Biomass with district heating

The UK's Heating Challenge

An increase in the development and distribution of biomass district heating networks can help the UK achieve its net zero targets for the domestic heating sector; one of the hardest sectors to decarbonise. With almost half of the UK's total spending on energy going towards heating our homes, not only would transforming the way we heat our buildings significantly reduce our carbon footprint, but there could be some substantial cost savings as well[1]. The biomass most often used in these systems are wood pellets, as well as wood chips, wood shavings and logs. There are other types of 'biomass' of course, such as agricultural residues, wastes and crops, industrial and municipal waste products, food waste and algae, however this article focuses on the use of woody biomass for producing heat.

Biomass Heating Systems

For heating individual rooms there are wood burning stoves, however these don't have a boiler incorporated into the design for heating a whole house. For heating more than just one room, there are a range of different biomass heating options. The four main types of heating systems that use biomass to heat a boiler are[2,3]: fully automated systems, semi-automated (or "surge bin") systems, pellet-fired, and Combined Heat and Power (CHP). Using these different heating systems, the biomass boilers can be used in place of a standard gas or oil boiler to heat radiators for a whole house, and to provide hot water. In these scenarios, the boiler is set to maintain a target temperature in a thermal heat store and can modulate (or 'turn down') to below the full capacity when the set temperature is reached. However, these systems can be scaled up and heat a series of houses or buildings, and this is called a biomass district heating network.

The District Heating Concept

Other renewable technologies (and traditional power plants) can also be incorporated into a district heating network, and newer generations of these heating systems have improved efficiency and used innovative solutions. As district heat networks are the main large scale user of biomass as a renewable technology, it is important to understand how this concept has developed over time and the key opportunities and challenges with this type of system that will need to be considered for potential future deployment of biomass district heating networks.

Some European countries provide a large majority of their energy from district heating. But now district heating (note this is not just biomass district heating) is becoming more common in the UK, especially as part of new housing developments and town expansions. Currently, there are around 17,000 district heating systems in the UK[4]. About 91% of the UKs' heat district network connections are in England, and 6% are located in Scotland[1]. Of the half a million UK customers on heat district networks, about

[1] The Association for Decentralised Energy. Heat Networks. Available: https://www.theade.co.uk/resources/what-is-district-heating
[2] Hurst Boilers. Types of Biomass Heating Systems. Available: https://www.hurstboiler.com/biomass_boiler_systems/types-of-biomass-heating-systems
[3] Renewable Energy Hub. Biomass boiler Types: The different Types of biomass boilers. Available: https://renewableenergyhub.co.uk/main/biomass-boiler-information/biomass-boiler-types-the-different-types-of-biomass-boilers/
[4] Switch2. The role of 4th and 5th generation heat networks in decarbonizing UK homes. Lucy Glynn. Available: https://blog.switch2.co.uk/blog/the-role-of-4th-and-5th-generation-heat-networks-in-decarbonising-uk-homes

450,000 are domestic customers, 33,300 commercial, 4,700 retail, 320 light industrial, 1,500 are universities or schools, and 4800 are 'mixed use' networks[1].

There have been five so called 'generations' of District Heating, beginning as far back in the UK in the 1880's[5]. Traditional coal fired and oil or gas fired power plants were the main energy source for the first two generations of district heat networks. However, by the 1970's, the third generation of district heat networks started to include biomass heating. The primary motivation for building these systems at the time was to enhance the security of the UK's energy supply by improving the energy efficiency after the two oil crises led to disruption of the oil supply[5]. Therefore, the third generation heating systems typically were based on coal, biomass and waste as energy sources, in preference to oil.

The fourth generation district heating (4GDH) is designed to further combat climate change and integrate high shares of variable renewable energy technologies into the district heating networks by providing a higher degree of flexibility to the electricity system[10,5]. The fourth generation has the ability to supply low-temperature district heating for space heating and domestic hot water to existing buildings, energy-renovated existing buildings and new low-energy buildings. It can also distribute heat in networks with low grid losses, recycle heat from low-temperature sources and integrate renewable heat sources such as solar, geothermal, Anaerobic Digestion plants and Energy from Waste plants[5]. This concept also makes it possible for storage systems to be utilised in a district heating system to help meet energy demand during peak times.

A fifth generation district heating and cooling network (5GDHC)[10], also called cold district heating, distributes heat at near ambient ground temperature for the principal network: this minimizes heat losses to the ground and reduces the need for extensive insulation[6]. The substations that connect to the principal grid network then upgrades the temperature to the required level, whilst thermal storage buffers any fluctuation in supply and demand[6]. 5GDHC systems are decentralised, bi-directional, close to ground temperature networks that use direct exchange of warm and cold return flows and thermal storage to balance thermal demand as much as possible[10,7]. 5GDHC offers a way to incorporate low temperature renewable heat sources including shallow geothermal energy, as well as reduce total demand by recuperating generated heat from cooling and generated cold from heating. Each building on the network uses a heat pump in its own plant room to extract heat from the ambient circuit when it needs heat, and uses the same heat pump in reverse to reject heat when it needs cooling[6,10].

Challenges and Opportunities of District Heating Networks

As with most technologies, there are some key advantages and some important disadvantages to consider when assessing the suitability of district heating as a technology option on a case by case scenario. A summary of the key points is shown in Figure 1.

The main challenges and drawbacks of this type of heating system include: major forward-planning required (difficult to retrofit), long-term financial commitment needed (so could be difficult to sell to homeowners) and connecting homes to a district heating system means residents can't change supplier down the line, meaning that they won't necessarily be getting the cheapest energy deal[8]. Additionally, it is less attractive in areas of many small buildings; e.g., detached houses than in areas with fewer larger buildings; e.g., blocks of flats, because each connection to a single-family house is quite expensive. At present, the majority of the UK's district heating systems are not regulated[10], so there's little to no

[5] Lund, H. et al. *Energy*. '4th Generation District Heating (4GDH): Integrating smart thermal grids into future sustainable energy systems'. **68.** (2014). Pg 1-11. Available: https://doi.org/10.1016/j.energy.2014.02.089.
[6] Interreg. 5GDHC in short. Available: https://5gdhc.eu/5gdhc-in-short/.
[7] Boeten, S. et al. *Adv. GeoSci.* '5th generation district heating and cooling systems as a solution for renewable urban thermal energy supply'. **49**. (Sept 2019). Pg 129-136. Available; https://doi.org/10.5194/adgeo-49-129-2019.
[8] Which? I have a problem with my district heating, what can I do? (March 2021). Available: https://www.which.co.uk/consumer-rights/advice/i-have-a-problem-with-my-district-heating-what-can-i-do-aEYhR6f0Do0e

consumer protection or minimum standards of service for customers. Breakdowns and service interruptions are therefore taken out of the occupants' hands. Some customers are taking legal action against the supplier for Misrepresentation & Unfair Trading, claiming their district heating is not delivering the savings promised by many heat suppliers[10].

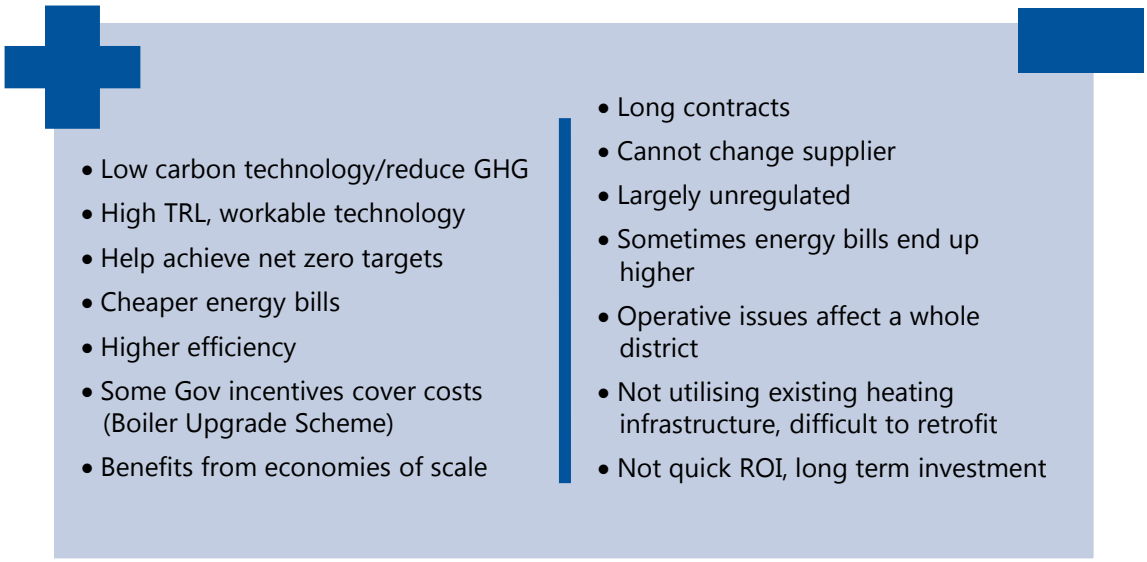

Figure 1. The main advantages and disadvantages of district heating systems.

An important potential issue with the deployment of heat networks for the future decarbonisation of existing infrastructure is that it is much easier to plan the heating network into the community design before building (e.g., for new housing estates) compared to retrofitting a heating network to an established built up community. However, in terms of individual homes, this system would be able to utilise the existing central heating pipework, so this technology is usually less disruptive to install than heat pumps, for instance[9].

The uptake of district heat networks also requires the estate management to persuade a lot of existing residents that it would be overall a good idea and that they wouldn't be left carrying the cost of installation, in order to pass any planning applications. Some of these major issues can be somewhat minimised in future with careful policy, regulations and logistical solutions for the operating and maintenance of the systems. Controls and tariffs will need to be carefully considered to create the most efficient solutions to such logistical and management issues going forwards.

Biomass with District Heating

Biomass heating can be used in large scale systems such as district heating networks, as a way to sustainably produce heat energy than can be sent via heat exchange pipes to large heat users, including residential homes, universities, hospitals, schools and swimming pools, when required. Around 450,000 kWh per year (equivalent to heating 40 average UK households) can be achieved with large scale biomass heating systems, resulting in a decrease of CO_2 emissions by 95 tonnes a year and considerable savings on heating costs compared to using fossil fuels[10]. Such large scale systems are typically housed

[9] Viessmann. Can you install a heat pump in an existing home. (June 2022). Available: https://www.viessmann.co.uk/en/heating-advice/heat-pumps/can-you-install-a-heat-pump-in-existing-home.html
[10] The Renewable Energy Hub UK. District and Community Biomass Heating Solutions: District Biomass Heating. Available: https://renewableenergyhub.co.uk/main/biomass-boiler-information/district-and-community-biomass-heating-solutions/

in their own buildings or boiler rooms, and then the hot water produced is piped underground via insulated pipes to the buildings requiring heat. For example, a community scale biomass district heat network would consist of a biomass boiler, back up fossil fuel boilers, a fuel store, large accumulator tanks, expansion vessels, a large plumbing network, a control centre and a buffer tank (which stores the hot water generated and circulates it, sometimes called 'thermal stores').

Biomass district heat networks can use any one of the four biomass heating systems, and the preference is mostly determined by the scale of the heat network. Typical small to medium scale networks (e.g., several houses or a school) tend to use either the semi or fully automated systems, whilst larger scale systems tend to use CHP (e.g., hospitals, industrial estates), which can generate power from the heat energy as well. Pellet fired systems can be used for a wide range of capacities and so can be used for small, medium or large scale systems. These tend to be more economical when the heat network is geographically close to a pellet manufacturer and can be preferred if there is limited storage space[2].

The unique advantages and opportunities that biomass district heating can benefit from includes lower carbon emissions than individual boilers, higher energy efficiency, especially if using CHP plants, which can generate electricity and gas simultaneously, and providing the opportunity for smaller dwellings to use alternative clean and renewable fuels like biomass that would otherwise be unsuitable or too expensive for installation in their property.

Pellet-fired Systems and the UK Pellet Industry

Pellet-fired biomass heating systems have a higher fuel cost per tonne than systems using wood chips due to pellets being more processed, however they are more efficient to transport due to their increase density. Pellets are more energy dense and therefore more efficient for heat generation than using wood chips. They are also safer to handle and store, with less dust and combustion safety issues[11]. In the UK there is the UK Pellet Council (UKPC)[12], which is a Trade Association for UK members, and itself is a Member of European Pellet Council (EPC). The UK pellet market promotes pellets that are classed as 'Premium (ENPlus A1)' as the most efficient and sustainable choice of wood pellet[13]. For these premium pellets, there are six UK & Eire producers, producing roughly 275,000 tpa, covering 45-47% of domestic demand. The total UK demand equates to approximately 600,000 tpa, and the European consumption is roughly 17.5 Mtpa[13].

Producers in the UK are in the process of scaling up production to minimise the shortfall in supply caused by the EPC withdrawing Russian ENPlus certification from April 2022, creating a 3Mt shortfall of premium wood pellets in Europe. For the UK, around 45% of wood pellets are sourced from Russia or the Baltics, a gap of around 200,000 tonnes[14]. This has resulted in a significant increase in the UK bulk pellet price from around £250/t to £400/t (June 2022 prices)[13,15]. However, it is important to note that despite these price increases, the use of wood pellets for heating is still less expensive than using heating oil, natural gas and electricity[14].

[11] Pellets2Heat. Wood Fuel: Information on the different types of biomass fuel available. Available: https://www.pellets2heat.com/wood-fuel-pelletschipslogs/
[12] UK Pellet Council. http://www.pelletcouncil.org.uk/
[13] REA. Wood Heat Forum Meeting. Mark Lebus, UK Pellet Council: Russia Situation and Supply Issues. (March 2022).
[14] UK Pellet Council. October 2022. Statement. Available: http://www.pelletcouncil.org.uk/statement-2/
[15] Woodlets. Wood Pellet Price Increases. (June 2022). Available: https://www.woodlets.co.uk/2022/06/wood-pellet-price-increases/

Conclusions and Learnings

Biomass heating within a fourth or fifth generation district heat network can offer certain advantages depending on the specific locations and situations. For example, where there is a school or swimming pool requiring constant heating, near an office block that needs cooling, nearby to a furniture manufacturer or managed forest that readily have wood residues that can be used as a feedstock locally. There are certain measures that can be incorporated into the heat network design to mitigate the main issues that have been observed in previous systems. These could include but are not limited to the following examples;[2,10,16,17]

- Install two or more boilers or keep the existing oil or gas boiler in place to enable hot water use by consumers during maintenance of the biomass boiler(s).
- Ensure the thermal store is sufficiently sized for the system, taking into account reaction time of the biomass boiler. If there are fundamental issues on biomass boiler sizing relative to the thermal store/buffer and the remainder of the system, then the system will likely not perform satisfactorily.
- Using the base load for the heat requirements to set the capacity requirement rather than the maximum load and using existing heat sources to make up the requirements in peak times, as biomass heating systems work much more efficiently when working near maximum capacity.
- Correct flue design and biomass boiler selection for the system.
- Consider heat load based control rather than return temperature control for temperature control systems.
- Try to incorporate consumers with a variety of load types, with different demand profiles, to be connected together to make the scheme more economically viable.
- Keep everyone in the community informed of intentions and activities, allowing opportunities for consultation, discussion and feedback.
- Assurances of competitive market rates for consumers, and a suitable governing body and regulator should be established for this sector. Alternatively, a suitable complaints procedure established for the district heat network to alleviate consumer concerns about future issues and prices.

No solution is ever without its respective issues. As with other types of renewable technologies, biomass heating certainly has its place within the heating sector. The continuous innovations in energy efficiency in this sector coupled with building on learnings from previous case studies will hopefully result in the widespread utilisation of district heat networks in future communities.

Overall, biomass as part of a district heating network is a great idea and should be rolled out to more communities to help reduce the UK's carbon footprint. This should be considered more so in the case of new housing estates and at the initial planning stages. In this way, biomass heating is likely to play a significant part in reducing the carbon footprint of the UK's heating sector on our path to net zero.

[16] Birling Consulting. Biomass Heating – Common problems and their resolution. (Nov 2015) Available: BiomassProblemResolutionNov15.pdf (usablebuildings.co.uk)

[17] Energy Saving Trust. Rural Biomass Community Heating: A Case Study. Available: https://www.theade.co.uk/assets/docs/case-studies/Llanwddyn_Biomass_Case_Study.pdf

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