District Heating in Wallacetown

Currently, the conventional gas boiler system is used for space and water heating in Wallacetown with a profile shown in Fig. 1. As expected, it is low in summer and high in winter. The total yearly demand is approximately 31GWh [1].

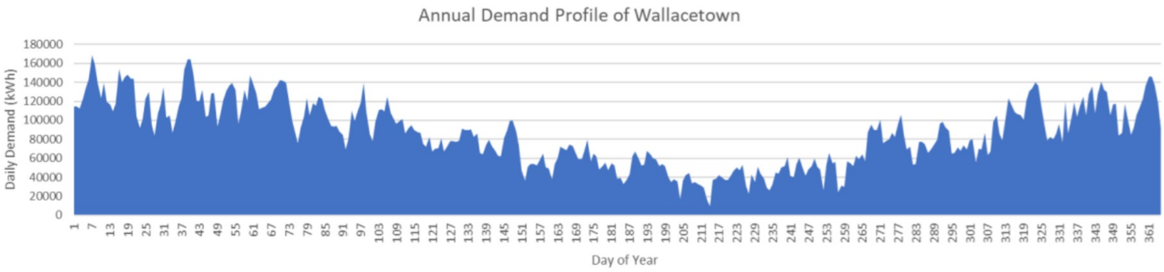

Figure 1: Demand profile of Wallacetown. Source: Scottish heatmap (2024) & Weather Data (2017-21)

Therefore, heating in Wallacetown contributes to the emissions of greenhouse gases (GHGs) into the atmosphere. This is not environmentally sustainable. There is need to decarbonise heating to lower the GHG emissions from district heating which constitute about 20% of all GHG emissions in the UK [2].

The Scottish Government through local authorities has put in place measures to achieve net zero by 2045. Some of the solutions as elaborated in the local heat and energy efficiency strategy (LHEES) report by South Ayrshire include: fabric improvements – which potentially lower the energy needed to heat the homes – and the incorporation of heat pumps in district heating networks [3]. The integration of all these for our Wallacetown scope to see how they would reduce fuel poverty and emissions.

District heating is of huge significance in the UK due to its cold climate. However, as recently as 2018, due to global warming, temperatures of 40°C were experienced in the UK for the first time ever and projections show that these hot temperatures will be more frequent than not [4]. In fact, according to a report by the House of Commons (2018), there will be 7000 annual deaths due to overheating of homes by 2050. Therefore, is it about time we started to consider cooling as being integral in district heating networks going forward. The good thing is the recent generations of district heating offer a way.

	1GDHN	2GDHN	3GDHN	4GDHN	5GDHN
Period of time	1880–1930	1930–1980	1970-now	Currently used	Currently used
Heat carrier fluid	Steam	Pressurised hot water	Pressurised hot water	Warm water	Low-temperature water/brine
distribution temperature	<200 °C	>100 °C	<100 °C	<50–70 °C	<30 °C
Pipes	On site insulated steel pipes	On site insulated steel pipes	Pre-insulated steel pipes	Pre-insulated steel pipes	Uninsulated steel/polymer pipes
circulations systems	Steam pressure	Centralised pumps	Centralised pumps	Centralised pumps	Decentralised pumping systems
Substation	Condensers	Tube-and-shell heat exchangers	Plate heat exchangers	Plate heat exchangers	Heat pumps
Most used source of heat	Coal, waste	Coal, waste, oil	Coal, waste, oil, gas, biomass, solar thermal energy	Waste heat, deep geothermal energy, biomass, solar thermal energy, centralised heat pumps	Low-temperature waste heat, shallow geothermal energy, savage water, river, lake and sea water
Thermal energy storages	Steam storages	Heat storages	Heat storages	Seasonal heat storages	Low-temperature seasonal thermal energy storages

Figure 2: District heat network progression [5].

District heating dates back to the late 1800s when the first generation was implemented. The heat transfer fluid was steam at temperatures around 200°C (Fig. 2). So, as you would imagine, it was a very inefficient system. But with advancements in knowledge and technology, UK is now popularised with 3rd generation networks pushing for 4th and 5th generations. These recent generations have the capability to utilise low temperature renewable sources and then boost the temperature using heat pumps to match the needs of the consumers. They therefore facilitate energy efficiency, less CO_2 emissions and hence a greener economy [6].

4th Generation District Heating Network (4GDHN) Characteristics

They have a centralised energy centre which houses a centralised heat pump (HP) and is responsible for suppling the heat to the buildings. The outgoing temperature has to match the building with the greatest demand within the network scope.

The supply temperatures are no more than 70°C. Because of the high supply temperatures and one central HP, the pipes need to be properly insulated to minimise losses. Cooling however needs to be a whole new setup altogether which comes with higher costs.

5th Generation District Heating Network (5GDHN) Characteristics

Unlike in 4th generation, cooling and heating are achieved within the same setup which is a plus. This is possible because of the bidirectionality of the system and presence of reversible heat pumps at each end user. This means that consumers can get heat or give heat to the network and are no longer consumers but prosumers. For instance, a data centre may require cooling most of the times and so would eject the heat to the network. This heat would be used by a home in need of heating simultaneously and hence balancing out the demand.

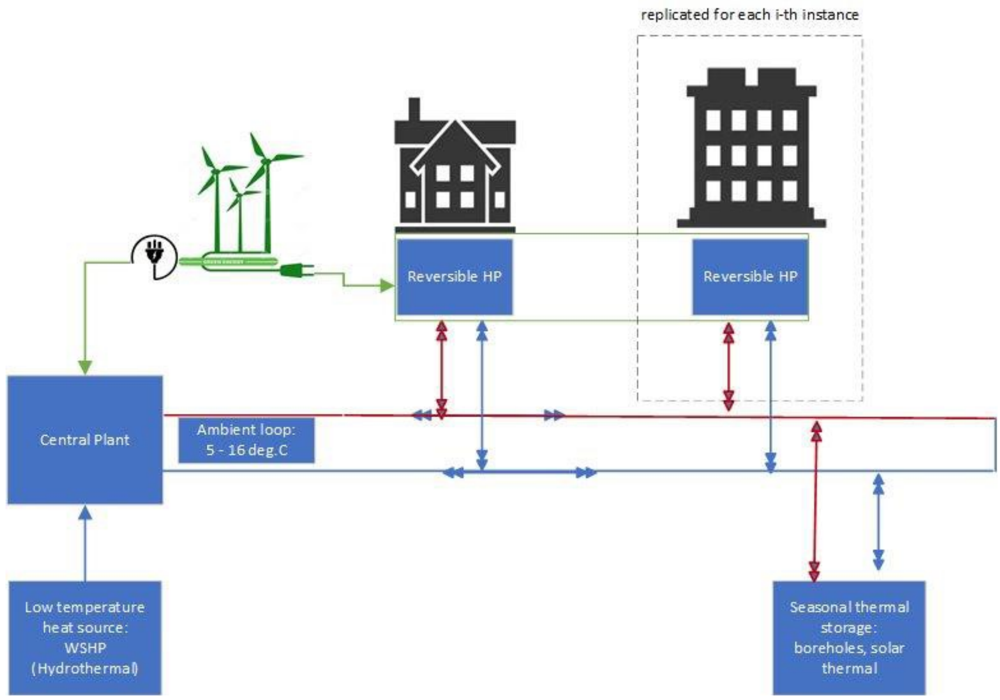

Figure 3: Schematic diagram of 5GDHN for Wallacetown

How the network operates in the case of the home (heating mode): heat transfer fluid goes to the evaporator of the HP where heat is transferred to the refrigerant, and then the lower temperature fluid goes to the lower temperature line (blue line Fig. 3). The refrigerant which we assume is ammonia, is then compressed to the condenser where heat is transferred to the hydraulic system in the home at 60°C. In the case of the data centre (cooling mode): heat transfer fluid goes now to the condenser where it takes heat from the refrigerant and goes back to the high temperature line (red line Fig. 3). The refrigerant then expands through the expansion valve and goes to the evaporator where it absorbs heat from the hydraulic system at end user, there by cooling the data centre.

The other characteristic of 5^{th} generation is that the main loop runs on ambient temperatures less than 30°C. The actual temperature ranges for the network vary according to location. In our case we have a range of 5°C (minimum return) – 16°C (maximum supply) throughout the year. This range was decided upon after analysing the average daily soil temperatures in Wallacetown. Due to this ambient loop, the network pipes are plastic and need little to no insulation since the losses are minimal.

Both 4GDHN and 5GDHN need a thermal store to balance peak loads in times of low supply. They both also need large pipe works and that adds to the complexity of the system. The decentralised HPs in 5GDHN potentially mean higher costs and higher electrical load than 4GDHN but since cooling and heating can be achieved within the same system plus the other pros mentioned above, we decided on analysing the 5GDHN for our Wallacetown scope.

Proposed Pipeline

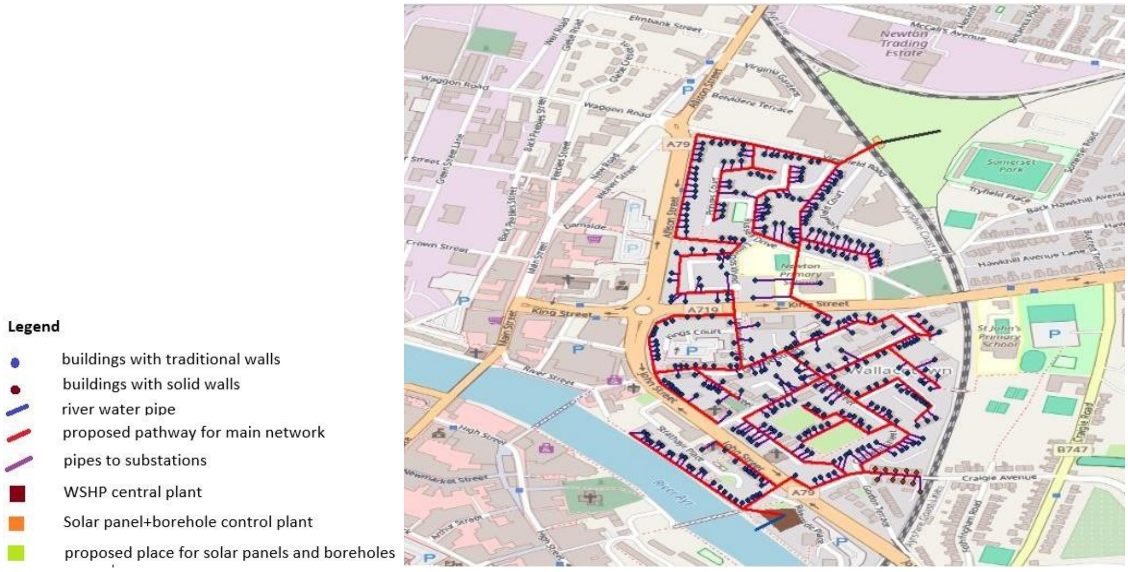

Figure 4: 5GDHN layout around Wallacetown scope

Fig. 4 shows the proposed piping across our area of interest in Wallacetown. The topology was analysed using the GIS software and the pipe layout was aligned with existing road networks including footpaths.

The system stretches up to 10km. However, when you look at the bigger picture where we are saving significant amounts of GHG emissions by implementing this network, it might be worth investing in.

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