cooling into a single network, minimising energy loss, allowing energy sharing and maximising the efficiency of the electrical shift. This 5DHC approach moves system from a current trend approach to a future trend approach (Figure 2.1).

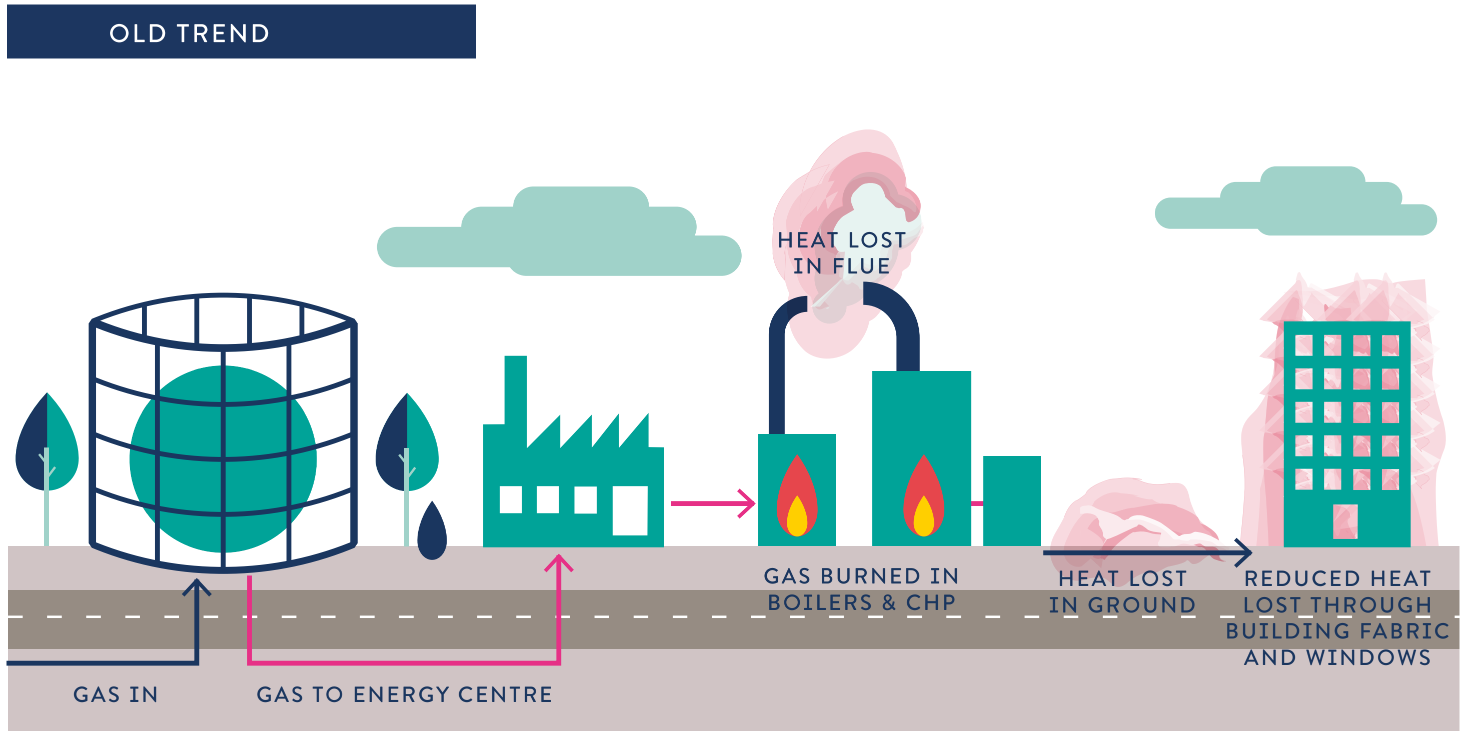


Figure 2.3: Old Trend - Individual Solutions

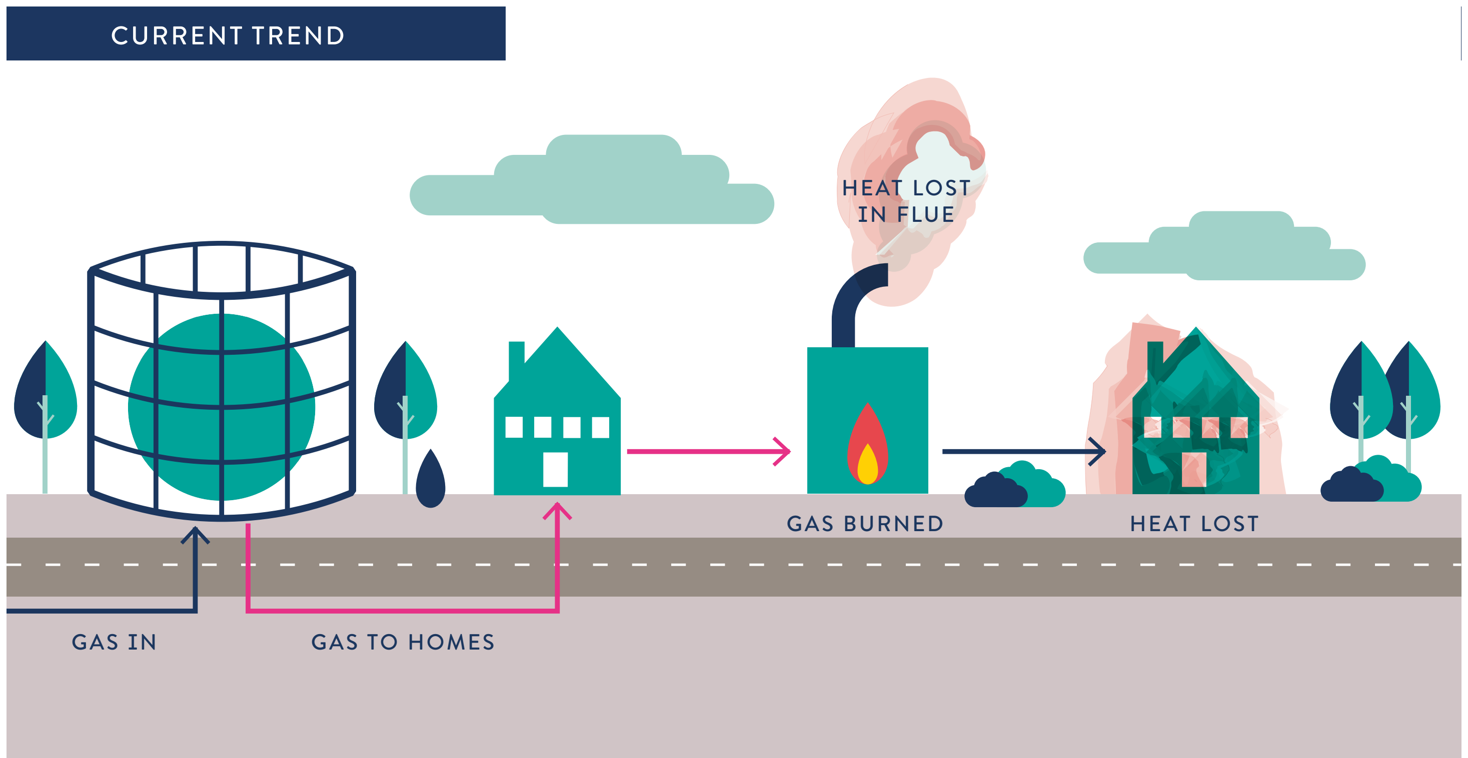


Figure 2.2: Current Trend - 3DHC

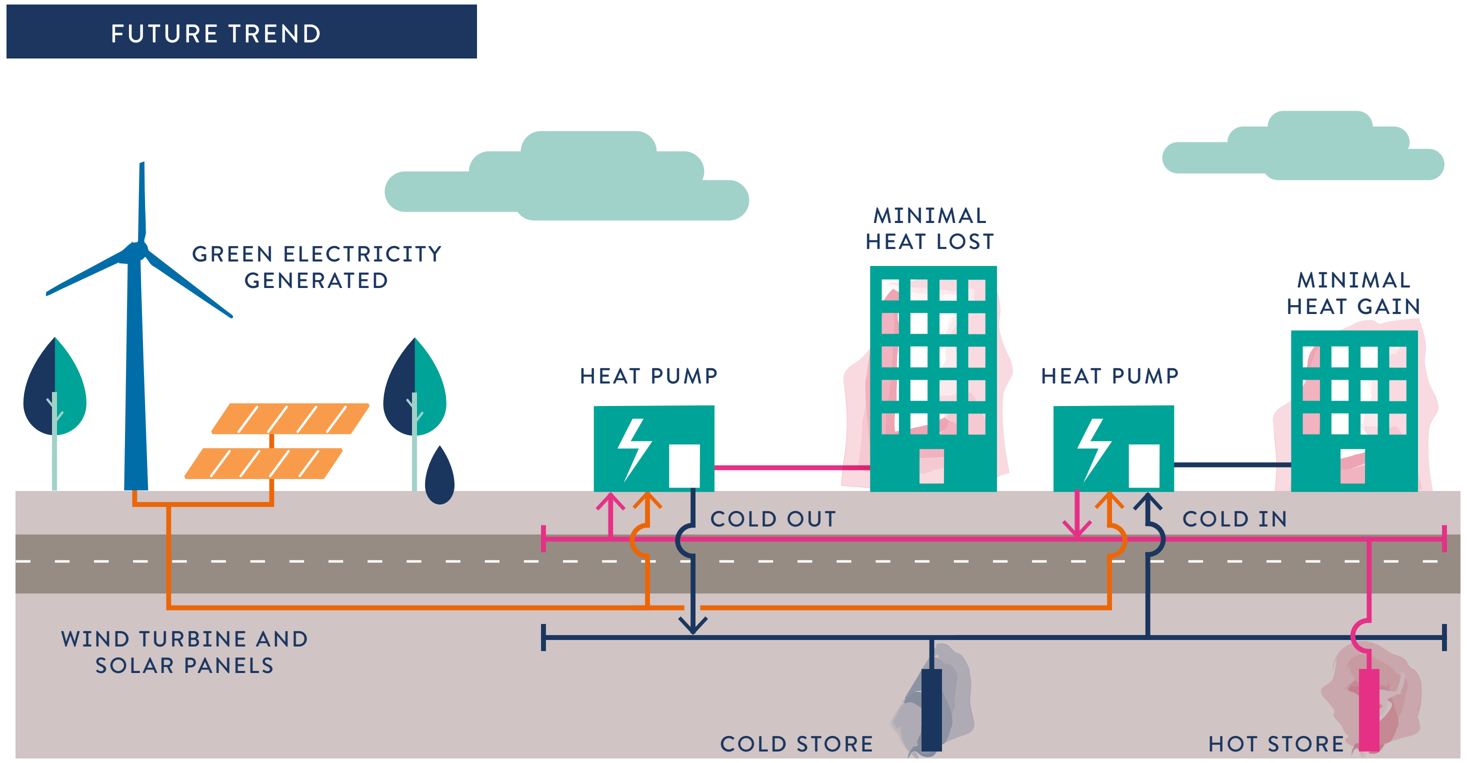


Figure 2.1: Future Trend - 5DHC

INTRODUCTION

2.2 POTENTIAL FOR DISTRICT HEATING IN PLYMOUTH

This image highlights locations where studies have been completed into the feasibility of district energy in Plymouth.

Green areas are those identified as district heating opportunity areas in the published Plymouth City-wide district energy strategy.

Purple areas are 4DHC opportunities as identified in this HeatNet project which are explored in more detail in the following section.

Red areas are 5DHC opportunity areas as identified in this HeatNet project.

On the image is the key technology which underpins the 4DHC opportunity in that area. The 5DHC opportunities are detailed in the following section. The opportunities highlighted in Figure 2.4 are traditional heat supply archetypes, whereby heat is generated at central source and used directly at connection without the need for any supplementary heating.

It is critical to that every development achieves emission reduction through alternative heating approaches to gas boilers. Developments outside of these areas should consider the use of electrified heat pump heating for their site. A principal aquifer is denoted by the black line whilst a secondary aquifer is present across the majority of the city. Both geologies can be suitable for open loop ground source heating therefore this indicates that the opportunity exists for widespread ground source heating across Plymouth.

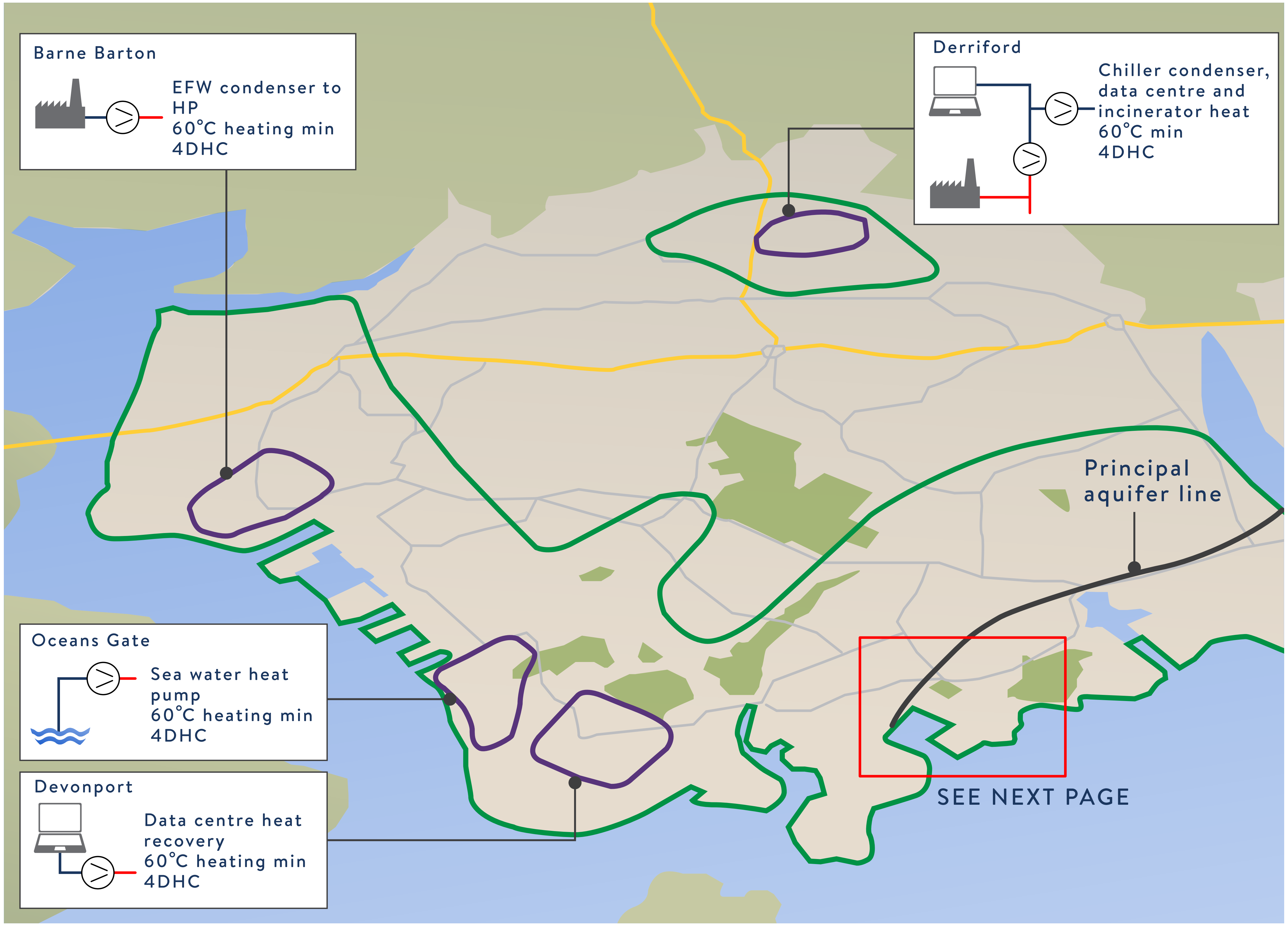


Figure 2.4: Plymouth Opportunities

INTRODUCTION

2.3 POTENTIAL FOR 5TH GENERATION DISTRICT HEATING AND COOLING IN PLYMOUTH

Whilst 1st to 4th generation district heating sees heat distributed from a central source, the 5th generation approach in this study takes the energy source to the connection. In order for this archetype to be successful there are several key criteria that the individual buildings and the cluster of buildings of interest must meet:

- A suitable heat source, the Plymouth opportunity relies upon a principal aquifer for energy source.
- Large scale energy storage, the Plymouth opportunity relies upon a principal aquifer for energy storage.
- Overall balance of heating and cooling in the cluster of ~60% or better.
- As low as possible building heating temperatures to ensure maximum heat pump efficiency. 40 °C flow temperature is considered an upper limit for efficiency however higher temperatures can be achieved at the cost of efficiency.
- An ideal scenario would see relatively low DHW demand within the cluster – due to relative inefficiency of generating this temperature.

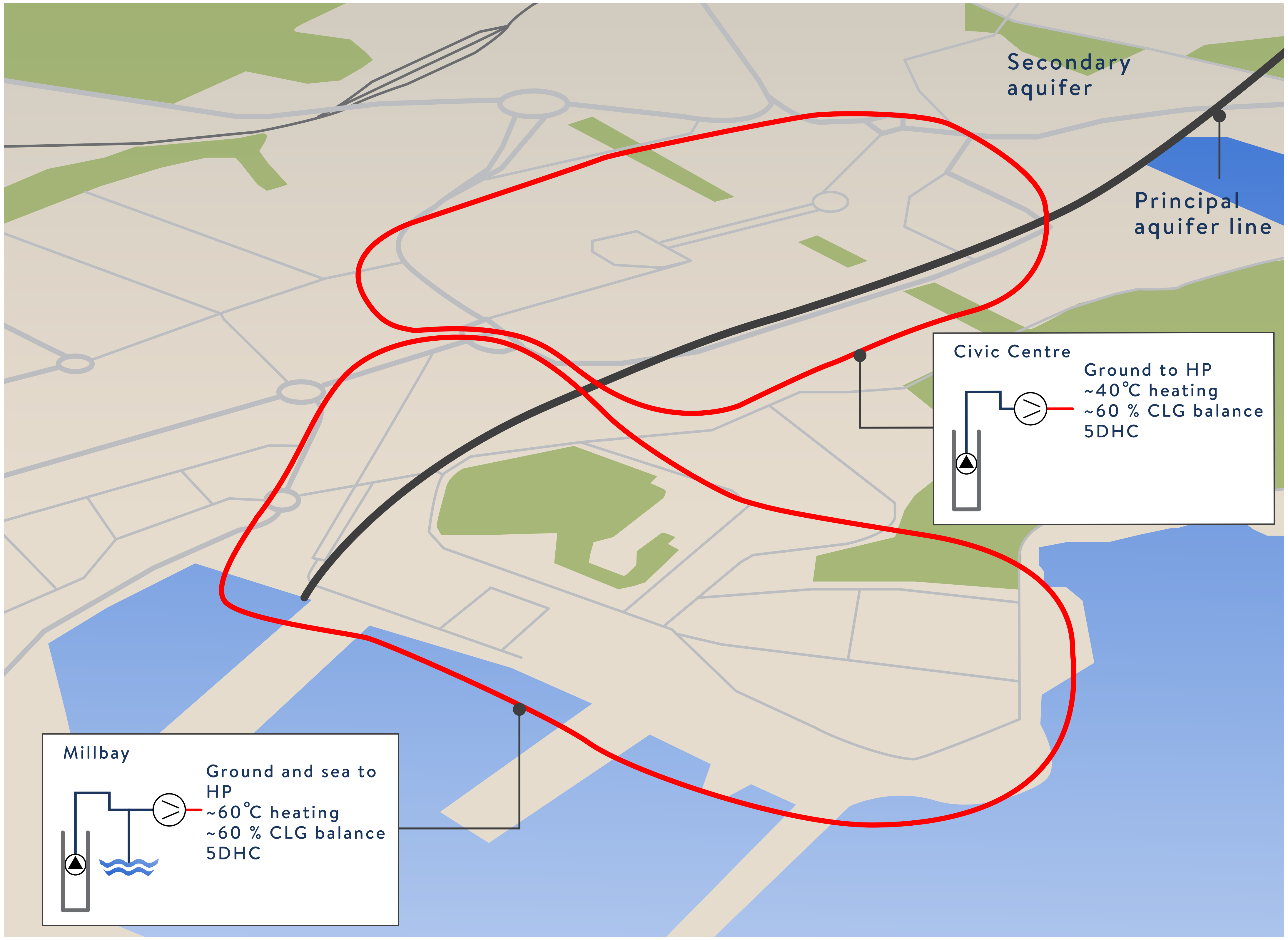
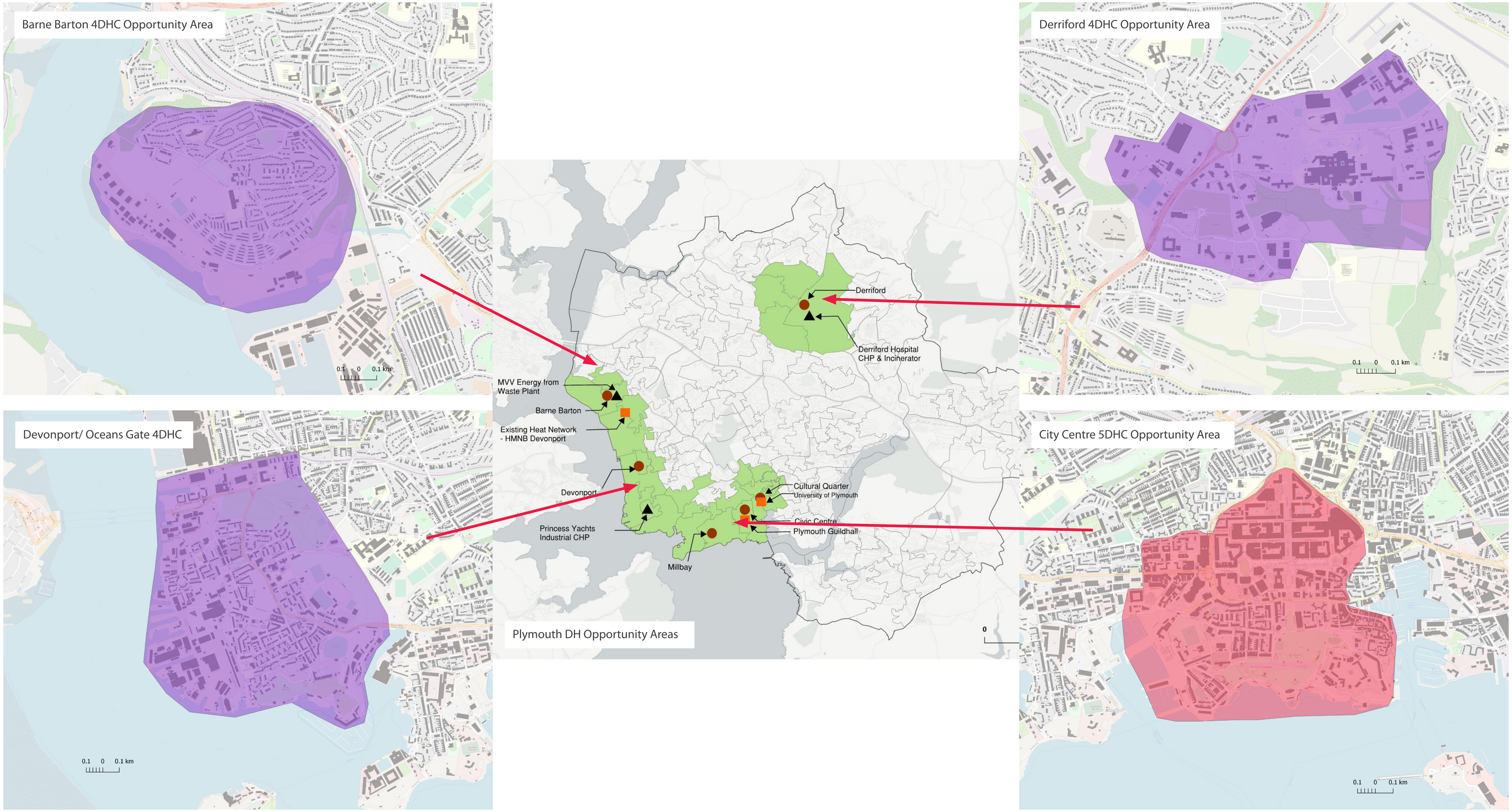


Figure 2.5: City Centre Opportunities

INTRODUCTION

2.4 SUMMARY OF 4TH AND 5TH GENERATION OPPORTUNITY AREAS IN PLYMOUTH



3 DRIVERS AND STAKEHOLDERS

National level – Government

At the national level, Government are responsible for setting the key policies, frameworks, and support mechanisms (including incentives) to achieve energy security, carbon reductions and address fuel poverty. These will be implemented at the local level by Local Authorities, developers and building owners.

PCC

Plymouth City Council are responsible for establishing local policy, underpinned and aligned with the more strategic national policy frameworks. The council can bring public funding rates to projects, are able to control planning consents and could be able to offer financial incentives for compliance with key local policies supporting DHC such as affordable warmth, carbon targets, encouraging new business among others..

DHC Operator

A network operator is responsible for operation of the scheme and is concerned with a return on investment, without which, schemes would not be possible. The operator should also be looking to offer the highest level of service to the end customer to preserve reputation and minimise damages. The operator can also offer design, build, operate services of secondary systems for developers guaranteeing them compliance both in planning terms and for connection to a potential network.

New Build Developers

Developers are critical to the implementation of a heat network however they work on a timeline which is completely independent of a network and therefore their interest must be captured early. This is particularly important if the load they are offering is significant and there is potential for a significant connection charge to be recovered. They are principally concerned with planning compliance and financial benefit.

Existing building owners (Landlords)

Currently an existing building owner must provide a lettable space with an EPC rating of E or better which is a principle driver for energy efficiency. They will also be keen to reduce operational costs and reduce carbon where possible. They may be keen to have spaces which are 'green' and marketable as such, as well as marketable as having low utility costs. If these loads can be captured they can be significant due to the older quality of building.

Tenants/ Occupiers

Tenants and owner occupiers both generally want cheaper bills, and potentially in the future there could be EPC regulations for private buildings. A proportion of tenants/ building owners may be attracted to an offer of a green heating source, or attracted to carbon savings in general as part of an ongoing rise in profile of sustainable operation.

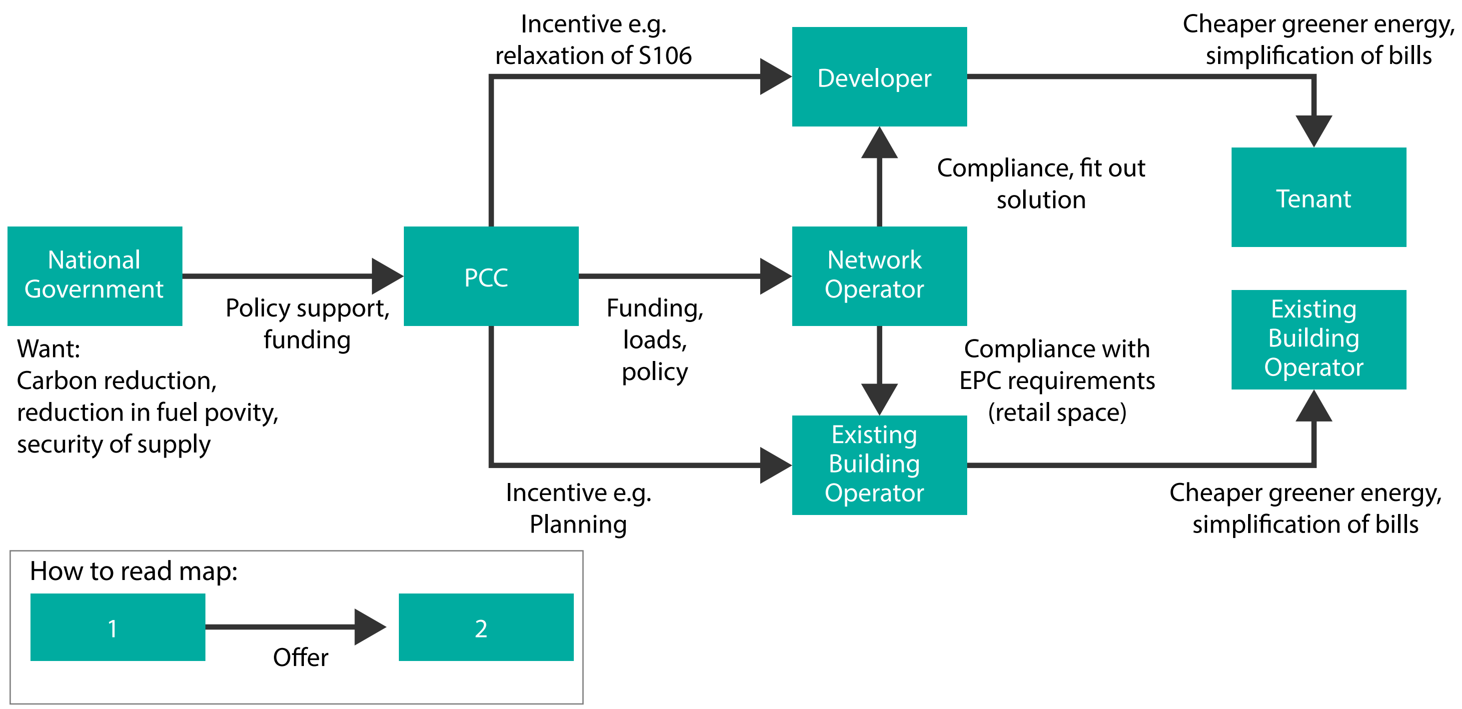


Figure 3.1: Stakeholder Map

4 CURRENT POLICY CONTEXT

4.1 NATIONAL

Clean growth strategy – the U.K. clean growth strategy published in October 2017 details the expectation that around 20% of properties will be services by a heat network by 2050.

SAP10 – Updates to the U.K. standard assessment procedure have rightly reduced the electricity carbon factor from 0.516 kgCO2/kWh to 0.233 kgCO2/kWh. This is good support for electrifying heat. The same update is also potentially punitive to heat networks by use of an inflated heat loss factor, although this is waived if a lower loss factor can be evidenced.

Building Regulations – the UK regulations are not prescriptive enough on key heating/ cooling measures such as temperatures and where specific systems are best suited. The industry relies on people adhering to best practice guidelines which is often not enough.

RHI – RHI currently offers favourable support to heat pump heating schemes, this is paid out annually, for 20 years, based upon heat provided to customers form the technology. This is often critical to the viability of a heat pump heating scheme due to the large spark gap in the U.K. This support is due to end in 2021 and through discussions with BEIS whatever is chosen to replace this will almost certainly change the context for heat pumps.

State Aid – State aid rules limit the amount of government grant investment that can be given to a project so as to not unfairly give competitive edge to any one entity. For a district heating project in Plymouth city centre this limit is 50% of the eligible costs (exemption Article 46). This raises issues for capex heavy infrastructure projects such as district energy as infrastructure was traditionally nationally funded and did not have to carry the costs that district energy now does.

Regulation – The Competition Markets Authority has ruled that Heat Networks should be regulated will come under CMA authority to deliver customer protection across the industry. This is under development and will come into force in the near future.

Conclusion – There are several levers in use throughout national policy to attempt to encourage electrification and district heating, however they appear at times to be in conflict with each other and are potentially leading to a situation in which direct electric heating is the go to solution for developers due to its compliance and low capex. This in itself is in conflict with the Clean Growth Strategy goals.

Actions – Given that the state aid issue cannot currently be overcome, it is essential that there be a replacement for RHI with supports electrification of heat to at least the same level as the existing support. Building regulations must become tighter, quickly, on things such as DHW temperature and maximum heating temperatures**.** The SAP could be more lenient toward heat networks to encourage exploration of a network over implementation of ad-hoc direct electric solutions, which are not efficient and do not represent good value on an annual cost basis to the consumer.

4.2 PLYMOUTH

This section reviews key Plymouth policies relating to district heating and suggests actions as to how additional policy could support the development of 4th and 5th generation solutions.

Plymouth Plan (Adopted) – Policy GR07.

1. Encouraging and enabling large scale uptake of retrofit insulation, and renewable /low carbon energy generation equipment and infrastructure to existing buildings, and promoting other energy demand reduction measures.
2. Supporting and enabling the installation of renewable and low carbon energy generation capacity, including encouraging community owned installations and identifying land for large scale renewable energy installations.
3. Promoting the creation of infrastructure to supply low carbon heat through the delivery and expansion of district energy networks.
4. Support the development of resilient, efficient local energy markets through the identification and promotion of local opportunities for SMART energy infrastructure that helps to balance local supply and demand.
5. Using planning powers to promote development that reflects.

Joint Local Plan (Draft out for consultation) – Policy DEV 34

Development proposals will be considered in relation to the 'energy hierarchy' set out below:

i. Reducing the energy load of the development.

ii. Maximising the energy efficiency of fabric.

iii. Delivering on-site low carbon or renewable energy systems.

iv. Delivering carbon reductions through off-site measures.

4. Developments should reduce the energy load of the development by good layout, orientation and design to maximise natural heating, cooling and lighting. For major developments, a solar master plan should show how solar gain has been optimised in the development, aiming to achieve a minimum daylight standard of 27 per cent Vertical Sky Component and 10 per cent Winter Probable Sunlight Hours.

5. All major development proposals should incorporate low carbon or renewable energy generation to achieve regulated carbon emissions levels of 20 per cent less than that required to comply with Building Regulations Part L.

6. Developments will be required to connect to existing district energy networks in the locality or to be designed to be capable of connection to a future planned network. Where appropriate, proportionate contributions will be sought to enable a network to be established or completed.

Conclusion – Plymouth policy is looking to enforce 'DH readiness' however there are limited mechanisms available at present to control standards within a building e.g. technologies used, operational strategies. This is leading some developers to produce compliant solutions which are only part DH connectable (e.g. electric space heating, centralised DHW) or completely omit connectabillty for things such as commercial units.

Actions – Through the planning process PCC can enforce minimum standards of building and connection to district heating schemes. To support this process PCC the establishment of 'priority zones' in policy both for connection to heat networks and for building quality would begin to generate areas of buildings which are ideal for connection to low temperature networks. The extent of an example low temperature building zone, in the city centre, can be seen in Section 2.4. This area has been identified through this study as having the correct characteristics for a 5DHC scheme to be developed. In addition to zoning, secondary system standards are invaluable to ensure building compatibility and PCC are in the process of developing secondary system guidance documents for standard issue to all developments.

5 CHALLENGES TO HEAT NETWORK DEPLOYMENT

The most critical challenge that a multi-site heat network faces during the life cycle of feasibility study to operation is timing. Timing of developer engagement, timing of the developments themselves, timing of securing funding, timing of business case sign off etc. All of these pieces must fall into place at the right time in order for the project to progress along the most optimal path. This cycle is represented in Figure 5.1. F. For the cycle to be broken naturally, the decision maker must be satisfied with each piece of the cycle, at the time of the decision . This will rarely happen.

A DHN scheme which struggles to break the cycle shown in Figure 5.1 might follow a path which resembles something like that which is shown in Figure 5.2.

Stopping the Cycle – is necessary to building a model which is easily repeatable.

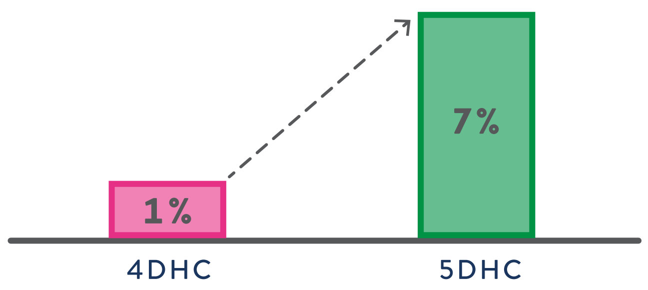
- Stopping the cycle at the opportunity stage is difficult. An opportunity needs to be proven to be able to secure funding and a business case.
- Stopping the cycle at the business case stage is risky. Rushing a business case draft and approval is not advisable as at this stage it is putting multiple parties at risk.
- Stopping the cycle at the customer is possible. An ESCo has the opportunity to take on a heat supply contract without a network in place. This has inherent risk however should the network not materialise, the ESCo is at least left with a revenue generating asset but at a building scale.

5DHC Example:

- Identify the cluster: To ensure that the optimal system is pursued the 5G characteristics of the cluster/ connection should be investigated.
- Enforce low temperatures: If they are identified then use a low temperature building zone policy to ensure/enforce connections have suitable systems.
- Identify the promoter: Identify a scheme promotor / heat supplier who is committed to delivering a system.
- Agree contracts with connections.
- Use secondary system guidance for
    - Customer systems to ensure performance.
    - This enables the timing issue to be overcome as secondary systems are compliant with a future network e.g. following schematic proposal includes an ASHP in advance of network (see Section 6).
    - Compliance with guidance and agreed contracts moves the responsibility for heat supply to the heat supplier.
- With contracts agreed a network can be constructed with confidence, from that point future developments are then sure of connection to the network.

5DHC Performance

In Plymouth the necessary characteristics for a 5DHC scheme are shown in the City Centre/ Millbay area (Section 2.3). In these areas, at least, the benefit of pursuing a 5DHC system over a 4DHC has been proven in this study. E.g. a 5DHC vs equivalent 4DHC system can be expected to perform up to 6% better in IRR terms over a 40 year project lifetime.



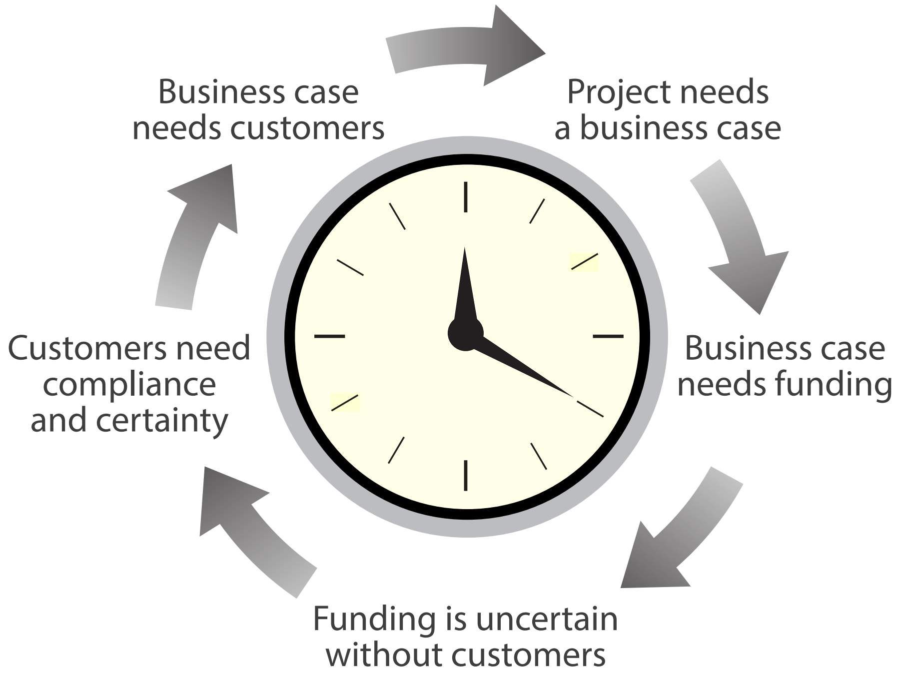


Figure 5.1: The Timing Cycle

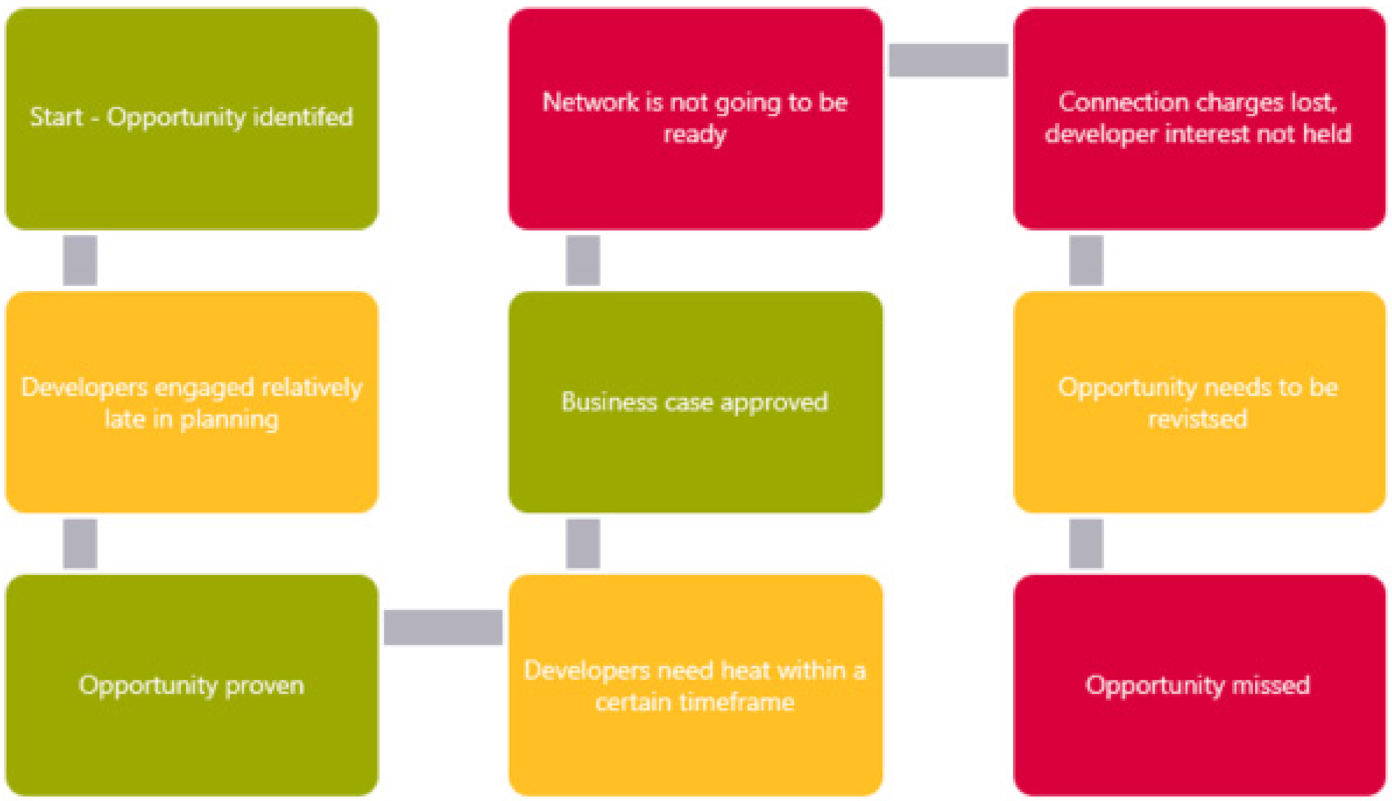


Figure 5.2: Example Missed Opportunity

6 TECHNICAL COMPLIANCE

To capture early development opportunities, an approach has been developed to allow for minimal abortive costs to be installed and future proof minimal disruption connectivity. 5DHC example:

1. Promoter installs heat pump technology with out-door air cooler – allows building to run in advance of network connection and commences a heat supply contract with the building owner.
2. Upon connection to the network, heat supply contract continues, however dry air coolers are removed from the roof for use elsewhere. Minimal disruption to existing installation and crucially risk during changeover is transferred to promotor protecting the owner/tenant.

Technical compliance is essential for a connection if it is to be connected to a network, particularly if it is be a future proofed connection which is to be connected at a later date. This even more essential for a 5DHC network than for any other typology as for a 5DHC system to realise its full potential, there must be centralised heating and cooling systems which are compatible with low temperature heating, and ideally high temperature cooling. Figure 6.2 shows a concept future proofed building, whilst Figure 6.1 shows a future proofing of a residential development which doesn't include cooling, Appendix A provides further options for Hotel and Commercial typologies. These options present the opportunity to re-use the heat pump element of this system and connect it directly into the 5DHC network. There is further potential to re-use the dry air cooler attached to this unit at another connection.

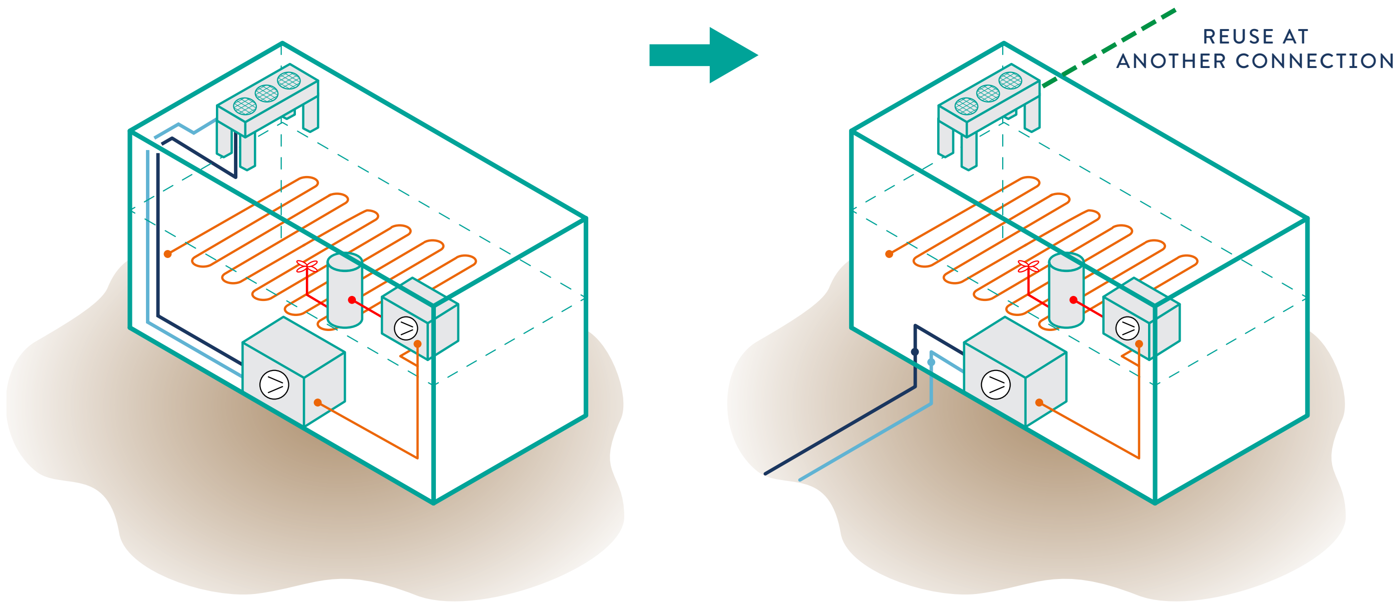


Figure 6.2: Future Proof Concept

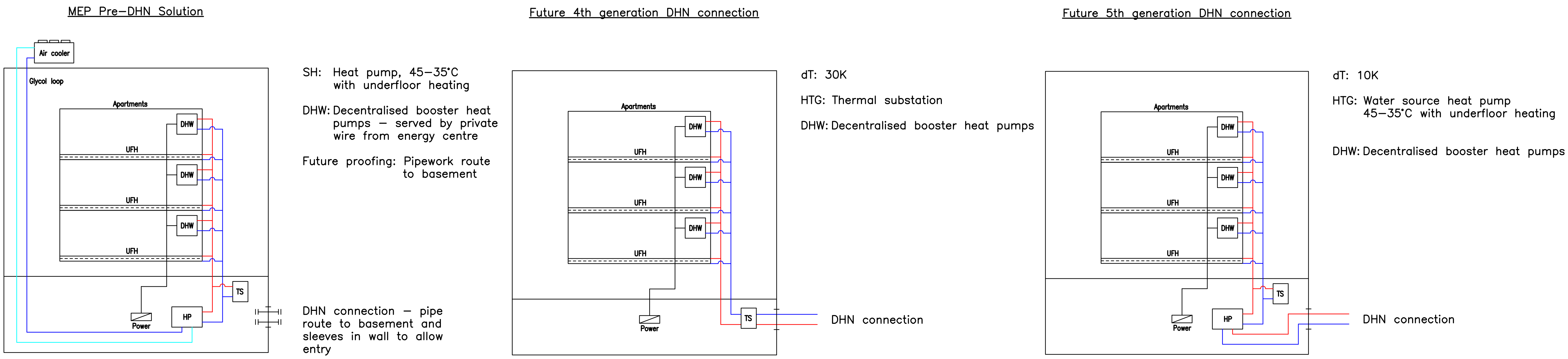


Figure 6.1: Residential Future Proofing and Connection

7 5DHC IMPLEMENTATION NEXT STEPS

Through the project the Civic Cluster has been found to be the most viable 5DHC cluster in Plymouth. It has connections at:

- Civic Centre
- British Land redevelopment
- Derrys
- Colin Campbell Court

There then may be scope to include the most suitable buildings of the Millbay area (as defined by the measures in Section 2.3):

- Ballard House – potential refit to include cooling and under PCC control.
- Moxy Hotel – engagements with developer suggest that the building will be 5DHC ready.
- Pavillions redevelopment – there is scope to be involved from a very early stage pre-planning.
- Bath Street West – there is scope to be involved from a very early stage pre-planning.
- Millbay Plot C3 – potentially too late to capture this load however there is expected to be significant cooling load so effort should be made.

The extent of this network is shown in the adjacent image Figure 7.1, building upon all of the actions and roadmaps proposed in this report, the key steps to implementation of the scheme are shown in Figure 7.2.

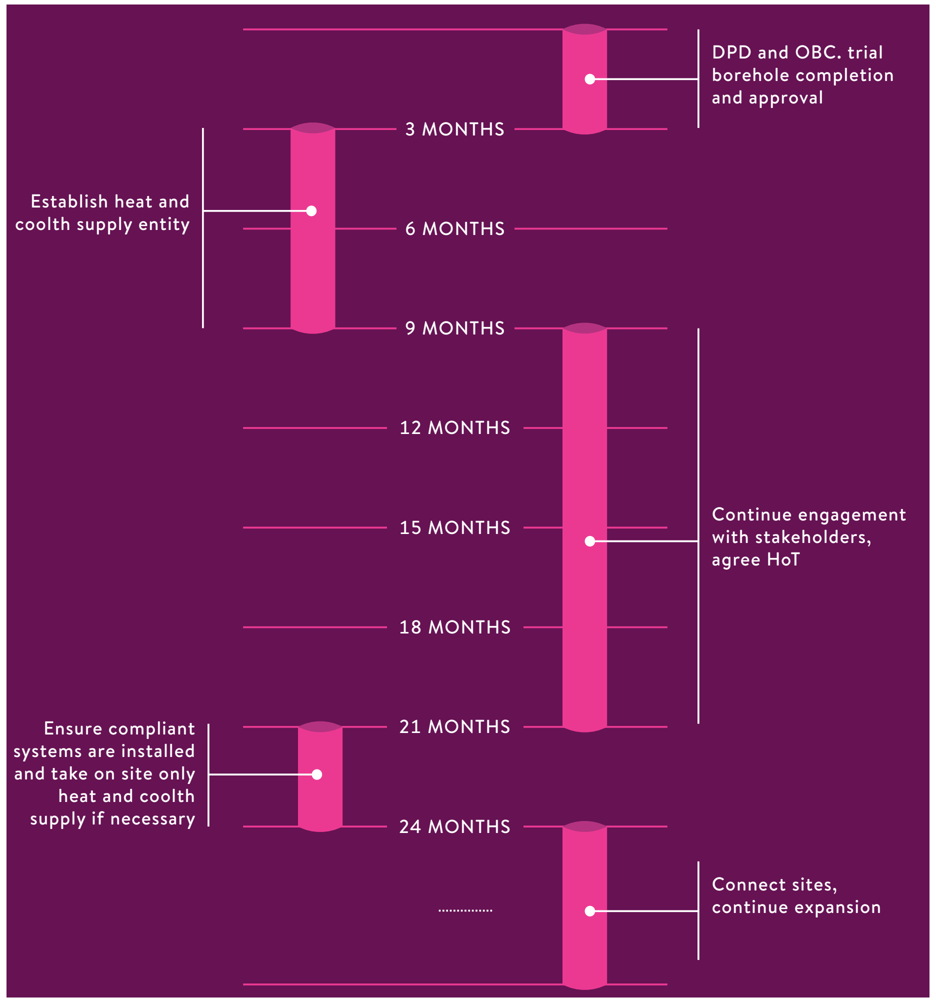


Figure 7.2: Civic Cluster Roadmap

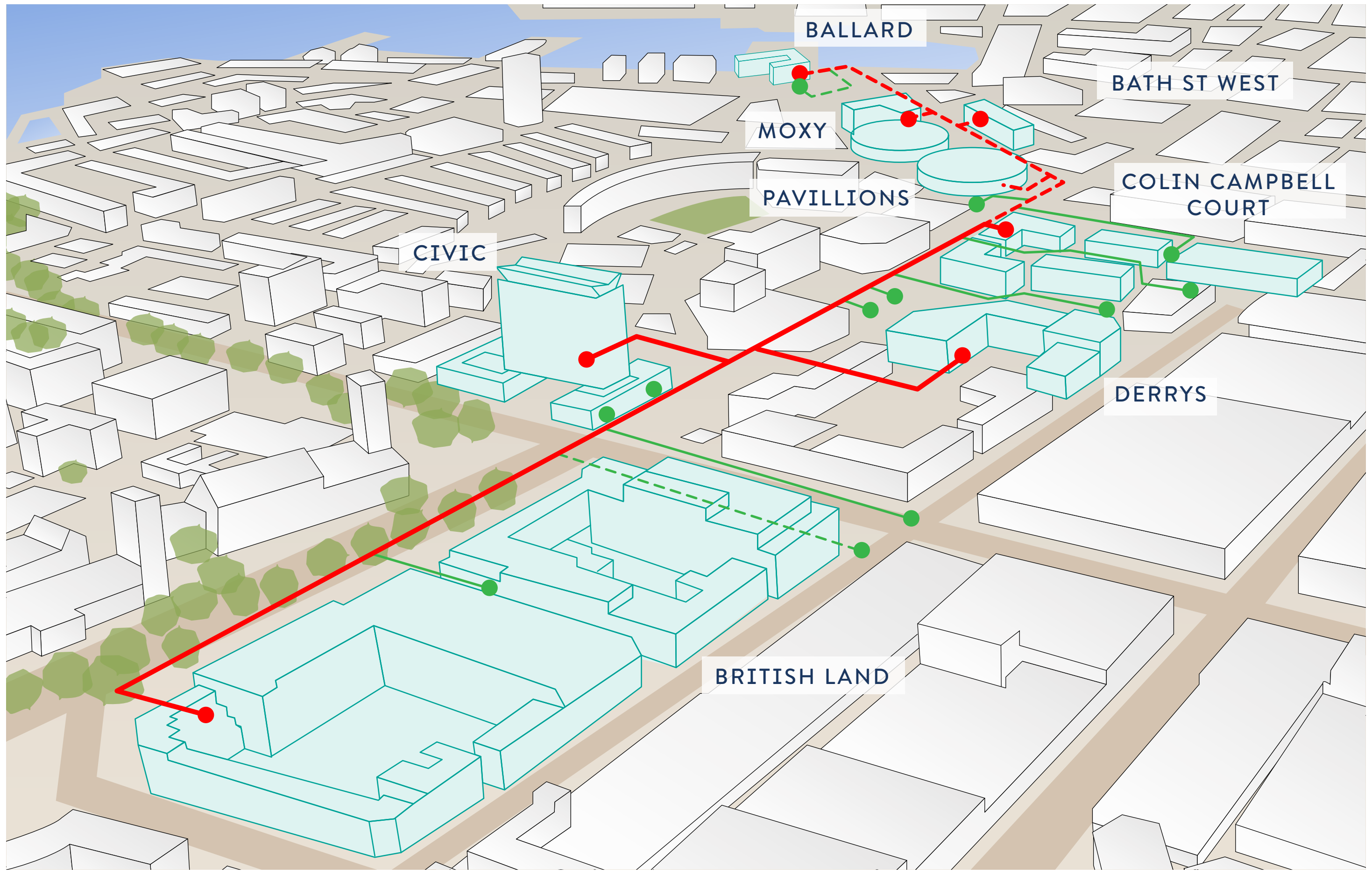


Figure 7.1: Civic Cluster Concept Graphic

8 THE ROADMAP

The roadmap has been put together to cover a five year period, split into short, medium, and long term. Actions are listed for stakeholders. The goal of the roadmap is to create an environment in Plymouth which encourages the propagation of 4th and 5th generation district heating and cooling systems in general. A more detailed matrix of text is given in Appendix A which expands slightly on the key headings given in the graphic. (graphic is not final version). The roadmap is then distilled into 6 key steps on the following page.

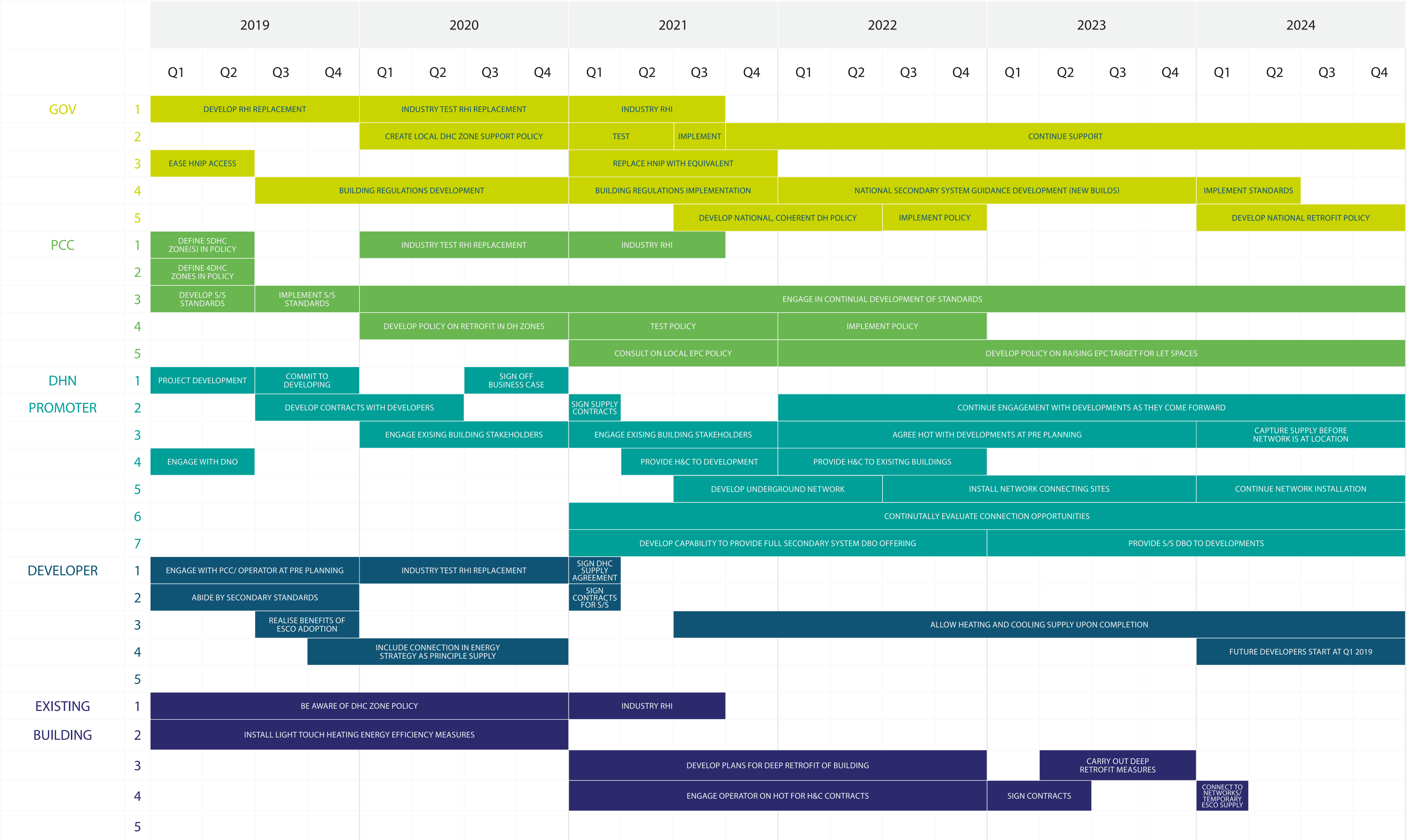


Figure 8.1: DHC Roadmap

THE ROADMAP

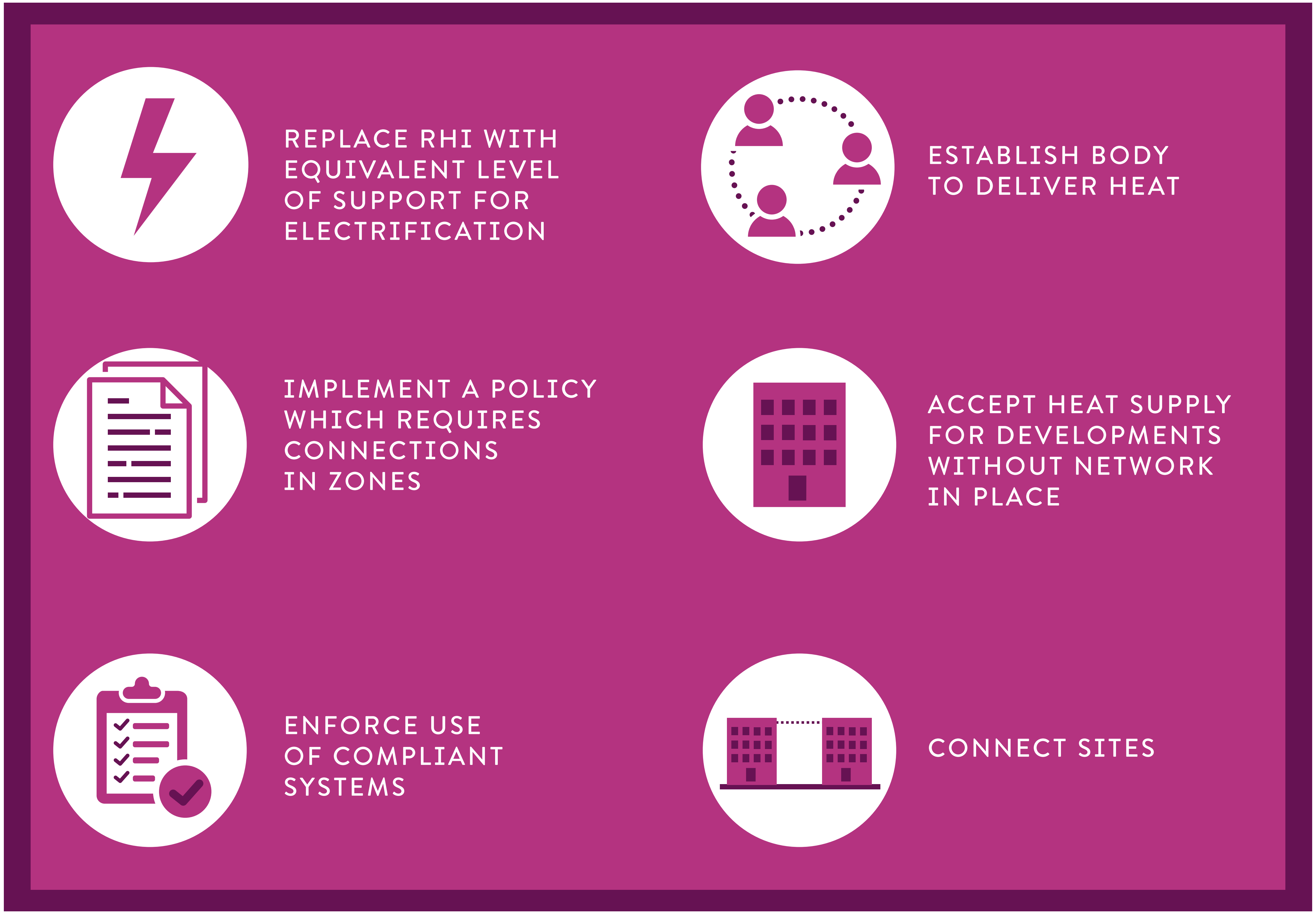
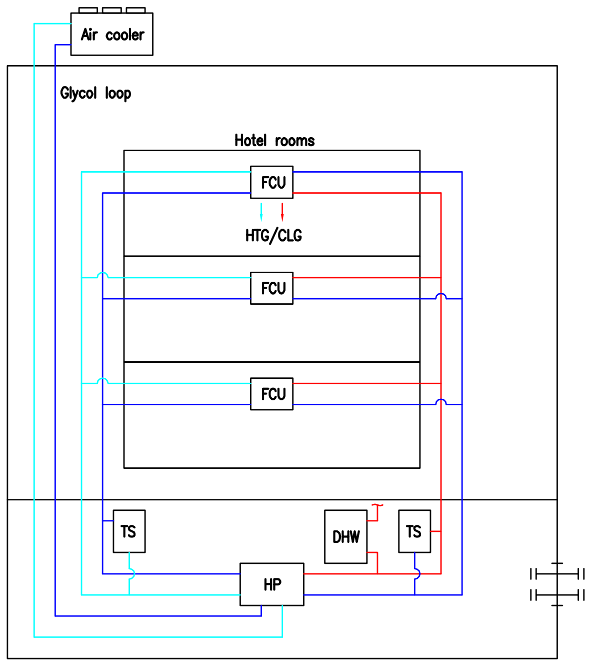


Figure 8.2: Distilled Roadmap

APPENDIX A CONNECTION SCHEMATICS

Plymouth Heatnet Roadmap – Hotel template schematics

MEP Pre–DHN Solution



HTG: Heat pump 60°C – 30°C

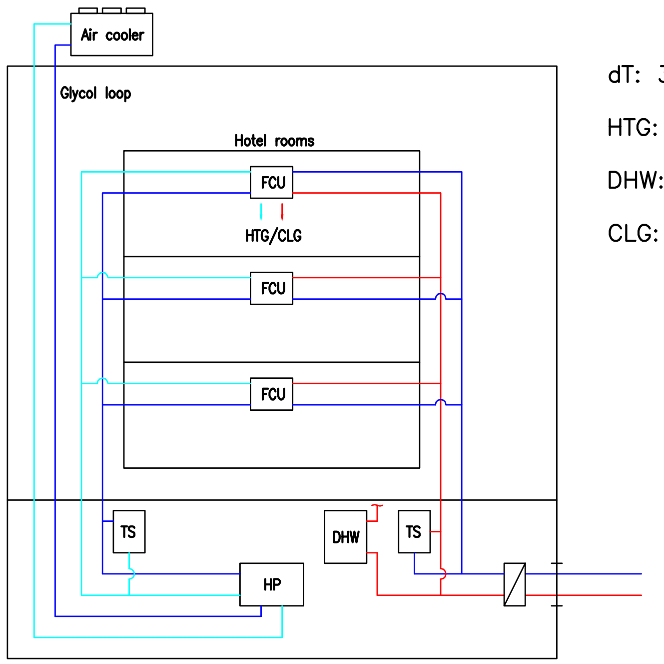
DHW: Centralised DHW
A) HP pre–heat & electric top–up
B) Direct gas fired

CLG: Heat pump 17/12°C

Future proofing: Pipework route to basement

DHN connection – pipe route to basement and sleeves in wall to allow entry

Future 4th generation DHN connection



DHN connection

dT: 30K

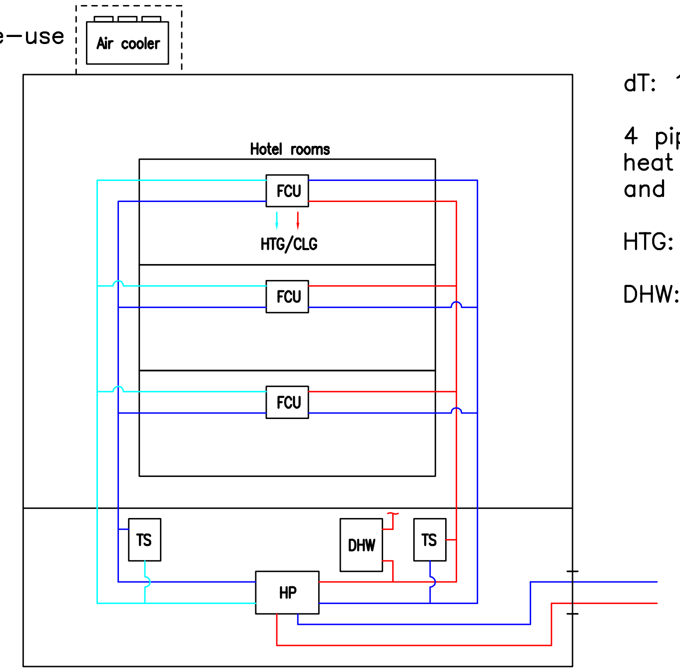
HTG: Thermal substation

DHW: Centralised DHW

CLG: From existing heat pump

Future 5th generation DHN connection

Remove and re–use



DHN connection

dT: 10K

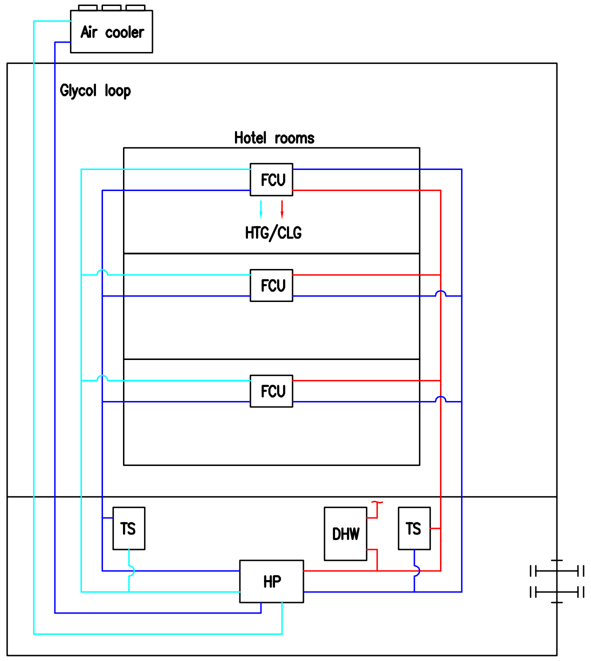
4 pipe water source heat pump for both HTG and CLG

HTG: 60°C if required

DHW: Centralised DHW via booster HP

Plymouth Heatnet Roadmap – Hotel template schematics

MEP Pre–DHN Solution



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A) HP pre–heat & electric top–up
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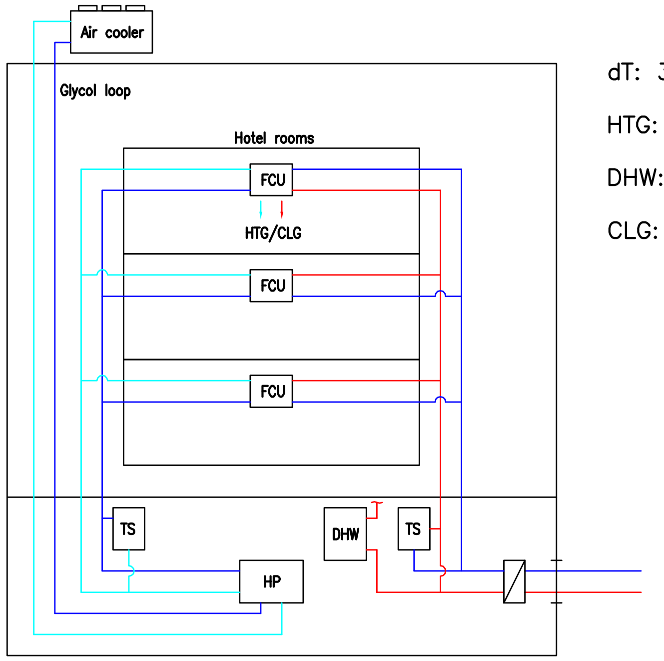
Future 4th generation DHN connection



DHN connection

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Future 5th generation DHN connection

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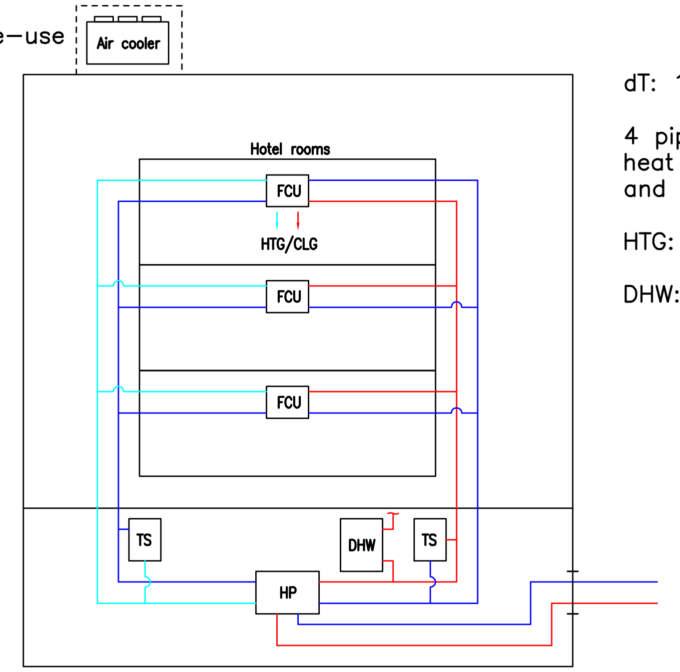

DHN connection

dT: 10K

4 pipe water source heat pump for both HTG and CLG

HTG: 60°C if required

DHW: Centralised DHW via booster HP

APPENDIX B ROADMAP DETAIL

	Short Term		Medium Term			Long Term
	2019	2020	2021	2022	2023	2024
Government	• Develop replacement for RHI scheme providing the same or better benefit to high efficiency electrical heating systems • Develop framework for funding for both operational viability and capital cost in tandem • Create policy supporting local Authority DHC zones • Support the access to HNIP financial support • Support the development of more prescriptive building regulations		• Implement RHI replacement • Continue to actively support Local Authorities in the establishment of zones • Replace HNIP scheme with continued but re-vised capital financial support • Implement more prescriptive building regulations to improve system operational temperatures. • Develop national strategy for DH rollout which is coherent with all policy and goes beyond providing funding i.e. stipulates connections, includes national secondary system guidance			• Implement national policy on secondary system standard for all new buildings • Develop national policy on retrofit of existing buildings to make existing buildings suitable for low temperature heating
Council	• Decide upon 5DHC low temperature zones in which all building fitting the necessary characteristics must connect • Establish secondary system standards for developers (all buildings within 5DHC zones must comply) - the templates and documents to back up • Create policy enforcing 5DHC secondary standards • Create policy enforcing secondary standards 4DHC and below in other opportunity areas		• Continue to enforce policies • Refine secondary standards • Develop policy supporting retrofit and heating energy efficiency measures in existing buildings (within zones)			• Continue to enforce policies
Operator/ Promoter	• Continue project development on proposed schemes • Commit to developing a scheme in opportunity area • Engage with developers to develop contracts for heat (and cooling) supply • Engage with developers around alignment of design and installation of secondary systems • Engage with existing building stakeholders to create appetite for connection • Sign off of business case by relevant parties • Develop the secondary system standard for the council policy to enforce		• Sign contracts • Potential to provide heat and cooling supply before network is installed • Install network covering sites which are ready for connection • Begin to engage with developers around taking over design and installation of secondary systems i.e. providing an all in energy package • Continually evaluate other opportunity areas for new developments			• Continue to install network to cover connections that are still coming forward • Engage with any more developments in the zone, ideally at pre planning stage • Agree Heads of Terms with any future connection as early as possible • Agree with future connections the full DBO of secondary systems • Continue to take on heat supply responsibilities of connections before network reaches them
Developers (either refurbishment or new build)	• Engage with PCC and operator early in development (pre-planning) • Make every effort to abide by secondary standard before written into policy • Realise benefits of receiving combined DHC from single operator • Include connection in energy strategy		• Sign contracts for DHC provision • Sign contracts for adoption of secondary system and plantroom by operator • Allow heat and coolth provision by operator even before buried network -installation			• Continue to take energy from network until contract ends as minimum • Any future developers return to 'short term' steps and allow the operator the DBO of secondary systems
Existing buildings in zone	• Be aware of policy regarding DH zones in Plymouth • Install light touch heating efficiency retrofit measures		• Develop plans for deep retrofit of building using PCC or network operator secondary system standards • Engage with operator to agree Heads of Terms for heating and cooling contract			• Sign contracts • Carry out deep retrofit measures or allow network operator to carry out measures • Connect to network or allow temporary energy provision by operator in the case that the network has not reached site yet

BUROHAPPOLD ENGINEERING

040974 PLYMOUTH HEATNET

STAGE 5 - PLYMOUTH ROADMAP

REVISION 03

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