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TEMPLATE PRELIMINARY FEASIBILITY ASSESSMENT FOR ROLLING OUT 5GDHC TECHNOLOGY IN 7 FOLLOWER REGIONS

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1. Introduction

Activities in the Long-term work package aim to sustain and roll out D2Grids outputs to a wide variety of target groups, including policymakers, financial investors, professionals, SMEs and other companies in the DHC industry, as well as to new territories ("follower regions"). Transnational roll-out beyond pilot sites will be facilitated by assessing replication potential of 5GDHC in these follower regions and preparing specific local action plans. This document is a template for regional vision development and preliminary feasibility assessment for rolling out 5GDHC technology in the 7 follower regions as defined in the application form: Parkstad Limburg (NL); North-East France; Luxembourg; Flanders (BE); Ruhr-area (DE); Scotland; East Midlands (UK). It aims to define ambitions for low-carbon heating & cooling and to assess the feasibility and potential of 5GDHC's roll-out.

The D2Grids project, has ambitious goals for the future. Five years after the project ends, 2 million m^2 of floor area in North-West Europe should be served by 5GDHC, of which 1.5 million m^2 by scaling up the D2Grids pilots and 0.5 million m^2 by rolling out into the follower regions. The overall capacity of these 5GDHC systems should be 180,000 MWh/a, including 100,000 MWh/a additional renewable energy source capacity. 10 years after the end of D2Grids, the total floor area should be 5 million m^2 and the overall capacity 450,000 MWh/a. This document presents a template for regional vision development, which describes ambitions of each of the follower regions on how the region can contribute towards this goal of 0.5 million m^2 of floor area after 5 years. To inform this regional vision, a preliminary feasibility assessment is conducted first (see D.LT.1.1).

The goal of the feasibility assessment is to find the potential of deploying 5GDHC in the follower regions within 5 years after the project ends, as well as finding possible longer-term opportunities. This is done by mapping strengths, weaknesses, barriers and opportunities of 5GDHC for each of the follower regions. This document explains the method for conducting a preliminary feasibility assessment for 5GDHC in a region. It includes some generic sources and methods of calculation, but these need to be supplemented with region-specific sources to come to a reliable regional analysis. The assessment consists of 5 categories: renewable sources; existing infrastructure and planned developments; thermal demand & supply profiles; legal & policy framework; financing options.

2. Characterising the region

In this report, the entire follower region of Scotland is being analysed. Very little implemented 5GDHC in Scotland to date, and as such this report will focus om how Scotland will look to integrate 5GDHC as a technology option for low carbon heat, through both legislative and practical elements.

Political environment

For Scotland, the Climate Change (Scotland) Act 2009 set a target renewable heat target for Scotland. Scotland's Energy Strategy, published in December 2017, set out the Scottish Government's vision for a flourishing, competitive energy sector, delivering secure, affordable, clean energy for Scotland's households, communities and businesses. Delivery of the Strategy is monitored via an Annual Energy Statement alongside the Annual Compendium of Scottish Energy Statistics (ACSES[1]). The Scottish government plan to publish a first review to the Energy strategy in Autumn 2022. The plan is to further refine the approach to heat de-carbonisation, ensuring a 'coherent whole-system view and further embedding our evolving policies within our wider approach to delivering on a just transition'.

Energy usage and climate ambitions

Scotland still relies heavily on gas for domestic heating purposes, with 80% of homes still utilising gas boilers. In 2020 Oil and Gas made up 78.4% of all Scottish energy consumption and 91% of heat demand.

The UK has set a Net-Zero carbon emissions target for 2050 in the UK (2045 in Scotland). In order to meet these targets meet Net Zero targets the UK need to convert 20,000 homes a week to low carbon heating.

Climate Change (Scotland) Act 2009 set a target renewable heat target for Scotland to reach equivalent of 11% of fuels (other than electricity) consumed for heat[2].

From a 2005-2007 baseline, Scottish Energy consumption was down by 13.1% in 2018. In 2019 24.6 % of Scottish households were classified as being in Fuel poverty, 12.4 % of which were classed as in extreme fuel poverty.

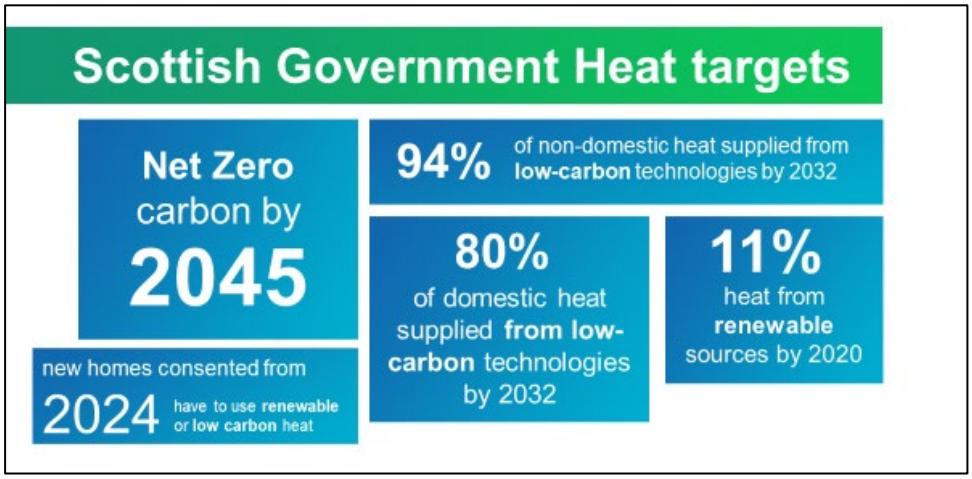


Figure 1. Scottish Government heat targets

[1] Annual Compendium of Scottish Energy Statistics 2020 (Scottish Government) ACSES+2020+-+December.pdf (www.gov.scot)
[2] The 2020 11% renewable heat target was set by the 2009 Renewable Heat Action Plan which was replaced by the 2015 Heat Policy Statement and the 2020 Routemap for Renewable Energy in Scotland. The 2021 Heat in Buildings Strategy replaces these earlier plans for the promotion of heat from renewable sources, and sets a provisional renewable heat target that will be reviewed in the 2022 Energy Strategy and Just Transition Plan.

Overall the annual compendium report 2020 found that Scottish energy consumption was down by 31.1% compared to 2018 (see fig 2 below)

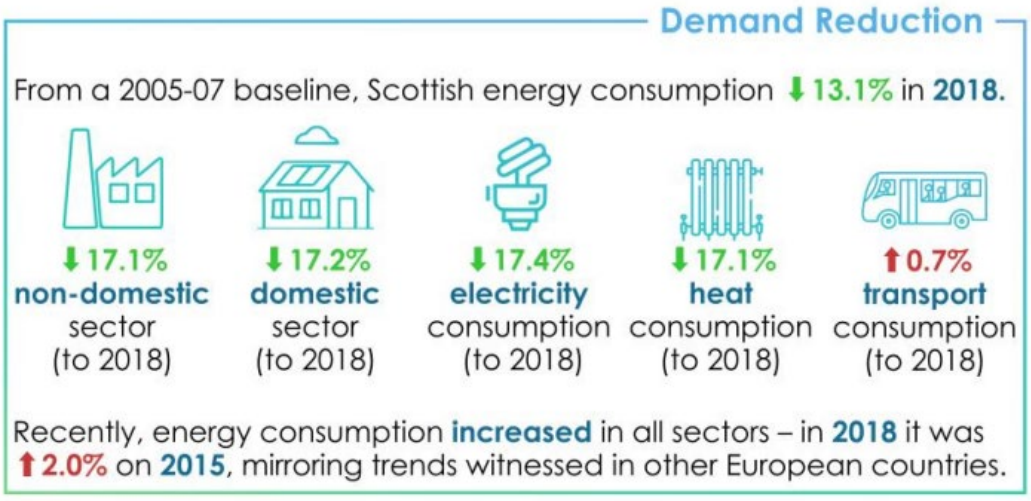


Figure 2. Energy demand reduction in Scotland [3]

There are only 2 implemented 5GDHC schemes in Scotland to date. Work so far has been to identify the opportunity for District heating generally (3GDH and 4GDH) and mapping to date has been on these rather than 5GDHC. In 2017 the Scottish Government introduced the concept of Local Heat and Energy Efficiency Strategy (LHEES), which set-out the long term plan for decarbonising heat in buildings across local authority areas. A pilot scheme has just been completed, with an evaluation report published in January 2022[4], the output of which will be taken forward for national rollout. The pilot scheme has resulted in detailed mapping of pilot regions and identification of heat network opportunities. Additionally, the pilot gives an understanding of energy efficiency and decarbonisation requirements for heating in pilot areas, and addresses the requirements for Funding, Skills development, external support requirements and partnership working in the delivery of low carbon heat in Scotland.

Energy-efficiency of buildings

The 2019 Scottish House Condition Survey found that Scotland's 2.5 million homes account for around 13% of the nation's total greenhouse gas emissions. Currently 55% of properties are still rated beneath the Energy performance Certificate (EPC rating) of C). To meet the 2045 net zero target, Scotland has committed to look at homes and buildings.

[3] Annual Compendium of Scottish Energy Statistics 2020
ww.gov.scot/binaries/content/documents/govscot/publications/statistics/2019/05/annual-compendium-of-scottish-energy-statistics/documents/annual-compendium-december-2020/annual-compendium-december-2020/govscot%3Adocument/ACSES%2B2020%2B-%2BDecember.pdf
[4] Local Heat and Energy Efficiency Strategy (LHEES) Pilot programme: Synthesis evaluation (Jan 2022) 5. Next steps - Local Heat and Energy Efficiency Strategy (LHEES) pilot programme: synthesis evaluation - gov.scot (www.gov.scot)

3. Analysis

In the next section gives a more detailed analysis of Scottish energy systems. Specifically, we look at the current heating context in Scotland, the current position of district heating, and at the type of energy sources and storage currently available in Scotland.

3.1. Heating regime

3.1.1. Current dominant heating technology or carrier in the region

Currently dominant heating technology in the region

Currently in the UK, more than 80% of UK homes (24 million) still use natural gas. Heating is the UK's largest source of greenhouse gas emissions, and he widespread de-carbonisation of heat is challenging.

According to the 2019 Scottish House Condition Survey[5] Scotland's 2.5 million homes account for around **13%** of the nation's total greenhouse gas emissions. To meet the 2045 net zero target Scotland has committed to turn attention to the efficiency of homes and buildings. In 2019, 81% of Scottish homes used mains gas as their heating fuel. 2% of non-domestic buildings are on the lowest energy performance (EPC) band G, and around 50% of these properties are using Heating, ventilation, and **air conditioning (**HVAC)

The same survey revealed that just 278,000 Scottish households (around 11%) are heated using a renewable or low carbon system, and while the energy efficiency of Scotland's homes is improving, around 55% of properties are still rated below the recommended minimum Energy Performance Certificate (EPC) rating of 'C'

Renewable heat

The Scottish 'Annual compendium of Scottish energy Statistics reported that Scotland generated 5,205 GWh of renewable heat in 2019, a rise of 4,8% since 2019. This is equivalent of supplying 385,000 Scottish homes with gas for the year, and represents 6.5% all non- electrical heat demand.

District heating only takes up a very small place in Scotland to date. Progress towards the renewable heat target In 2020, for useful renewable heat produced in Scotland was equivalent to 6.4% of fuels (other than electricity) consumed for heat. This realized an increase from 6.2% in 2019. The majority of this heat came from biomass, contributing 70% of useful renewable heat. The next largest contribution was biomethane at 14%. Growth in renewable heat from 2019 to 2020 was limited by a 52GWh output reduction from large biomass sites due to changes in operation at a small number of sites. Whilst biomass and biomethane dominate renewable heat generation, there has been a steady growth in heat produced by heat pumps. Heat pumps saw the largest increase in number of installations and output with an additional 3,020 installations.

In 2020 the Energy Saving Trust published their renewable heat in Scotland report[6]. In 2020, 6.4% of non-electrical heat demand was met by renewable technologies which places Scotland a little over half-way towards the target of 11% by 2020. This represents an increase of 4.5 percentage points (up from 1.9%) since 2010 and an increase of 0.2 percentage points from 2019.

An estimated 5,008GWh of useful heat output was generated by renewable technologies in 2020, an increase of 2% (83GWh) from 4,925GWh in 2019 and more than triple the output generated in 2010 (1,667GWh). The increase in output between 2019 and 2020 was primarily from heat pumps (83GWh), medium sized biomass installations (32GWh) and biogas (19GWh).

[5] Scottish House condition survey 2019 Acknowledgements - Scottish house condition survey: 2019 key findings - gov.scot (www.gov.scot)
[6] https://energysavingtrust.org.uk/report/renewable-heat-in-scotland-2020/#:~:text=Summary%20of%20key%20findings,target%20of%2011%25%20by%202020.

Overall growth has been limited by a 52GWh output reduction from large biomass sites due to changes in operation at a small number of these sites.

2.14GW of renewable heat capacity was operational in Scotland by the end of 2020, up from 2.06GW in 2019 and from 0.44GW in 2010.

District heating in the current heating regime

Heat Networks currently meet circa 2% of heat demand in the UK (Including Scotland), with natural gas as the primary fuel source. In Scotland, a national comprehensive assessment by BEIS1 found that economically viable heat networks could supply 28% of total heat demand. 5GDHC could make up a subsection of this heat supply, although the immaturity of the technology makes it difficult to make a specific assessment of the exact scale for its application.

3.2. Position of district heating

3.2.1. Regulation of district heating providers and 5GDHC

As detailed in section 3 above the Scottish policy environment is generally very supportive of heat networks. Policy has enabled targeted financial support towards low carbon heat networks, however the Scottish regulatory landscape for district heating is very much still under development. New district heat networks will need to below carbon in order to attract government funding, however it is important to clarify that at present both legislative and funding positions relate to district heating generally and are not specifically targeted to support 5GDHC.

Regulation of heating networks in Scotland

The devolution of heat policy and heat network regulation across the UK is complex. In Scotland heat policy is devolved, but consumer protection is reserved to the UK Parliament. Unlike gas and electricity, heat networks do not currently have an official regulator in Great Britain. This means that while the supply of gas to a heat network is regulated, the supply of heat from the network to homes is not.

Regulation of heating networks in Scotland falls under several complimentary themes

The **HEAT NETWORKS (SCOTLAND ACT) 2021** sets out the first steps towards regulating heat networks in Scotland. It is intended to enable increased deployment of heat networks across the country. The definition of heat networks is very wide but would include 5GDHC in addition to 3G and 4G technologies. The legislation focusses on the Renewable sources of production and use of waste heat are relevant considerations for licensing and regulation of networks, but as yet, the legislation should be viewed as 'enabling legislation', with further detail to follow in Secondary legislation, which may not be fully rolled out until 2024.

Heat Network delivery plan

The Heat network Delivery plan was Issued March 2021 as a requirement of the Heat Networks act. It sets out a strategic level plan focused on the following;

- Sets out a programme for rolling out regulation
- Includes Heat network targets of targets for 2027 and 2030 (6twh)
- Describes the approach to buildings and developments to facilitate connections
- Sets out wider policy such as skills and fuel poverty
- Gives detail on Capital programme and funding

There is no specific provision within the plan for 5GDHC, and there are limited references to renewable heat networks. The plan does however confirm 90% non- domestic rates relief for heat networks using renewable heat generation until March 2024, but does not confirm any obvious substitute for the current Renewable heat incentive (RHI)

Policy environment is generally supportive but perhaps a lack of targeted support.

3.2.1. Ownership and operation of district heating systems

The devolution of heat policy and heat network regulation across the UK is complex. In Scotland heat policy is devolved, but consumer protection is reserved to the UK Parliament. In February 2022 The house of Commons published a research briefing on Heat networks and energy pricing [7]

Heat networks currently do not have an official regulator in Great Britain. The Office for Gas and Electricity Markets (Ofgem) regulates the supply of electricity and gas, but heat networks are not – at present - within its remit. This means that while the supply of gas to a heat network is regulated, the supply of heat from the heat network to homes is not. The Government has set out proposals to regulate heat networks, including appointing Ofgem as the regulator. It has said it will introduce legislation for this before the next general election.

3.2.1. Regulation of price setting

The Heat Network (Metering and Billing) Regulations 2014 require that where cost effective and technically feasible, heat network suppliers must provide individual meters to heat network customers, and provide them with bills based on the meter readings.

The energy price cap (also known as the Default Tariff Cap) sets a price limit on default tariffs for domestic supplies of electricity and gas. The cap rose by 54% on 1 April 2022, increasing the average annual domestic energy bill to around £2,000. It is forecast to rise by a further 30 to 50% in October 2022. Most heat network customers are not protected by the cap, since the supply of gas to heat networks is commonly classed as "non-domestic". This is because the heat network operator purchases gas and then converts this to heat, before selling the heat on to households, often on a commercial basis. Heat networks operated on a not-for-profit basis can be classed as domestic supply (and so covered by cap), under certain circumstances.

The impact of energy price rises on heat network customers Since late 2021 energy prices have risen substantially. Heat network operators who have renewed their commercial gas contracts since the autumn have seen large price increases, which they are passing onto customers. According to Heat Trust (a consumer protection scheme), consumers and landlords have reported heat network price rises of up to 700%. The Government has said that price rises on larger district heat networks are "broadly in line" with the energy price cap, but noted that larger increases have been seen on smaller communal heat networks. In response to the price rises, there have been calls in Parliament, and elsewhere, for the Government to introduce price protections for heat network customers.

In Proposals to regulate heat networks The British Government has said it wants "heat network consumer to have comparable levels of service and protection to those using electricity and gas".

Following the recommendations of the Competition and Market Authority's (CMA's) 2018 Heat Network Markets Study, the Government has developed proposals to regulate the heat networks sector. These include appointing Ofgem as the regulator, and granting it new powers to regulate heat network prices. Under the proposals the Government does not intend to introduce a price cap for heat networks currently, but it plans for the Secretary of State to have powers to introduce pricing regulation in the future. The Government has committed to introducing legislation to regulate heat networks during this Parliament.

[7] House of Commons Research briefing Heat Networks and Energy pricing April 2022 CBP-9528.pdf (parliament.uk)

3.2.2. Role of building owners and building occupants

Deciding the heat source of the building

Currently it is a decision of Domestic property owner to choose the heat source for their building.

However, through the Heat in buildings strategy published October 2022 the Scottish government sets out the regulatory approach that they will consult on in order to introduce regulations by 2025 to require owners to reduce demand for heat through energy efficiency improvements where feasible, and install a zero emissions heating supply, within the extent of our powers.

In the Energy Efficient Scotland Route Map 2018, the Scottish government set the prediction that regulations be phased in, starting with the largest buildings with the scope of the regulations increasing over time so that by 2045 all non-domestic buildings would be improved. A phased approach is likely to remain appropriate.

Public sector buildings

The Scottish government intend to set the example through commitment that the public sector needs to act more rapidly and in advance of the introduction of further regulations for new-build and existing non-domestic buildings. They are developing a set of phased targets, stating with easy targets in 2024, with the most difficult buildings like hospitals being decarbonised by 2038, and for all publicly-owned buildings to meet zero emission heating requirements, with a backstop of 2038.

They expect public sector leadership to include the early phase-out of all fossil fuel-based heating systems in the public estate at the earliest feasible dates.

Investments and energy bill

Currently domestic customers are expected to meet the cost of investment in low carbon technologies, though domestic customers are ow eligible to apply for funding under the £300 million Heat Network Fund described in section 4.2.4 below.

3.2.3. Financing and subsidies

Localized subsidy or grant mechanisms available

The **Scottish Government Heat Network Fund** was launched in February 2022. **£300 million** has been made available over the next parliamentary session to support the development and rollout of zero emission heat networks across Scotland.

The Government aim is to stimulate commercial interest, and investment in order to maximise Scotland's potential in the low carbon sector, whilst contributing to the positive progress on reducing Scotland's greenhouse gas emissions.

From April 2021 businesses in Scotland are eligible to claim a 50% relief on non-domestic their premises is being used for a district heating network, or mainly being used for a district heating network. This relief will be available until 2032. A 90% relief is available for district heating networks powered by renewables. This relief will be available until 31 March 2024.

3.3. Available energy sources and storage

For the development of 5GDHC, it is important that each region gains insights in other (possibly low temperature) heat sources which are available today or in the future. As part of the work in D2Grids, a preference scale of energy sources has been developed (see D.T1.1.4 generic 5G technology model). The structure of this section reflects this ranking, with the highest-ranking forms of energy mentioned first. These sources are in most cases not only relevant for 5GDHC development. When there are many high or medium temperature sources available in a region, the case of 4GDH might be

better than for 5GDHC. Currently, we have no way of quantitatively saying what the shares of low grade sources would be in order to make a decent 5GDHC business case. At the time of writing, D.T1.1.4 has not been finalized.

3.3.1. Reuse of thermal energy, by exchange between heating and cooling demands

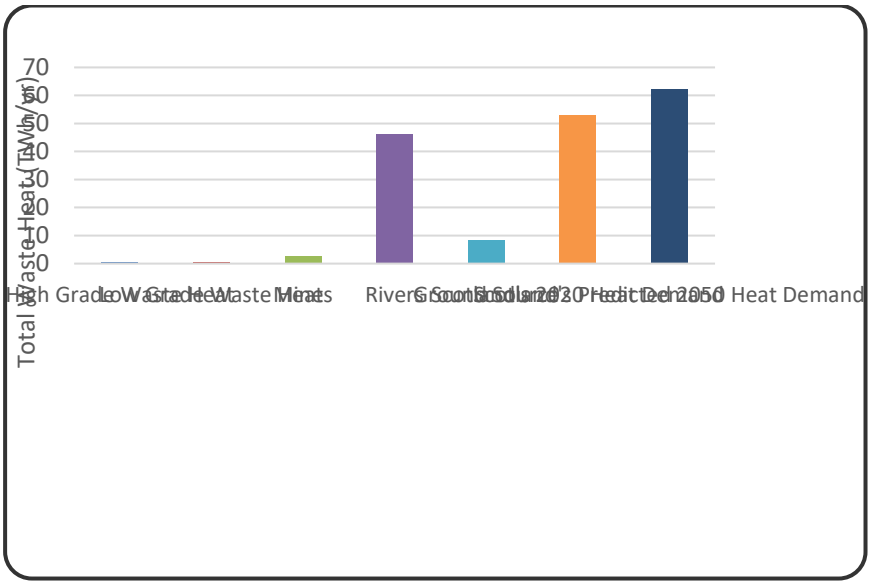
The core idea behind 5GDHC is to facilitate energy exchanges between local buildings. For instance, if one building is producing heat for its own consumption, it automatically also creates cold which ideally could be supplied to a nearby building. In Scotland there is little or no need for cooling in a domestic setting.

Ideally, as much local energy should be reused in order to minimize any possible type of energy losses. Analyzing the potential of these types of energy exchange is, however, not possible on a national scale. It highly depends upon the project, and detailed buildings consumption and production data, for different time periods, are needed. Its potential highly depends on the design of the network and the type of users involved. Ideally, when considering a new network, developers should engage and appoint a a good mix of consumers should be present, so that their energy flows and needs are complementary.

Making all building data available to local authorities during the LHEES could help in the consideration and development of viable 4GDHC networks in Scotland. action point to take up in the action plan. It is important that all demand and supply profiles can be compared, as this might provide incentives for complementary sectors to join the new site.

3.3.2. Ambient thermal sources from soil, water, air, and low temperature solar heat

Scotland has a wealth of ambient heat sources available for potential heat networks, such as soil, water air and sun. These have been quantified in fig 3 below.



Heat Source	Total Heat (GWh/yr)
Mines[1]	2,722
*Rivers[2]	46,312
*Ground Source[2]	30,272
High Grade Waste Heat[3]	665
Low Grade Waste Heat[3]	407

Figure 3. Ambient thermal sources in Scotland

Waste heat is available in Scotland and will further be discussed in section 4.1.1. below. However, using waste heat will only satisfy a small portion of Scotland's demand, we will need to utilize these ambient sources to be capable of fulfilling the rest of the heat demand, and as can be seen from the table, there is plenty of heat available to Scotland in various forms. In addition to these sources, there is also heat available from the ambient air that can be used in Air source heat pumps. A benefit of these natural, sources that some of them are seen as more reliable than waste heat in the long term, as they do not rely on the continued operation of another facility (e.g. a data centre) to provide heat. However, Scotland does have

some very reliable long term sources of lower grade waste heat which is suitable for 5GDHC, which should be considered carefully when assessing potential heat sources, especially when existing locally to the heat users.

3.3.3. Higher temperature industrial waste heat, otherwise rejected in the environment

Waste Heat Sources

When high grade heat is available in large quantities it is better utilised in 4GDH systems. 5GDHC systems are flexible to incorporating a wide range of heat sources into the network, including low grade waste heat, without having to upgrade it.

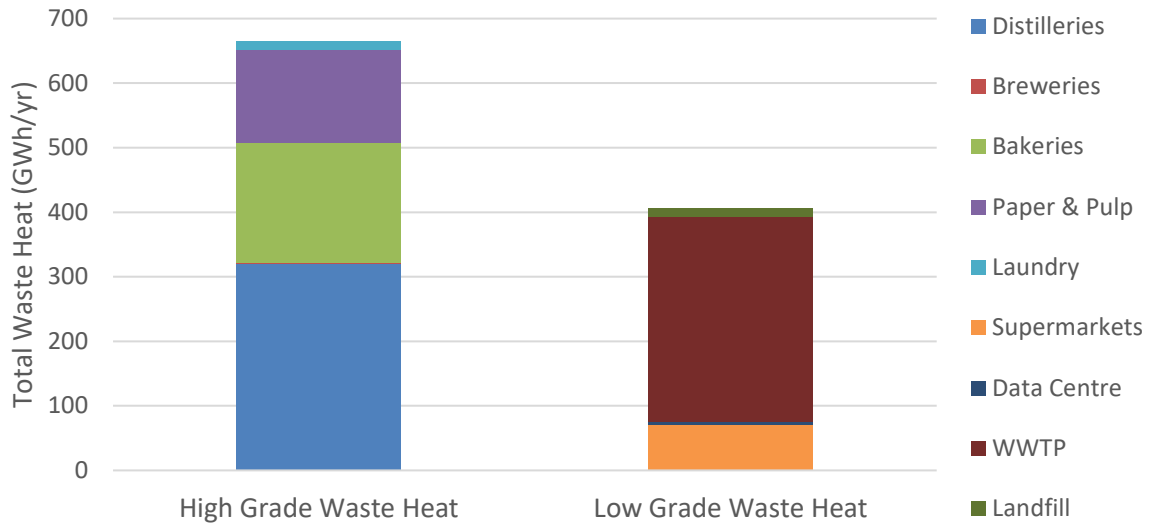


Figure 4. Waste heat sources in Scotland

Grade	Heat Source	Average Waste Heat Per Site (MWh/yr)	Total Waste Heat (MWh/yr)
High Grade Waste Heat (>50°C)	Distilleries	2,481	320,104
	Breweries	17	992
	Bakeries	2,562	187,040
	Paper & Pulp	23,901	143,405
	Laundry	1,631	13,341
Total High Grade Waste Heat			**664,882**
Low Grade Waste Heat (<50°C)	Super-markets	162	69,889
	Data centres	505	4,546
	WWTP	13,287	318,905
	Landfill	76	13,680
Total Low Grade Waste Heat			**407,020**

Source: "Potential sources of waste heat for heat networks in Scotland", ClimateXChange (2020)

Note: There are some uncertainties in these values and they should be used for indicative purposes only.

[2] estimated the technical potential of waste heat per EU country and the UK, per temperature level, per industrial sector. They found that waste heat of less than 100 °C was only available in the food and beverages industry. They calculated the fractions of the contribution of each of these industrial sectors towards the total national industrial waste heat for each European country.

Waste Water

The use of wastewater as heat source in Scotland is a reliable long term option for 5GDHC. Over 921 million litres of wastewater are produced daily in Scotland source of renewable heat energy that we are only just beginning to exploit. Scottish Water owns and operates over 31,000 miles of sewer network. These networks and WWTW (final effluent) present an enormous opportunity for 5GDHC, through extracting the heat form the wastewater as shown in fig 5 below

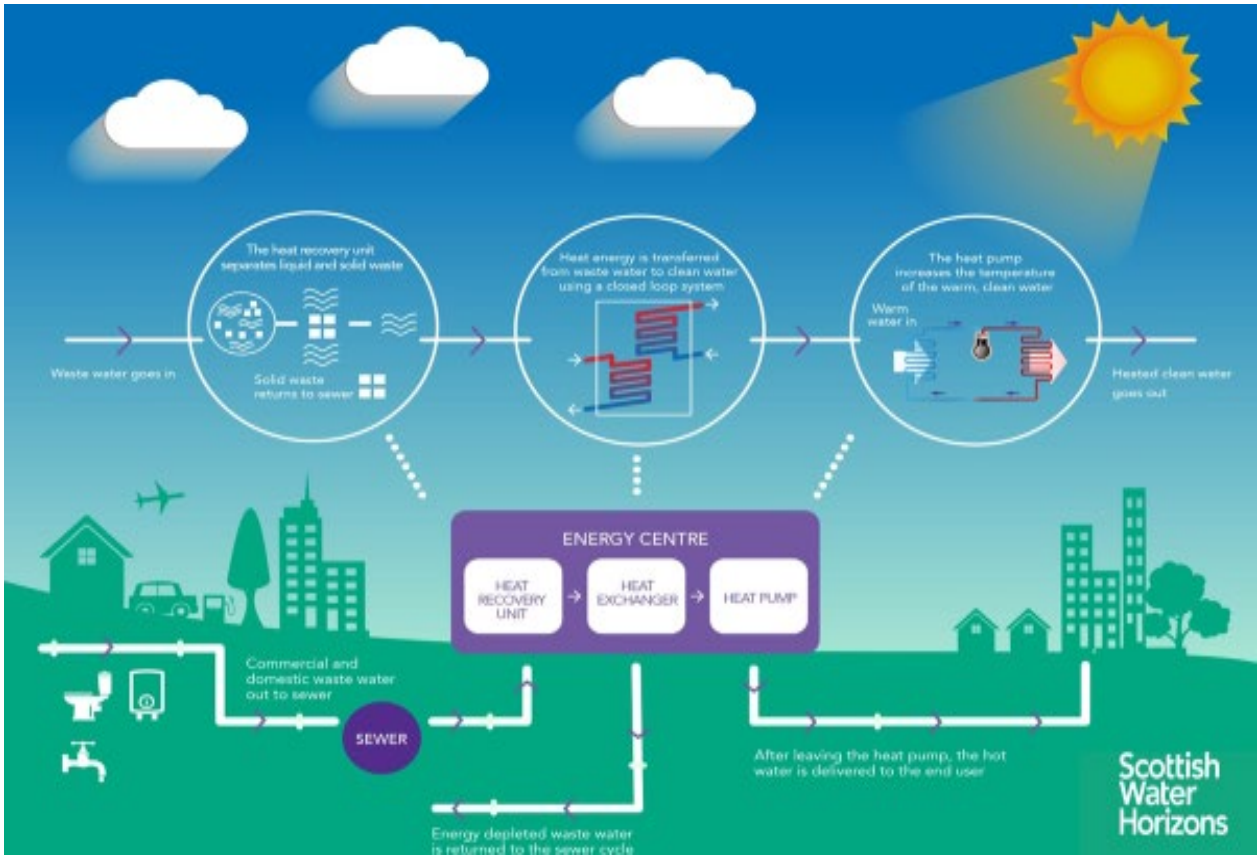


Figure 5. Wastewater extraction from waste water

Low grade thermal storage possibilities

Scotland does not yet have any DH networks that utilise large ambient thermal storage. However, there are many large mines which could be used for long term storage in ambient networks, suggesting a key capability gap that might support the 5GDHC market .

3.3.4. Higher temperature renewable sources like geothermal, solar heat

There are two classifications of geothermal heat, Shallow Geothermal and Deep geothermal. Fig 4 below shows the differences between the two.

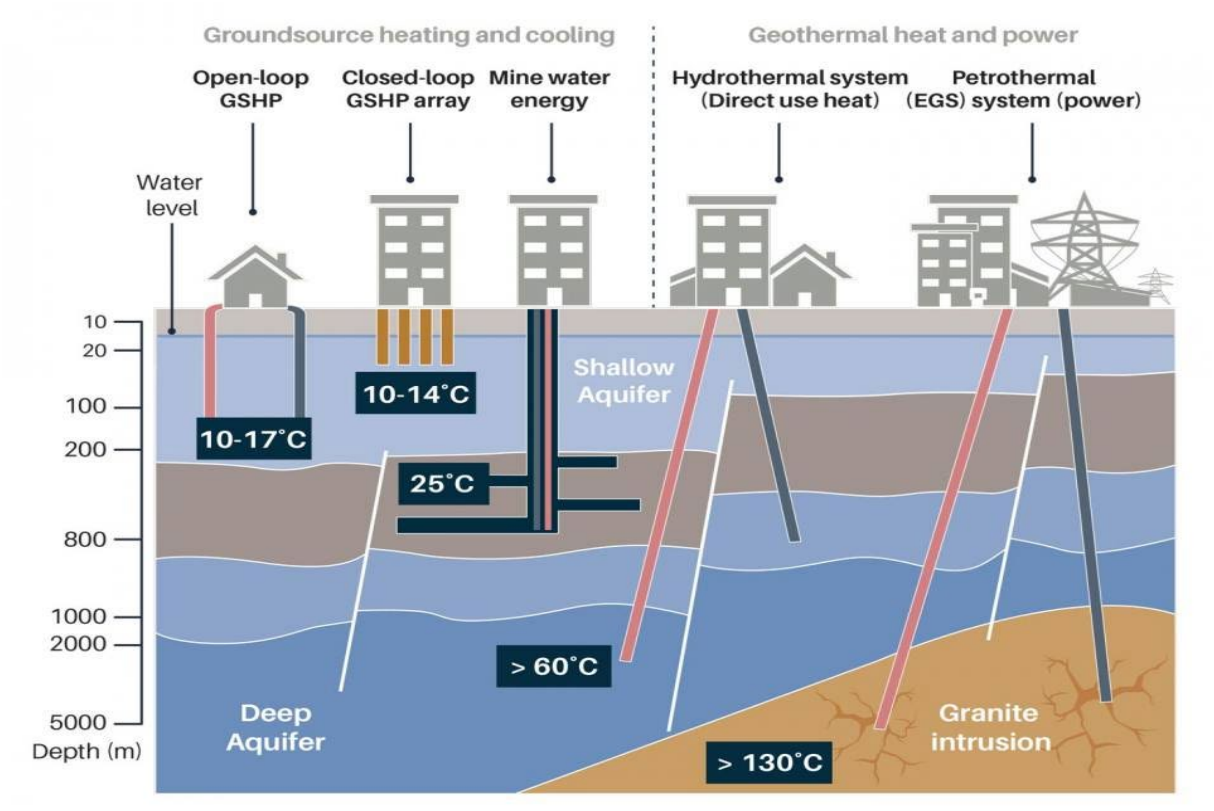


Figure 6. Shallow vs deep geothermal energy

The most common form of shallwo geothermal energy systems in Scotland provide heating through a ground source heat pump, as can be seen on the left hand side of the digram above . Up to 7.6 TWh of energy is available on an annual basis in Scoltand from this source.[8]

Deep geothermal

Scotland has geothemal sources in Deep hot sedimantary aquifers, Igneious granites and hydrocarbon wells.. These can be used or both heat and power through enhanced geothrermal systems. These can be seen in fig 7 below.

[8] McLoughlin, Nicola (12 July 2006) "Geothermal Heat in Scotland

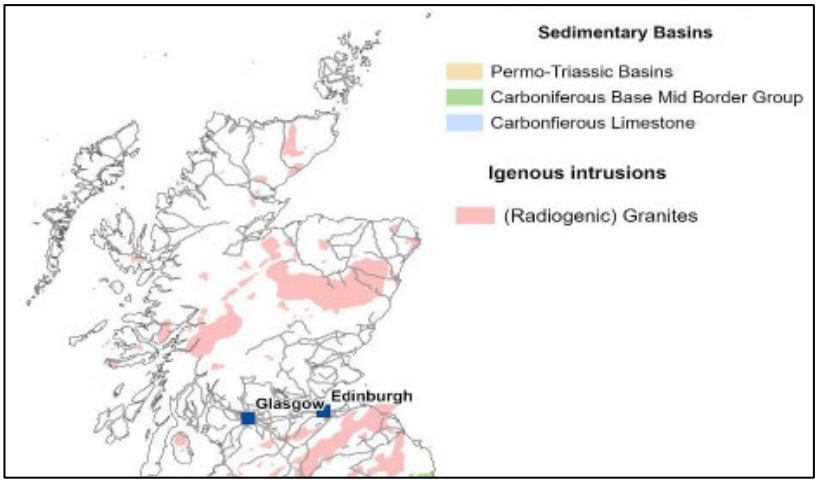


Figure 7. Scottish Deep Geothermal Stores

Areas of increased heat flow are associated batholith in the Eastern Highlands of Scotland. Mine-water geothermal systems are also being explored, utilising the consistent ambient temperature of the earth to raise the temperature of water for heating by circulating it through unused mine tunnel.

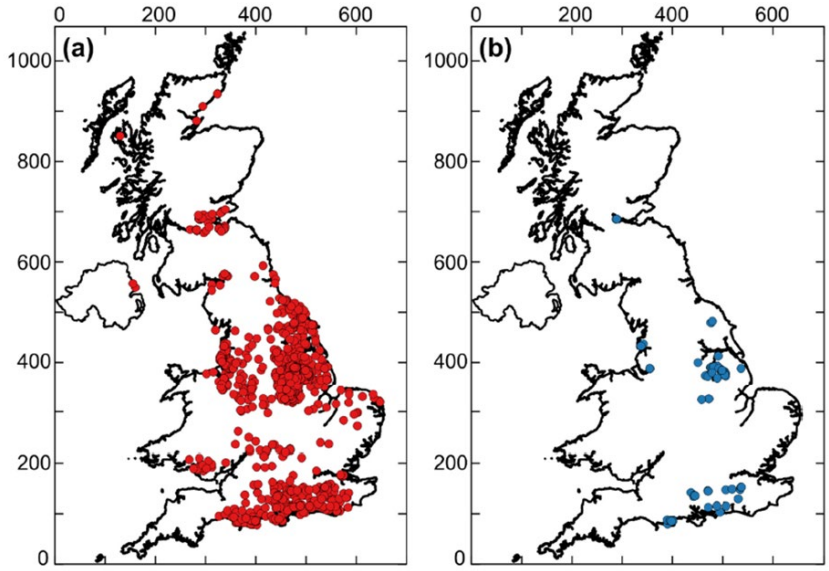


Figure 8. potential locations for deep geothermal in the UK

There are some concerns about the widespread use of geothermal as a heatsource, largely related to resource potential, regulation and economic barriers. There is also potential for geothermal energy production from decommissioned oil and gas fields.

3.3.1. Renewable electricity from local sources like wind, sun.

The Scottish government has a target to generate 100% of Scotland's own electricity demand by 2020. Scotland currently generates renewable electricity equivalent to 98% of its annual demand. 2020 was a record year for renewable electricity generation in Scotland with 31.8 TWh generated, 4.2% up on 2019. In 2020 had Scotland had 11.9GW of renewable electricity operational and 14 GW of projects consented in the pipeline, Scotland generated 30.5TWh of renewable electricity in 2019 73.1% was from wind. Renewables make up 54.9% of all electricity generated in Scotland in 2018 compared with just 28.9 % in England and Wales.

In 2019, the equivalent of 90.1% of gross electricity consumption (Gross electricity consumption refers to total electricity generation minus net exports) as from renewable sources, rising from 76.7% in 2018. Much of this increase is due to wind; in the 2019 there was an almost 1.0 GW increase in wind capacity, which contributed to approximately 3 TWh increase in electricity generation via wind.

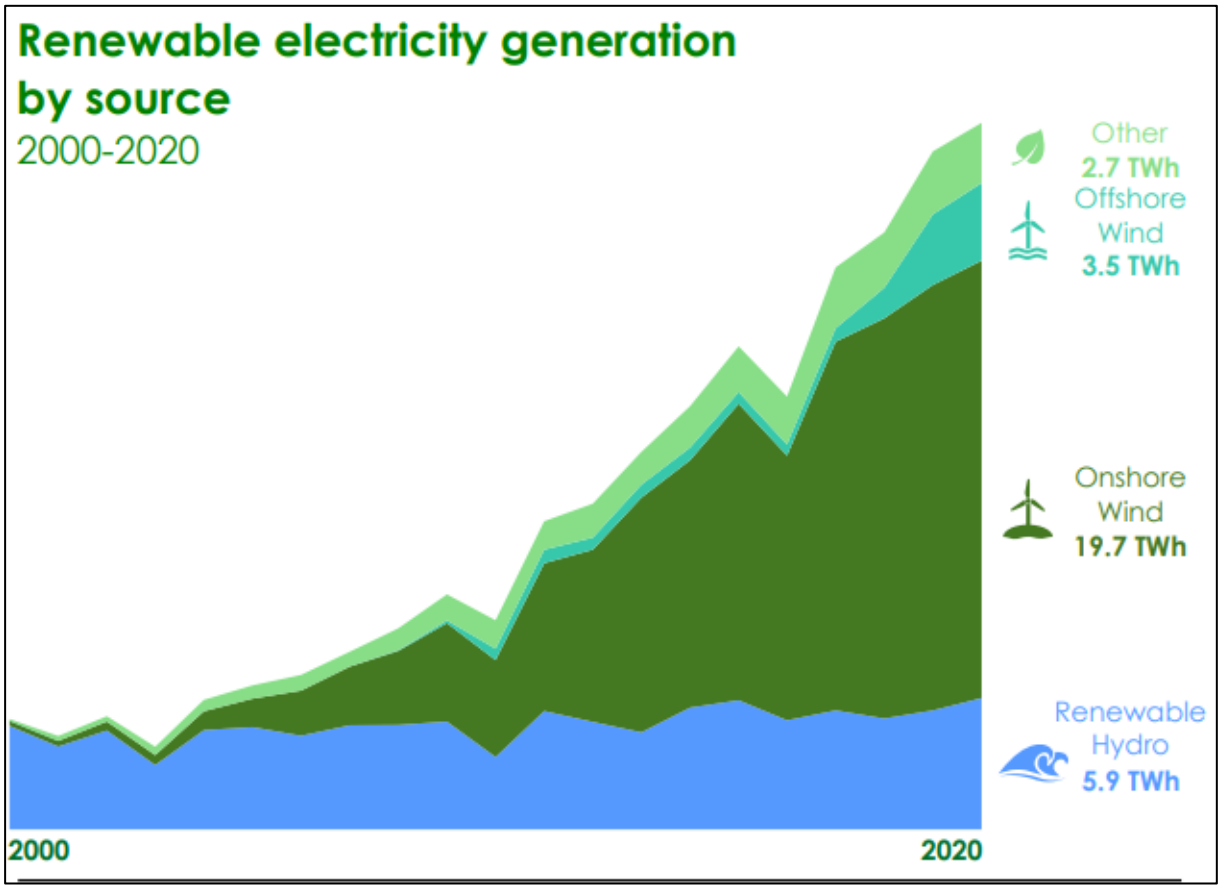


Figure 9. Renewable electricity generation in Scotland

3.3.2. Electricity use at times of renewable overproduction, e.g. when spot price is low

For now, this is only relevant in areas with known overproduction, like the north of the Netherlands (overproduction of PV) and the north of Germany (wind).

3.3.3. Electricity mix from the external grid

Most electricity in Scotland is carried through the national grid with Scotland's renewable mix thus contributing to the electricity production of Great Britain as a whole. Scotland has its own networks, run by SSE (Scottish eand Southern energy) and SP energy networks ((Scottish Power Energy Networks)

The table below shows the difference in energy mix between SSE when compared to the UK National grid.

SSE Generation Mix (relates to electricity supplied in the period April 2019 to March 2020)		
Electricity supplied has been sourced from the following fuels	Electricity supplied by SSE % of total	Average for UK (for comparison) % of total
Coal	0.0%	3.9%
Natural Gas	48.1%	39.4%
Nuclear	0.0%	16.6%
Renewable	51.9%	37.9%
Other	0.0%	2.2%
Total	100%	100%
Environmental impact	Electricity supplied by SSE	Average for UK
High-level radioactive waste g/kWh	0.0000	0.0012
Carbon Dioxide emissions g/kWh	178	198

3.3.1. High temperature heat from burning biofuels, biogas, biomass

Scotland utilizes a number of known technologies for the generation of heat from renewable sources. Fig 4 shows the current mix of renewable heat generation capacity in Scotland. 2,140 GW of renewable heat capacity was operational in Scotland by the end of 2020, up from 2.06 GW in 2019 and 0.44 GW in 2010. Biomass accounts for 81 per cent of the total capacity followed by heat pumps which account for 13 per cent of the total. Fig 5 details renewable heat output by technology in 2020. In total, 5,008

GWh of heat was produced from renewable sources; total renewable heat output has increased by 2 per cent from 2019.

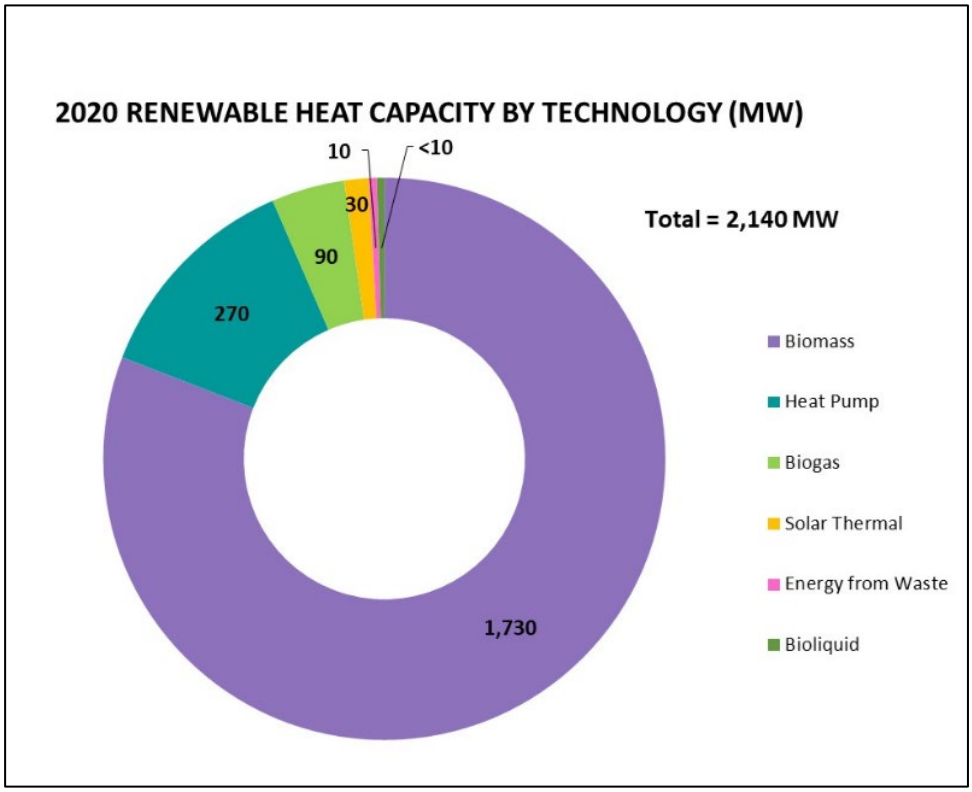


Figure 10. Scottish Renewable heat generation capacity in 2020

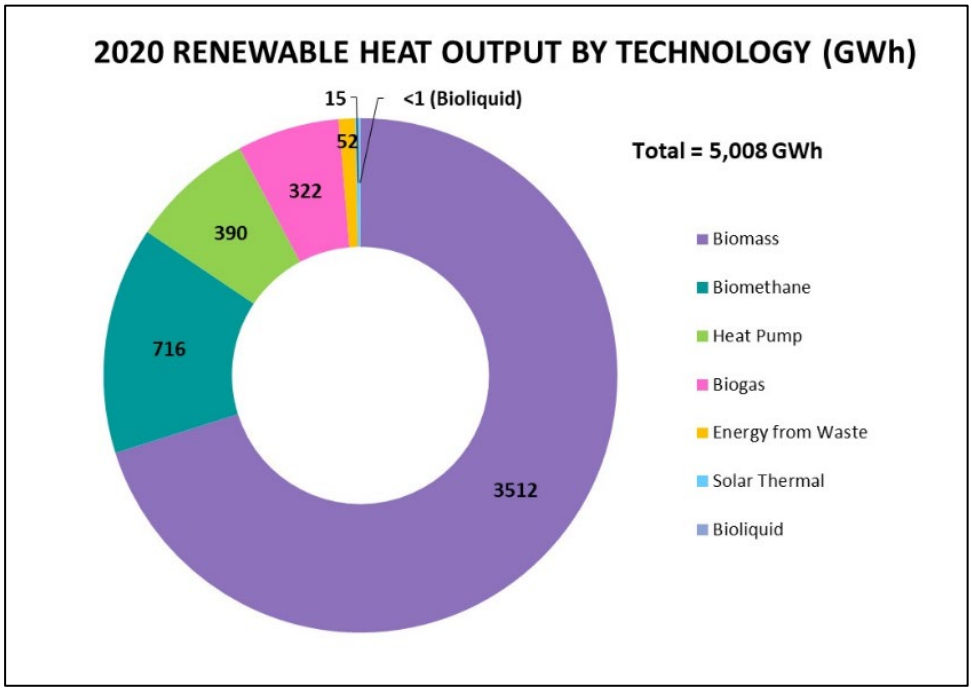


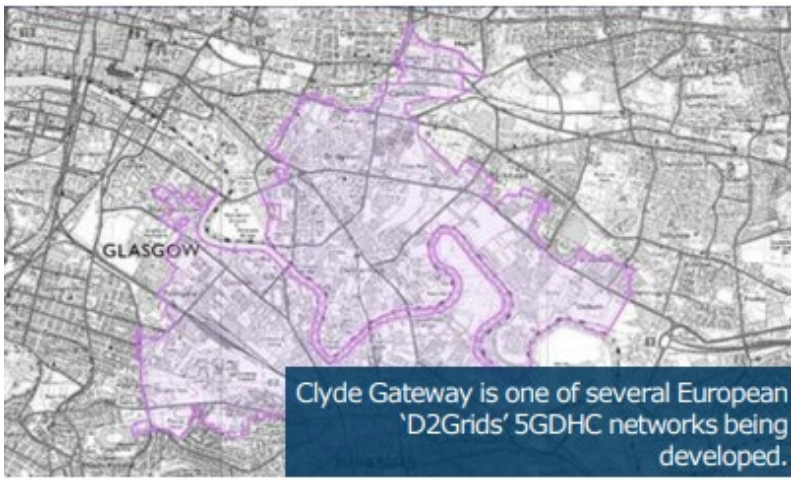
Figure 11. Renewable Heat output in Scotland 2020

3.4. Infrastructure, skills and capabilities in Scotland for 5GDHC

3.4.1. Existing projects

There are currently only two pilot projects for 5GDHC in Scotland, AMIDS, and Clyde Gateway.

Clyde Gateway represents "Scotland's largest and most ambitious regeneration programme" and is located in the east end of Glasgow. The regeneration programme will include two district heating networks, a traditional centralised network, and a 5GDHC network. The networks are being developed in partnership with Scottish Water Horizons. The 5GDHC network is one of five Interreg D2Grids pilot projects, which aims to set industry standards for 5GDHC. The 5th generation network will originally connect to 3 office buildings, with plans to increase this to 8 buildings in the future. The network will recover waste heat from the final effluent of a local waste water treatment works. It is due to be completed by early 2023.



The **"Advanced Manufacturing Innovation District Scotland" (AMIDS)** will be an internationally-recognised centre for advanced manufacturing – ideally placed in Scotland's industrial heartland." AMIDS is located in Paisley, Renfrewshire, and will have a 5th generation district heating network. Partners of the project include Renfrewshire Council, Scottish Water Horizons, Scottish Enterprise, Scottish Futures Trust and Zero Waste Scotland. The network will originally connect to two buildings; the National Manufacturing Institute Scotland (NMIS) and the Medicines Manufacturing Innovation Centre, with the capability to expand as more buildings are constructed in the district over the next 10 to 15 years. The network will recover waste heat from the final effluent of Scottish Water's Laighpark Waste Water Treatment Works through a heat exchanger. It is due to be completed by mid-2022.

3.4.2. Main capabilities for implementing 5GDHC and retaining value in Scotland

In 2021 Scottish Enterprise commissioned a report to assess the potential for Scotland to be a leader in 5th Generation heating and cooling networks[9].

The Ramboll report provided an analysis of the 5GDHC Market and supply chain in Scotland, and aimed to set out the opportunities and challenges for Scotland in developing these networks through conducting desktop studies, expert and industry interviews, and analyzing the role of policy in enabling these networks to develop.

As we see from the pilot projects above, 5GDHC is not yet established in Scotland, and there is limited knowledge of 5GDHC in the industry and public domain, however Scotland does have some existing capability which would enable the implementation of 5GDHC, and the Scottish government have committed to support industry in the local manufacture of components of Heat networks, including those required specifically for 5GDHC.

Scotland has a thermal storage manufacturer, Sunamp, located in Scotland, is the only thermal storage manufacturer in the world to be awarded A Grade RAL Certification, the independent quality mark and the only global standard for Phase Change Material (PCM) and PCM products, confirming reliability and long life of Sunamp thermal batteries. These units allow the use of off peak electricity for storage of heat at the end user's property with 3x the density of a water tank.

In terms of pipework, 5GDHC utilizes the same uninsulated pipework as gas and water mains used in Scotland. As such Scotland has good experience, expertise and existing contractor capable of installing mains required for 5GDHC, however there are currently no manufacturers of uninsulated pipework in Scotland, which may cause issue with supply chain in a growing heat network market. Scotland has two existing heat pump manufacturers, however they are not currently producing technology suitable for 5GDHC, and additionally Scotland has a lack of heat pump installers. Upskilling in these areas is a key priority for the Scottish government.

Component manufacture and emerging markets.

The Scottish A 2022 report was commissioned by Scottish Enterprise, analyzed key components required for district heat network and existing supply chains, and he markets for these in Scotland, UK, Denmark and France[10]. The report investigated the part Scotland may play in contributing to the emerging District Heating market. The report considered both 4 and 5G networks, and found there was a strong market growth forecast for the key components, but particularly in the UK and France. The study concluded that within heat pumps, compressors and controls were identified as two of the components with the most potential for Scotland. For heat networks, it was controls and pre-Insulated steel pipes. These components were selected according to their value, existing expertise in Scotland, innovation potential, procurement difficulty, and potential for retrofits. and all show strong forecast market growth. Across all, where predicted growth rates were highest. This was found to be due to a combination of factors including macro trends towards decarbonisation and security of supply and local policy environments.

[9] Scottish Enterprise – Analysis of potential for Scotland to be a leader in 5th Generation Heating and cooling networks (Ramboll November 2021)
[10] Heat pumps and Heat networks assemblies and Key component analysis (Ramboll April 2022)

4. SWOT analysis

Given the information gathered above on the market and on availability of energy resources, an analysis of the strengths, weaknesses, opportunities and threats when implementing 5GDHC in the region can be made. The SWOT analysis will help to interpret the information given earlier and will as such help to understand which locations Scotland might be better suited for 5GDHC.

4.1. Strengths

In what follow, strengths of Scotland as a region, that could give 5GDHC an advantage over other projects and technologies, are discussed.

4.1.1. Existing skillset:

On a practical level, Scotland has existing skills which would support the implementation of 5GDHC Nationally. Incumbent gas and water networks all rely on the same trench digging and installation expertise for of HDPE Pipework which would also be required for 5GDHC in Scotland. Scotland also has a wealth of experienced boiler fitters which could be retrained to install heat pump technology. The Oil and has industry also utilises drilling techniques which would transfer well for deep geothermic drilling which is also present in Scotland as a potential heat source.

4.1.2. Scottish Legislative Policy and support

The legislative and government support for Heat networks gives a favorable environment for the implementation of 5GDHC in Scotland. Although currently Heat Networks in Scotland are well behind many European counterparts, the Scottish government has set some ambitious targets, supported with both a developing legislative framework and funding to push Scotland forwards quickly as a leader in Heat networks in 5GDH

4.2. Weaknesses

4.2.1. Energy demand suitability

Scotland does not currently utilise space cooling in many domestic and public building settings and, as such this does not lend itself naturally to the implementation of 5GDHC in these settings.

4.2.2. Technical issues

Currently in Scotland there is a large gap in understanding with regards to 5GDHC in the industrial supply chain, and public understanding of Heat networks. While the government is implementing policy and support to rectify these issues through funding, training, and policy development these policies are aligned more generally to district heating and not unique to 5GDHC. when compared with 4GDH 5GDHC has larger spatial requirements for the larger pipework, which could cause issue particularly in retrofitting to older infrastructure. Additionally, unlike with 4GDH, 5GDHC requires changes to electrical infrastructure on an individual building basis, where 4G requires this at a centralised energy centre only.

4.2.3. Financial modelling and viability.

Lack of previous exemplar projects make the timeline to deploy projects difficult to plan, and with no secure supply chain financial models are fairly difficult to predict accurately, to ascertain the financial viability of the project. Projects in Scotland today would not have been able to proceed without funding, and 5GDHC is unlikely to be financially competitive with other heat networks unless government schemes such as the recently introduced Heat network fund continue to support these projects.

4.3. Threats

A 5GDHC Business model is difficult to develop where cooling is not required. While not necessary, a network will be a lot more viable where both heating and cooling requirements are present within the anchor loads of the scheme.

Projects to date have realized a major threat to be in the complex nature of business and financing for 5GDHC. Alignment of planning, funding, and the onboarding of anchor load customers to enable the financial viability of a project is more difficult where individual premises need to adapt or design their electrical infrastructure on a building by building basis rather than with a large energy centre as found in both 3G and 45 DH systems .

4.4. Opportunities

There is recognized potential for the development of existing pilots, namely , the AMIDS and Clyde Gateway projects in Renfrewshire and Glasgow. Both projects were built to allow for future expansion when additional heat users and funding become available.

Use of existing resources:

Scotland has an array of natural and man made resources which lend themselves towards the implementation of district heat networks generally, as well as 5GDHC. Flooded Mines have the potential to provide thermal stores, and the wealth of rivers, coastline and recovered heat from the sewer provide readily available heat sources close to heat users which would enable development of new networks.

The Implementation of LHEES by local government, will be aided by the by the first National assessment of potential Heat Network zones in 2022, and findings will give will give the opportunity for local council areas to quickly build on the national information with local knowledge to develop local plans which should include consideration of 5GDHC as a longlist option for any plans going forward. As there is relatively little District heating developed in Scotland to date, the consideration for 5G should not be complicated by a need to connect to existing 3G and 4G systems.

Legislative and financial incentives such as the Heat network fund 2022 will encourage both public and private investment, and help to develop the market, thus driving down cost in the longer term (both in terms of infrastructure and unit cost of heat).

5. Regional vision

The regional vision addresses which barriers need to be addressed first and which opportunities should be taken when rolling out 5GDHC in the region. The vision includes a roadmap describing how much thermal demand (in MWh and/or floor area) could be fulfilled between the end of D2Grids and 2030, including likely locations where implementation can start.

5.1. High potential areas and potential pilot sites

The First National Assessment of Potential Heat Network Zones (FNA)[11] was completed for Scotland in 2021. The work undertook an analysis to identify areas that might be suited to heat network development from a heat demand density perspective. The focus of the work was to Identify potential zones through assessment of nationally available data on heat demand density, and provided and assessment using national datasets of the areas that are most suited to heat networks from a demand density perspective. The study gave heat demand data for identified zones,

The assessment and identification of potential zones was not specific to 5GDHC and the report acknowledges the requirements for further studies that incorporate local development plans, existing heat networks and sources of waste or surplus or low carbon heat. It is intended that the FNA study can be built upon by local authorities, and further work should incorporate assessments on economic viability, and detailed technical or stakeholder related aspects of project opportunities in identified zones. Further detailed assessment will also be required to understand if heat network projects within potential zones could offer heat to properties at a cost that is competitive against alternative options, and to consider 5GDHC in the longlist of options.

5.2. Roadmap

The FNA is framed by two key policy drivers discussed in section 4.2.1 above (the ongoing development of Local Heat and Energy Efficiency Strategies (LHEES) and the Heat Networks (Scotland) Act 2021 (the 2021 Act)). This work is aimed to support the development of policy and regulations, including informing the Heat Networks Delivery Plan (as detailed in the 2021 Act) and the local identification of potential zones for heat networks as part of LHEES, including 5GDHC. The work may also be used to support wider policy development.

Regarding LHEES, the local authority specific analysis provided by the FNA (and shared with local authorities as part of the LHEES National Assessment outputs) is intended to support local authorities to work towards their requirements within LHEES in regard to heat networks. The LHEES process includes local consideration of potential zones outputs, bringing in local knowledge to sense-check anchor loads and other factors such as local development plan sites, existing heat network connections within potential zones and other requirements as set out in the 2021 Act, refreshing the outputs as required. This work has also informed updates to the LHEES process, and these will feed-in to ongoing development of the LHEES methodology.

It is predicted that Scotland will have a cumulative expenditure of **£5.2BN** on heat networks from 2022 to 2030. Based on Scottish Government Targets to meet 2.6 TWh of renewable heat networks by 2027 and 6 TWh by 2030 there is a requirement for a multi-disciplinary approach. We will need to deliver a combination of government policy, packages of financial support and funding, and progression in technical and manufacturing capability. Additional targets to enable delivery will be set for 2035. These will be put to national consultation in early 2023.

[11] First national assessment of Potential Heat Network Zones Baseline and stringent assessment for Scotland using the LHEES Methodology (V03, August 2021) – Zero Waste

6. References

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