Grow Green, Burn Blue

A comparison of renewable heating options for different building heating needs including District Heating systems

Grow Green, Burn Blue

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1. Executive Summary

This report contains the outcomes of work package 5 of the "Grow Green, Burn Blue" project, prepared by Codema and Dowmann Ltd. for the Sustainable Energy Authority of Ireland (SEAI) Research, Development & Demonstration Programme. The report provides a comprehensive comparison of renewable heating technologies for various building types, with a focus on district heating systems and innovative fuel sources such as Intermediary Bioenergy Carriers (IBCs).

The study evaluates the techno-economic and environmental performance of a range of heating options, including heat pumps, biomass boilers, gasification systems, and district heating networks fuelled by waste heat, gas, standard biomass, and IBCs. It presents a series of representative residential and non-domestic use cases to identify optimal solutions based on heating demand, cost, system efficiency, and carbon emissions.

Emphasis is placed on the role of IBCs—solid, liquid, and gaseous fuels derived from biomass via pyrolysis—which demonstrate high energy density and lower carbon intensity compared to conventional biomass. These fuels show significant promise for integration into heating networks and industrial applications.

The report also explores the effectiveness of Heat Interface Units (HIUs) in district heating schemes, comparing single and twin plate exchanger configurations, and outlines the relevant policy and regulatory considerations, including alignment with UK and EU directives.

Using DEAP and iSBEMie modelling tools, the study conducts detailed energy and carbon assessments, producing cost-benefit analyses for different heating configurations. The findings highlight that district heating systems, particularly those incorporating IBCs or waste heat sources, can offer substantial long-term economic and environmental advantages, especially in mixed-use developments.

The report concludes with a decision-making framework and targeted policy recommendations to support the wider adoption of low-carbon heating technologies across Ireland.

2. Introduction

2.1 Codema

Codema is a semi-state body funded by the four Dublin Local Authorities. It acts as Dublin's Energy Agency and is committed to leading Dublin's low-carbon transition towards 2030 and 2050. It provides a wide range of energy and climate mitigation services to the four Dublin Local Authorities and other stakeholders in the region. It supports each council in leading and influencing the low-carbon transition by improving their energy efficiency, incorporating renewable energy technologies and reducing their greenhouse gas emissions.

2.2 Dowmann

Dowmann Ltd is an Irish company specialising in the development of advanced pyrolysis processes to maximise the potential of biomass and waste resources for the energy transition, circular economy, and decarbonisation. Dowmann can produce a variety of different products from waste biomass using pyrolysis. They split the biomass into solid, liquid and gaseous forms. Each form contains energy and can be applied to a different downstream application. Collectively, these products are known as Intermediary Bioenergy Carrier (IBCs) and are formed when biomass is processed via pyrolysis. The IBCs are **analogous to coal, oil, and gaseous fossil energy carriers** and have higher energy densities than their parent biomass.

2.3 Work Package 5 Brief

This work package aims to compare the renewable heating options for different building needs. A cost-benefit analysis of district heating systems using different fuel types and heat sources, including IBCs (as per figure 1), standard biomass, heat pumps and energy from waste (EfW) can been conducted to inform this comparison. Several representative scenarios of renewable heating use cases will be identified for comparison. The expected use cases include housing estates with commentary on their integration with multi-user developments, swimming pools, and industrial customers, among others.

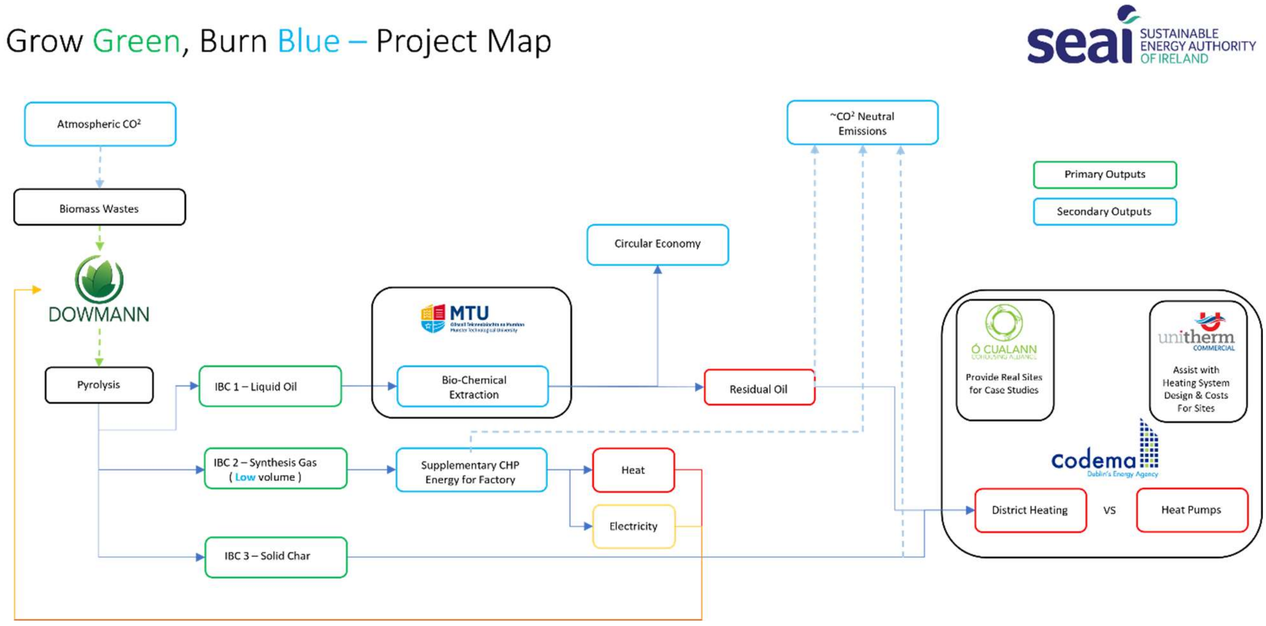

Figure 1: Grow Green, Burn Blue – High Level Project Map

The heating needs for these use case scenarios are expected to be modelled using DEAP & NEAP SBEMie software the following range of renewable heating option:

1) District Heating (Standard Biomass)
2) District Heating (IBCs in boiler)
3) District Heating (IBCs in CHP)
4) District Heating (Waste Heat from Energy-from-Waste Plant)
5) District Heating (Communal Heat Pumps)

Following this, it will inform policymakers by expanding upon the results of the cost-benefit analysis to include assessments of barriers to the uptake of the various renewable heating options, including IBC fuels. The ultimate objective of WP5 is to provide policymakers with a practical framework to promote the selection of the optimal renewable heating option for different building heating needs scenarios, which are laid out in clear policy recommendations.

2.4 Thermochemical Processes – What is Pyrolysis?

Biomass has traditionally been used for energy through direct combustion to produce heat. This process follows the fire triangle principle (Figure 2), where fuel and heat, in the presence of oxygen, trigger a thermochemical reaction (combustion) that releases the energy stored within the fuel.

However, an interesting phenomenon occurs when oxygen is removed from this equation. When biomass is heated in an oxygen-free environment, thermochemical reactions still take place, but without combustion or significant energy release. This process is known as pyrolysis and results in the separation of the parent biomass into solid (char), liquid (bio-oil) and gaseous (syngas) components known as IBCs. IBCs are energetically denser, more storable, and transportable than raw biomass, making them suitable for a variety of potential energy applications.

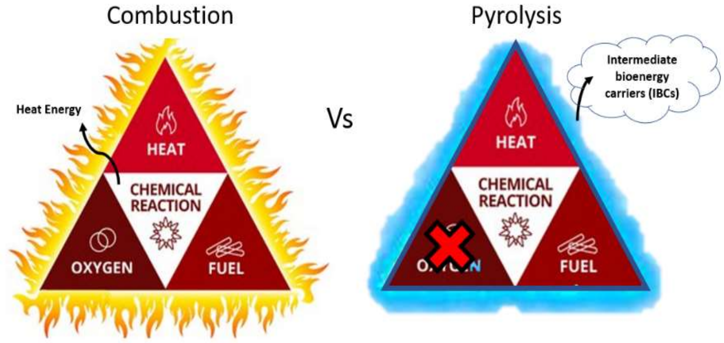

Figure 2: Illustration comparing combustion vs pyrolysis

Pyrolysis is defined as the thermal degradation of materials at temperatures ranging from 150°C to 1,000°C in an inert, oxygen-free environment. It is a well-known technique that has been used for centuries, particularly in charcoal production. However, traditional charcoal production is highly inefficient in terms of both resource and energy use. It can also result in the release of substantial amounts of CO_2, CH_4, and other greenhouse gases (GHGs).

2.5 What are IBCs?

Biomass is a challenging material for energy purposes. It is a complex organic mixture, it is extremely wet, more than 50% water in most cases, exceptionally bulky and generally of low value per unit weight, making it transport prohibitive over long distances. As an organic material, it is also prone to rotting if left outside or if not correctly stored. Biomass is composed of 3 main components, hemicellulose, cellulose, and lignin, in roughly equal proportions. Hemicellulose contributes least to the energy content of a biomass but contributes to almost 30% of its dry weight. Lignin however contributes the largest amount to the energy content of biomass. For energy purposes, a higher proportion of lignin is desirable.

Figure 3 - IBCs produced from Straw during the project by Dowmann – (L to R) Biomass, Solid, Liquid & Gas

Intermediate bioenergy carriers (IBCs)[1] (Figure 3), are considerably different in form and appearance compared to the initial biomass. Each IBC has unique characteristics which are suitable for different end use applications and can potentially be used directly for heat or power generation or further refined to final bioenergy or bio-based products.

The main objectives for processing biomass are to improve the physical or chemical fuel properties for the specific use case or to optimise the fuel supply chain (e.g. homogeneous fuel, high density and suitable for storage).

[1] Images provided courtesy of GGBB project.

At the outset of the project, the primary IBC of interest for district heating was IBC char due to its highly energy density.

2.6 How are IBCs made?

Depending on the processing time, temperatures and heating rates of the biomass, the yield and energy concentration of each IBCs can be altered or customised as desired. Slower heating rates during pyrolysis can thermally degrade the hemicellulose content of the biomass into gas, oils and tars that can be filtered out, while the cellulose and lignin contents remain as a solid char. This reduces a highly variable biomass to a highly carbonised and useful form, while increasing its energy density (from ~17 GJ/T to 32GJ/T). This in turn reduces its weight and volume for storage and transport. Faster heating rates produce higher yields of combustible oils and gases.

The proportion and characteristics of each IBC is entirely dependent on the feedstock type processing conditions and process pathway taken. In this way, specific desired properties can be obtained by altering the processing conditions to suit the final use case for each IBC. The pyrolysis processing temperature is the most influential factor in determining the yield and composition of IBCs.
As process temperatures increase:

- Biomass undergoes increasing levels of carbonisation
- More material is converted from the solid phase (char) to liquid (bio-oil) and gaseous (syngas) forms

The exact yield of each product is highly dependent on process temperature, residence time, particle size, and the type of biomass used. Therefore, pre-processing biomass is crucial to ensure a uniform feedstock enters the pyrolysis process, optimising efficiency and output quality. For this study, pre-process & dry biomass materials were used due to their uniformity and consistency during the testing phases.

2.7 Potential IBC Use Cases

The specific form and composition of the intermediate bioenergy carrier (IBC) influences its optimal use case — like how wood pellets and wood briquettes serve distinct niches. Wood briquettes are more commonly suited to manual stoves and open fires, while wood pellets are ideal for automated feed systems, including residential pellet boilers or commercial biomass plants.

The cascading use of biomass concept in the bioeconomy, prioritises material and biochemical applications first, with energy recovery as a last resort. This means that potentially higher value applications may exist for IBC's and only after such applications are satisfied should energy be considered.

IBC – Carbonised Biomass (Biochar, Bio-coal, Charcoal) (Overview & Applications):

- Direct combustion in high-efficiency solid fuel systems.
- Specialist industrial use (e.g. metallurgical coke replacement in steel or cement).
- Soil amendment substrate in agriculture, improving water retention and nutrient cycles.
- Long-term carbon sequestration, offering a stable and verifiable negative emissions pathway.

IBC – Pyrolysis Oil (Overview & Applications):

- Chemical feedstock potential: suitable for extracting valuable compounds prior to residual combustion.
- Combustion in large industrial boilers and cement kilns as a low-carbon fossil fuel replacement.

IBC – Synthesis Gas (Overview & Applications):

- Direct combustion for heat (e.g. kilns, furnaces).
- Use in combined heat and power (CHP) engines for local electricity and heat supply.

3. Optimal Heating System Selection for Different Use Case

3.1 Use Case Scenarios

Five use cases were selected to model for compliance, two domestic and three non-domestic. The two domestic use cases are a new apartment and a semi-detached house. The three non-domestic use cases are a leisure centre, a new office, and a retail unit.

The semi-detached building is a two-storey end-terrace new build in Ardmore village, Waterford. It has a total floor area of 87 m^2, split equally among both it's 43.5 m^2 floors. Including the gable, the height of the house is 9.53 m.

3.2 Heating Technologies

3.2.1 Residential Heat Pumps

A heat pump (HP) is a technology that extracts heat from a source (air, water, ground, etc) at a lower temperature and increases its temperature to then be injected into a building for space or hot water heating. It makes use of a refrigerant in a vapour-compression cycle - like a domestic fridge (Figure 4). Where a fridge extracts heat from an enclosed space to be rejected in another location, a heat pump extracts heat from an external source and injects it into a space.

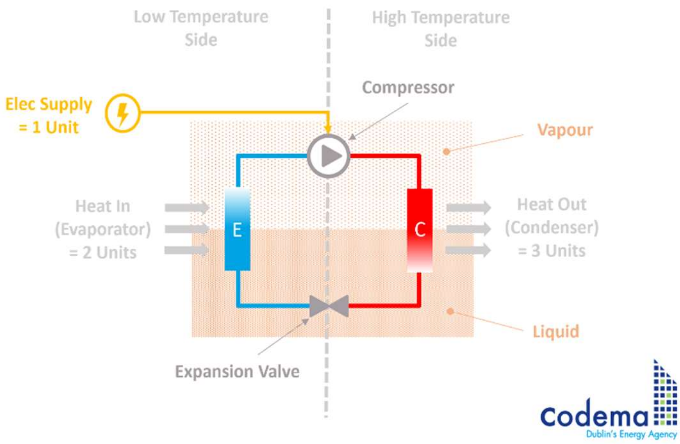

Figure 4 - Heat Pump Diagram

In the refrigeration cycle the heat pump undergoes, heat is absorbed from a source by the refrigerant as it is evaporated, a physical process that inherently absorbs heat. The refrigerant, as a vapour, is then placed under more pressure in a compressor. This is the only part of the process where electrical energy is input. With the refrigerant compressed, it is more readily able to release heat. It is passed through a condenser inside the building, heating the inside as it becomes a liquid. As a liquid, it is passed through an expansion valve, lowering its pressure so it is easier to evaporate as it interacts with the source, repeating the cycle. The performance of any heat pump is dictated by and varies with the temperature of the outside source, air in most cases.

Figure 4 shows the elements for a heat pump with a Coefficient of Performance (CoP) of three, i.e. three units of heat is produced for every unit of electricity consumed. The CoP is used in place of efficiency as a more accurate description of the Energy Input against the Heat Output. This is representative of the annual average efficiency of a well performing air-source heat pump. Current average CoP for heat pumps in Ireland is approximately 2.8 but it is believed that a CoP of 3 or higher will become easily achievable as designers and installers increase their experience of optimising heat systems which use heat pumps.

3.2.2 Monobloc Heat Pumps

Figure 5: Double & Single Fan Monobloc Heat Pumps

Monobloc heat pumps (Figure 5) consist of a single standalone unit. This unit houses all the necessary components - compressor, heat exchanger and water side of the refrigeration cycle. This compact design simplifies installation because it eliminates the need for refrigerant lines between the indoor and outdoor parts. Instead, water pipes connect the monobloc unit to the building's heating system, circulating heated water into the home for space heating or hot water production. They are popular in residential settings due to their efficiency, ease of installation, and lower maintenance compared to more complex heat pump systems. Monobloc heat pumps are particularly suitable for homes with limited indoor space, as the entire system remains outside, requiring minimal interior modifications.

Monobloc heat pumps are fully self-contained or standalone units which are hydraulically connected to the hot water cylinder or heating circuit inside the building. They do not require external refrigeration works and are supplied pre-charged from the manufacturer.

As the hot water is generated outside the building envelope and is pumped inside for use, some losses exist (5-10%) depending on the run length of the pipework and how well insulated these pipes are. Monobloc units' performance is slightly lower than that of a split unit.

3.2.3 Split Heat Pumps

A split heat pump (Figure 6) consists of two main components: an indoor unit (also known as an air handler or evaporator) and an outdoor unit (which contains the compressor and condenser). These two units are connected by refrigerant lines of copper pipe, allowing the system to transfer heat between the indoor and outdoor environments. The indoor unit can be "an integrated split" or a "hydrobox". The integrated split units contain an integrated pre-plumbed hot water cylinder and helps minimise plumbing works on site.

Figure 6: Single & Double Fan outdoor units with an Integrated Split and Hydrobox

A hydrobox is used mainly when a large buffer or existing hot water cylinder is already available or perhaps when multiple units are combined via a cascade system.

A split heat pump can be installed in various configurations, making them suitable for different types of buildings and room layouts. Multi-split systems allow multiple indoor units to be connected to a single outdoor unit, enabling individual temperature control in different rooms. Different rooms or areas can be set to different temperatures, increasing comfort and energy savings. Split heat pumps also come in different options such as with an integrated hot water cylinder (in various sizes 180-260Ltr) or without one whereby a third-party hot water storage cylinder is used.

Split heat pumps are typically more efficient as the hot water generation takes place within the building envelope itself in the indoor unit.

Split heat pumps require addition trade skills sets and services to correctly install them which can add further cost. A qualified F-Gas registered technician is needed to connect the indoor and outdoor units with copper and then charge tis refrigerant loop with the correct amount of the specified refrigerant.

3.2.4 Exhaust Air Heat Pumps

Exhaust air heat pumps (are a specific type of heat pump that captures heat from the warm, stale air being exhausted from a building's ventilation system. Essentially, it reuses the energy from waste air before it is expelled from a system. The system works in conjunction with a mechanical ventilation system, ensuring continuous airflow throughout the building while efficiently recovering heat that would otherwise be lost. These HPs are especially suitable for well-insulated, airtight buildings where there is a constant flow of exhaust air, such as in modern energy-efficient homes. They are particularly advantageous in climates where air-source heat pumps may struggle to extract sufficient heat from the outside air during colder months. Since they rely on indoor air for heat, they are less affected by outdoor temperatures. However, their performance is highly dependent on the volume of exhaust air available, which means they are best suited for buildings with mechanical ventilation systems. In buildings with low air exchange rates or poor insulation, the system may not be as effective, as there is less heat to recover.

3.2.5 Cascaded Heat Pump Systems

Cascaded heat pump systems are advanced thermal systems that utilise multiple heat pumps working in series to achieve higher levels of efficiency and performance. Two heat pumps are usually all that is needed for a cascading system, with some applications requiring three. The first heat pump in the series draws heat from a low-temperature source from which the temperature is then raised. Each following heat pump further increases the temperature to the desired level. An intermediate heat exchanger is placed in between each heat pump to act as a thermal bridge, allowing the heat pumps to work together efficiently.

There is no requirement for each heat pump to be the same, allowing for more flexibility in the of each heat pump, making use of different sizes and refrigerants. This combined with the efficiencies seen in splitting the temperature lift over two stages, makes cascading heat pumps extremely effective when the use case demand it.

This system is particularly advantageous in regions with extreme climates, where a single heat pump might struggle to maintain optimal temperatures. It is also used in industrial processes where high temperatures are needed, such as chemical processing, food manufacturing, and drying processes.

3.2.6 Large Centralised Heat Pump

Larger Air Source Heat Pumps (ASHPs) (Figure 7) are available for larger centralised system and can be cascaded to increase total capacity. These are typically located on the rough of buildings or in a dedicated energy centre. They operate in a similar fashion to residential heat pumps however more novel refrigerants are possible such as CO_2 or Isobutane etc, which can improve the overall efficiency of the unit and reduce their global warming potential.

Figure 7: Swegon "Blue Box" Commercial Heat Pump

Figure 8: Solid Energy MW Scale Commercial Heat Pumps

Megawatt scale centralised Air Source Heat Pumps (ASHPs) can play a pivotal role in modern district heating schemes by providing efficient and sustainable heat distribution (Figure 8). These systems consolidate heat production into a central location, reaping benefits such as enhanced energy efficiency, load balancing, and reduced environmental impact. By harnessing economies of scale, centralised ASHPs operate more efficiently and economically than individual building-based systems, resulting in significant energy savings. Flow temperatures as high as 85 Celsius are possible via a two-stage compression cycle. The centralisation facilitates optimised heat distribution across diverse building types and varying demands, ensuring stable performance. Moreover, the centralised approach allows for advanced emission controls and noise reduction measures, making these systems suitable for densely populated urban areas. ASHPs can be installed in any location in Ireland given the temperate climate, provided there is sufficient space and utilities to house the equipment at the site.

3.2.7 Combustion Technologies – Boilers

Boilers are a conventional heating system that work by burning fuel to heat water. Commonly used fuels are gas, oil, and biomass (often wood.) In most boilers, fuel is ignited in a combustion chamber, and the heat produced from this process is transferred to water via a heat exchanger. The hot water is then pumped through the building's heating system. Not all heat output by the fuel is collected by the boiler, in fact it is thermodynamically impossible to do so, with modern models featuring efficiency rates of around 90%. While they pale in comparison to heat pumps in terms of efficiency and carbon emissions (essentially less sustainable), boilers can produce high temperatures relatively quickly. Boilers can also be combined with heat pumps, being used in place of the heat

Figure 9: Wood Pellet Bulk Storage & Boiler – Courtesy of HDG & Glas.ie

source to "boost" the heat extracted by the fuels, enhancing the system's overall performance and flexibility. This configuration is sometimes referred to as a hybrid system.

Fuel storage and delivery systems (Figure 9) are tailored to individual site conditions, with options ranging from sack hoppers to purpose-built or adapted fuel stores near the boiler location. For greater convenience, prefabricated boiler houses and fuel stores can be supplied, ready for immediate on-site installation.

3.2.8 Biomass Gasification Technologies

Wood gasification systems (Figure 10) are a form of biomass-to-energy technology that convert wood and other carbon-rich materials into a combustible gas mixture, often referred to as "producer gas" or "wood gas." This gas can be used for power generation, heat production, or combined heat and power (CHP) applications. A variety of different gasifier systems exist.

Compact Gasifiers: Typically used in small to medium-scale applications, compact gasifiers offer decentralised energy production by converting biomass into energy at or near the point of use. These systems are valued for their simplicity, efficiency, and suitability in off-grid or localised settings.

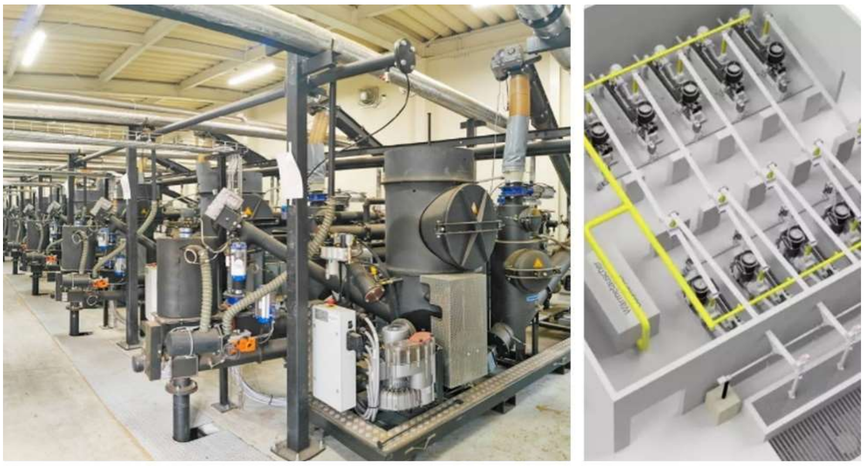

Figure 10 - Spanner Re2 HKA700 Biomass Gasification Energy Centre (Inside & Overview)

Modular Gasification Units: Modular systems are designed for flexibility and scalability. They allow components to be configured according to specific energy requirements and can be expanded incrementally. This makes them appropriate for applications where demand may increase over time or vary seasonally.

Combined Heat and Power (CHP) Systems: CHP gasification systems can produce both electricity and thermal energy from wood gas. This co-generation approach significantly improves overall energy efficiency, particularly in settings where both heat and electricity are needed, such as in industrial processes or district heating networks.

<u>**Key Characteristics**</u>

- **Efficiency**: Modern gasification systems are designed to optimise energy conversion, offering higher thermal and electrical efficiencies compared to traditional biomass combustion.
- **Renewability**: Wood gasification supports sustainable energy goals by utilising renewable biomass resources, reducing reliance on fossil fuels and contributing to carbon neutrality when feedstocks are sourced sustainably.
- **Scalability**: Systems can range from small-scale installations for rural or residential use to larger configurations suitable for industrial or municipal energy systems.
- **Integration Potential**: These systems can be integrated into existing energy infrastructure and are particularly useful in settings with reliable biomass supply chains and a local demand for both heat and power.

Wood gasification continues to gain interest as a versatile solution within the broader context of distributed renewable energy technologies.

3.3 Heat Interface Units (HIUs)

Heat Interface Units (HIUs) are essential components in district heating and communal heating networks, acting as an intermediary between a central heat source and individual dwellings (Figure 11). They allow buildings to benefit from a shared heating system while still providing independent control over heating and hot water for each residence.

HIUs eliminate the need for individual heating sources such as boilers and heat pumps within apartments or commercial spaces, instead using plate heat exchangers to transfer heat efficiently. This approach enhances energy efficiency, safety, and maintenance while supporting sustainability goals. Installation time per system is also simpler, faster and less costly compared to a dedicated system including the heat source.

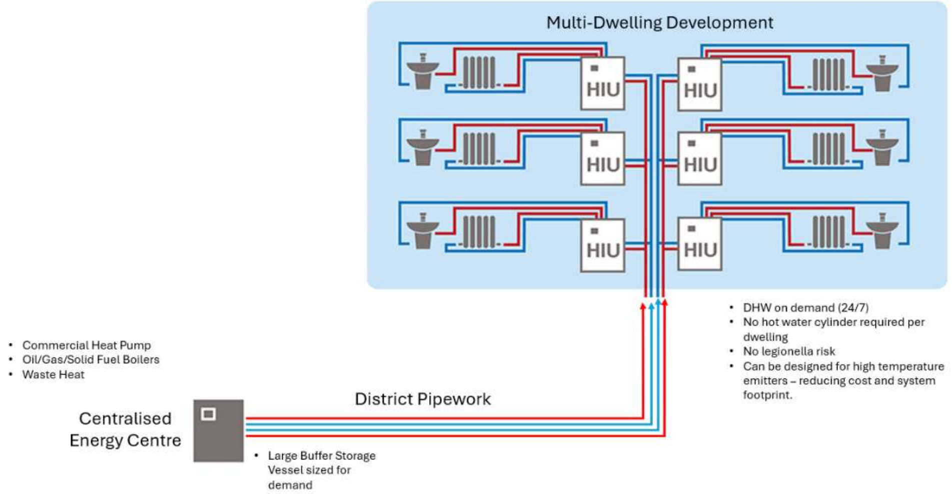

Figure 11: Conceptual layout of a District Heating Network incorporating Heat

Key Functions of HIUs:

1. Hot Water Supply: HIUs provide on-demand domestic hot water (DHW).
2. Space Heating: Supplies heating for radiators or underfloor heating.
3. Metering & Billing: Individual units track energy consumption for accurate billing.
4. Hydronic Control: Ensures proper temperature regulation and water flow.

One of the key design variations in HIUs is the type of heat exchanger used. The choice between a single plate and a twin plate heat exchanger depends on factors such as network design, efficiency needs, and hygiene requirements.

3.3.1 Single Plate Heat Exchanger HIUs (Direct Connection)

Single plate heat interface units (HIUs) (Figure 12) are devices used in buildings connected to district heating systems or central heating networks. They act as an interface between the building's heating system and the central heat source, providing an efficient and controlled way to distribute heat for space heating and domestic hot water.

The "single plate" in these units refers to the presence of one heat exchanger, which transfers thermal energy from the central network to the building's internal system. The use of a single heat exchanger simplifies the unit, making it compact and cost-effective, ideal for smaller residential applications or buildings with lower heating demand.

Figure 12: Single Plate HIU - Courtesy of Oventrop UK

A single plate heat exchanger HIU transfers heat from the primary network directly to the heating system in each dwelling. This setup is commonly used in direct HIUs, where the primary network water circulates through the apartment's radiators or underfloor heating without additional separation. A key benefit of single plate HIUs is their efficiency and reliability in managing heat distribution. Since they rely on a single heat exchanger, they are generally easier to install.

Advantages:

- Higher efficiency – Less heat loss compared to twin plate systems.
- Lower initial costs – Fewer components make it a cost-effective choice.
- Simple design – Easier installation with fewer parts.

Disadvantages:

- Risk of contamination – The primary water directly enters the dwelling's heating system, requiring strict water quality control.
- Not ideal for poor water conditions – Scaling and corrosion can be a concern in hard water areas.

3.3.2 Twin Plate Heat Exchanger HIUs (Indirect Connection)

A twin plate heat exchanger HIU uses two separate heat exchangers—one for heating and one for domestic hot water (DHW) (Figure 13). This design ensures complete separation between the primary and secondary heating circuits, making it the preferred choice in district heating schemes.

Advantages:

- No cross-contamination – The primary heating network remains separate, improving hygiene and reducing scaling risks.
- Ideal for variable pressure networks – Helps stabilise system pressure in older or high-rise buildings.

Figure 13: Twin Plate HIU - Courtesy Oventrop UK

- Compatible with diverse heating sources – Works well with district heating and renewable energy sources like heat pumps.

Disadvantages:
- Slightly lower efficiency – More heat transfer steps mean slightly higher losses.
- More components, higher cost – Requires additional piping and controls.

Common Applications:
- Single plate heat exchanger HIUs are suitable for low-rise apartment blocks and new-build developments where water quality is strictly controlled.
- Twin plate heat exchanger HIUs are preferred in district heating schemes, high-rise buildings, and retrofits where system separation is essential.

Typical Costs:
- Single Plate: € 1350 - 1550
- Twin Plate: € 1700 - 1900

Advantages of HIUs in Modern Heating Systems for Property Developers & Operators:
- Lower installation costs – Only three supply pipes needed per riser.
- Space-saving – Removes the need for gas flues and ventilation systems.
- Renewable-ready – Works with district heating, heat pumps, biomass, and solar thermal.
- Legionella risk reduction – No stored hot water, minimising bacterial growth.

For Residents:
- Consistent hot water and heating – Independent control within each dwelling.
- Better safety – No risk of gas or refrigerant leaks compared to traditional boilers or heat pumps.
- Lower maintenance – Primarily a simple mechanical device with few moving parts means less wear and tear and easier maintenance.
- Accurate billing based on meter readings – Integrated water and heat meters ensure fair and transparent costs.

Challenges & Considerations:
While HIUs offer multiple benefits, they come with certain limitations:
- Dependence on central systems – If the district heating network fails, all connected units lose heat.
- Initial infrastructure investment – Requires significant district heating setup costs.
- Scaling and corrosion risks – Nickel-brazed heat exchangers may be necessary in hard water areas.
- Efficiency depends on design – Poorly managed heat networks can lead to higher energy costs for end-users.

3.3.3 Building Engineering Services Association UK (BESA) HIU Test Standard

The BESA HIU Test Standard is a voluntary testing regime designed to assess and compare Heat Interface Units' performance. It aims to improve information for specifiers and enhance the user experience. The standard has been updated to include a modular approach, covering seven HIU types, and features a DHW load test. It provides evidence of compliance with performance metrics like DHW response times and offers assurance with pass/fail thresholds. This standard supports informed decision-making and drives manufacturers to improve their products, contributing to the efficiency and decarbonisation of heat networks.

The BESA standard requires the HIU to incorporate a PICV control valve for automatic balancing. This is not needed in all scenarios. Many EU HIU suppliers do not get their products tested to the BESA test standard. It is an added cost, voluntary and only recognised in the UK. Meeting the BESA test standard is optional in Ireland. This creates a barrier to entry for supplying and installing EU manufactured HIU's in the Irish market who choose not to test their products against the BESA standard. Clarity regarding what is and is not acceptable for installation of HIUs in Ireland should have a corresponding EU equivalent standard to allow EU manufacturers supply into the Irish market.

HIUs play a crucial role in modern, energy-efficient heating systems, offering space savings, safety, and sustainability. The choice between a single plate or twin plate heat exchanger depends on network design, pressure requirements, and contamination risks.

- For new developments with controlled water quality, a single plate heat exchanger HIU offers higher efficiency at a lower cost.
- For district heating, high-rise buildings, and retrofits, a twin plate heat exchanger HIU ensures better pressure stability and water hygiene.

With increasing pressure to adopt low-carbon heating solutions, HIUs will continue to be a key technology in the transition toward more efficient and sustainable heat networks.

3.3.4 HIU Policies

Several key reports and policy measures have been released in relation to HIUs on the EU level, which Ireland is subject to. It's also common for Irish standards to align closely with UK standards, with manufacturers and suppliers in Ireland often offering HIUs compliant with these broader regulations. While there isn't any specific EU or UK legislation exclusively governing HIUs, several directives and regulations impact their design, performance, and integration within heating systems.

Ecodesign Directive[2]: This directive establishes a framework for setting mandatory environmental performance requirements for energy-related products. It aims to improve the energy efficiency and overall environmental impact of products throughout their entire lifecycle. This means all manufacturers, including HIU manufacturers, must consider the entire lifecycle from the design stage, production, usage, and end-of-life disposal. This includes using environmentally materials, optimising manufacturing and usage efficiency, and facilitating disposal, reuse, and recycling. Under this directive, specific regulations, such as the Energy Efficiency Directive (2012) have been passed.

The **Energy Efficiency Directive (2012/27/EU)[3]** is a key policy tool designed to promote energy efficiency across the European Union. It mandates energy-saving measures across the energy chain, with relevance to district heating systems and HIUs. Recent revisions under the EU Green Deal have strengthened the directive, with increased emphasis on decarbonisation and renewable integration. It mandates that accurate metering of individual energy consumption is required, ensuring end-users are informed about their energy usage. HIUs often integrate metering capabilities to comply with this requirement. Member states are also encouraged to adopt measures that promote efficiency in heating and cooling systems, which can influence the deployment and standards of HIUs within district heating networks.

[2] Commission Regulation (EU) 2016/2281: https://eur-lex.europa.eu/eli/reg/2016/2281/2017-01-09/eng
[3] Directive 2012/27/EU of the European Parliament: https://eur-lex.europa.eu/eli/dir/2012/27/oj/eng

The **CIBSE Code of Practice CP1 (2020)**[4] provides comprehensive guidelines for the design, construction, and operation of heat networks in the UK. This is also relevant for Ireland, which largely mimics the UK standards. A key aspect of this code is the emphasis on the selection and application of control valves, which are essential for ensuring efficient and reliable operation of heat networks

For enhanced performance, the code recommends the use of pressure-independent Thermostatic Radiator Valves. These valves automatically adjust to maintain consistent flow rates despite fluctuations in system pressure, ensuring optimal heat distribution and comfort.

The code advises the installation of Differential Pressure Control Valves to maintain stable pressure conditions across control valves. By regulating differential pressure, these valves help prevent issues such as noise, wear, and inefficient operation, thereby extending the lifespan of system components.

The code also emphasizes the importance of proper system balancing to achieve design flow rates and temperatures. Balancing valves are essential tools in this process, ensuring that each part of the network receives the appropriate flow, thereby optimizing overall performance.

The **Building Engineering Services Association (BESA) HIU Test Regime**[5] is a UK-based standard designed to evaluate the performance of Heat Interface Units (HIUs) under conditions typical of UK district and communal heating networks. Developed in partnership with the Energy Saving Trust, FairHeat, and the UK Government (formerly DECC), it allows for consistent comparison of HIU performance to support efficient heat network design and operation.

The test regime evaluates a range of performance factors. Domestic hot water performance is tested to assess how quickly HIUs can reach the target temperature, their flow rate and volume capacity, and the stability of the water temperature during use. Space heating control is examined under varying load conditions to evaluate efficiency and accuracy.

The regime also assesses the energy use and heat losses associated with the HIU's keep-warm functionality, which maintains a ready supply of hot water. Another key metric is the return water temperature, which is critical for overall network efficiency. Lower return temperatures enable more effective operation of the district heating network. Additionally, the standing heat loss of the unit during idle periods is measured, along with performance under realistic differential pressure and flow conditions.

The BESA Test Regime provides a foundation for informed specification and procurement of HIUs. It encourages the selection of products that support lower return temperatures, which enhances network efficiency and reduces energy waste. The regime also helps ensure that HIUs deliver hot water quickly and maintain comfortable, stable heating for residents, contributing to a better user experience. Ultimately, it drives the market toward higher performing, more reliable units.

The BESA regime aligns with and supports the CP1, which outlines best practices for the development of heat networks in the UK. CP1 recommends the use of HIUs tested under the BESA regime to promote consistency, quality, and energy performance.

3.4 Heat Emitters

Heat emitters are simply a way to deliver heat into a space. This can be done in several ways, but the most common method is via radiators or underfloor heating. Underfloor heating has not been

[4] CIBSE CP1: https://www.cibse.org/knowledge-research/knowledge-portal/cp1-heat-networks-code-of-practice-for-the-uk-2020-pdf

[5] BESA website: https://www.thebesa.com/besa-latest-news/besa-launches-updated-and-expanded-hiu-test-standard

included in this study as it is a more expensive solution and is typically only an option for new buildings and is only suitable for retrofitting if substantial improvements to the building envelope are also being carried out. Underfloor heating is also limited to low flow temperatures due to the thermal limitations of floor screeds to prevent cracking.

Steel and aluminium radiators are two popular options for home heating systems, each with distinct characteristics and benefits.

Thermal Properties of Steel vs Aluminium Radiators

The thermal properties of steel and aluminium play a crucial role in their performance as radiator materials.

Figure 14: A typical steel double panel radiator

Thermal Conductivity

Aluminium has superior thermal conductivity compared to that of steel. This higher conductivity allows for rapid heat transfer from the water inside the radiator to the surrounding air.

Heat-up and Cool-down Rates

Due to the higher thermal conductivity, aluminium radiators heat up and cool down much faster than steel radiators. This makes them more responsive to temperature changes. Steel retains much of its heat for a longer period after the heating system switches off. This can be an advantage for maintaining a consistent room temperature.

Figure 15: A typical sectional aluminium

Thermal Mass

Aluminium radiators have a lower thermal mass, which contributes to their quick heat up and cool down properties. Steel has a higher thermal mass, and this allows steel radiators to act as a thermal buffer, gradually releasing heat over time.

Energy Efficiency

This is a potential area of disagreement among suppliers. Both aluminium and steel radiators are equally capable of heating the same space. Due to material properties, how fast they heat the space is the only difference between them. Example, if a room requires 1kWh of heat, a 1kW rated radiator can meet that requirement regardless of the material it is made from.
What is commonly referred to as "energy efficiency" is probably more accurately describing "response time" or how fast the heat is delivered to a space. Aluminium responds faster to both heating and cooling but is no more efficient (which is a measure of total energy in vs total energy out) at heating the space.
Additionally, both radiator materials are suitable for high and low temperature designed heating systems as demonstrated in Figure 17, however there are cost implications to be considered.

These thermal properties highlight the trade-offs between the two materials. Aluminium offers rapid response and potential energy savings, while steel provides consistent heat output and longer-lasting warmth.

Comparing Design Flow Temperatures

The below overview and analysis were performed on a sample house 2A provided by O'Cualann Cohousing Alliance and in accordance with the recommended Internal Design Temperatures as per SR50 design recommendations in *Table 17 - Appendix: Technical Information on Heating System Design.*

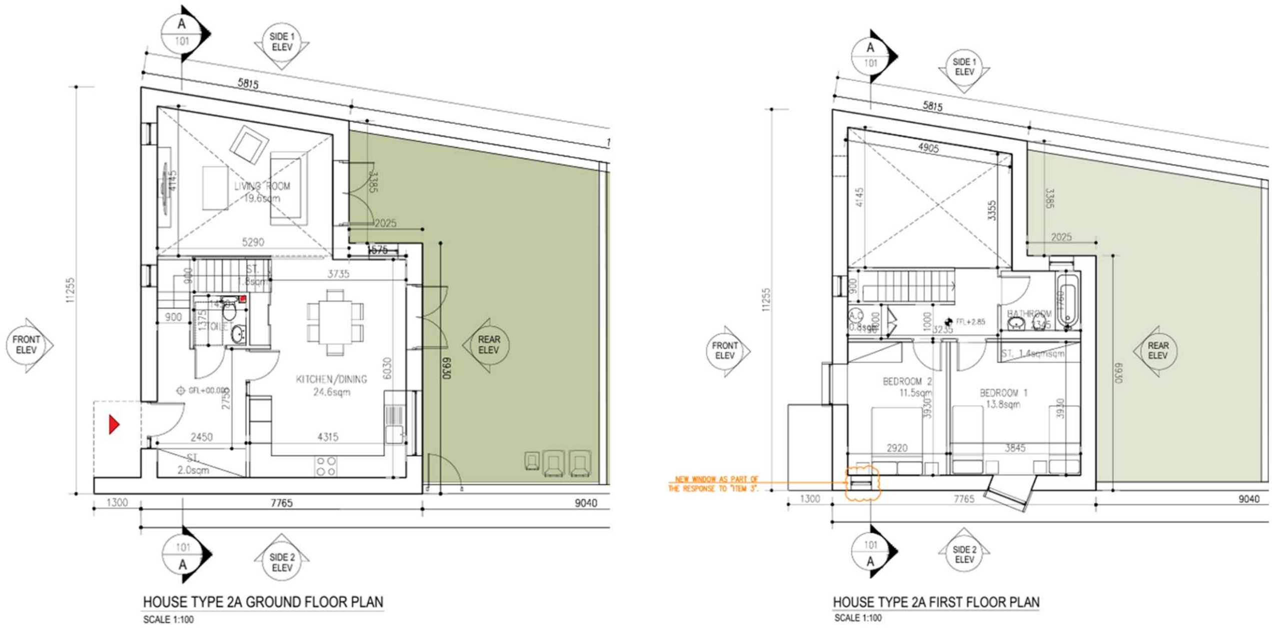

Figure 16: Sample House 2A as basis for below analysis

The floor areas and heating loads were calculated for sample house 2A based upon the specific internal design temperature requirements. The measurements and heat loads are shown in Table 1.

Table 1: Typical room types and sizes with heating loads and recommended design temperatures

Room Type	Room Name/Floor	Measured Area (m2)	Room Design Temp (°C)	Heat Load (W)
Living Room	Living Room (GF)	18.10 m2	21°C	724W
Kitchen/Dining	Kitchen/Dining (GF)	24.50 m2	21°C	980W
Toilet	Toilet (GF)	2.00 m2	18°C	80W
Storeroom	Storeroom (GF)	4.60 m2	16°C	184W
Hall	Hall (GF)	7.80 m2	18°C	312W
Bedroom	Bedroom (FF)	13.65 m2	18°C	546W
Bedroom	Bedroom (FF)	10.51 m2	18°C	420W
Bathroom	Bathroom (FF)	4.69 m2	22°C	188W
Landing	Landing (FF)	4.62 m2	18°C	185W
Storeroom	AC (FF)	3.56 m2	16°C	142W

All prices are shown in Figure 17 are "list" prices excluding vat and are prior to any contractor or project discounts being applied.

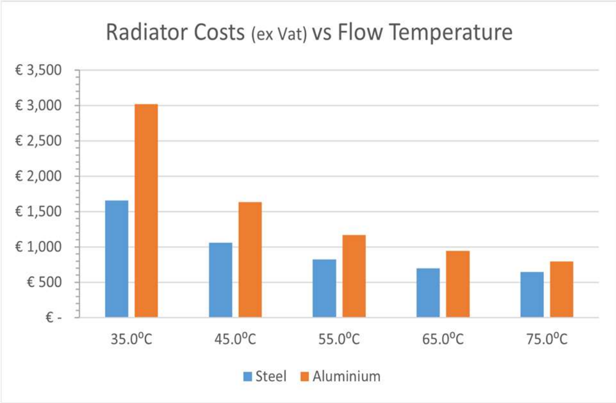

Figure 17: Steel & aluminium Radiators Costs vs

At lower flow temperatures, steel radiators are considerably more cost effective per unit of heat delivered than aluminium radiators. Underfloor heating is more expensive per unit of heat required than for steel or aluminium. Underfloor heating is only suitable for low temperature applications <(45C) due to the potential to crack floor screeds above this design temperature. Aluminium radiators are generally more aesthetically pleasing and can accommodate more complex manufacturing processes compared to steel radiators. At increasing flow temperatures, the cost difference between steel and aluminium starts to converge with aluminium radiators being slightly more expensive due to physical material cost differences between steel and aluminium.

Design decisions to lower heating system flow temperatures increases costs in other areas, such as heat emitters. While this may be acceptable for one off dwellings or small schemes, it is incredibly cost inefficient for larger schemes, even accounting for bulk purchasing discounts.

The same amount of energy is required to adequately heat each space regardless of flow temperature. i.e. there is no energy saving to be made. The dwellings heating needs are a function of the fabric and ventilation of the building not the design flow rate. This design choice is typically made due to the performance reduction of heat pumps with higher temperature demands.

As flow temperatures increase, less radiator surface area and physical material are required. This has significant impact on materials costs and wall/floor space occupied by radiators. Higher flow temperatures such as 75⁰C, are common for boilers, district heating and high temperature commercial heat pumps systems. It would therefore raise for consideration, that there should be a decision matrix based upon building heat demand and density per hectare to help guide the designers as to the most cost-effective heating solution. This is a special consideration for social housing.

3.5 IBC Fuels

Intermediate Bioenergy Carrier fuels, as described in section 2.5, are processed to energetically denser, more storable, and transportable intermediary bioenergy products with energy performance analogous to non-renewable fuels. IBCs can be directly used for heat and energy generation. Each IBC type is suited to different end use applications.

Figure 18 compares the energy density of different IBCs to their parent biomass as well as conventional fuels. IBCs consistently sit somewhere between biomass and fossil fuels in terms of energy density.

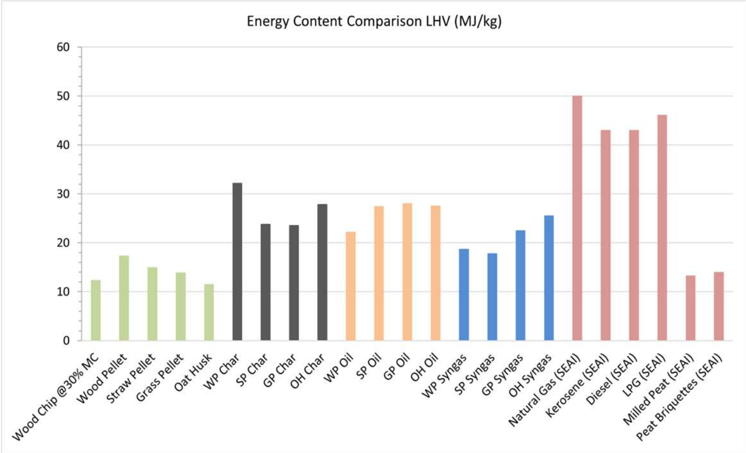

Figure 18: IBC's vs Conventional Fuels Energy Basis per Kilogram

IBC Chars Have Among the Highest Energy Densities in the Dataset

IBC chars (especially wood char and oat husk char) reach up to ~32 MJ/kg, surpassing all conventional biomass fuels and approaching the energy content of fossil fuels. This positions them as high-performance solid fuels, suitable for dense energy storage and specialist combustion applications.

IBC Oils Offer Competitive Mid-Range Energy Output

IBC oils from all feedstocks consistently deliver energy densities higher than parent biomass fuel. Their liquid form and energy content make them a promising candidate for renewable fuel substitution in industrial heat applications. IBC oils are more acidic than conventional fuels which limits their use in conventional boilers and engines. Further refining is also a possible avenue of exploitation.

Syngas from IBCs Shows Modest Energy Content, but High Cleanliness

Although IBC Syngas has the lowest energy density of the IBCs (up to ~25.5 MJ/kg), it does surpass other biomass fuels with ultra-low carbon emissions (see Figure 19). This makes it ideal for clean, decentralised electricity or CHP systems.

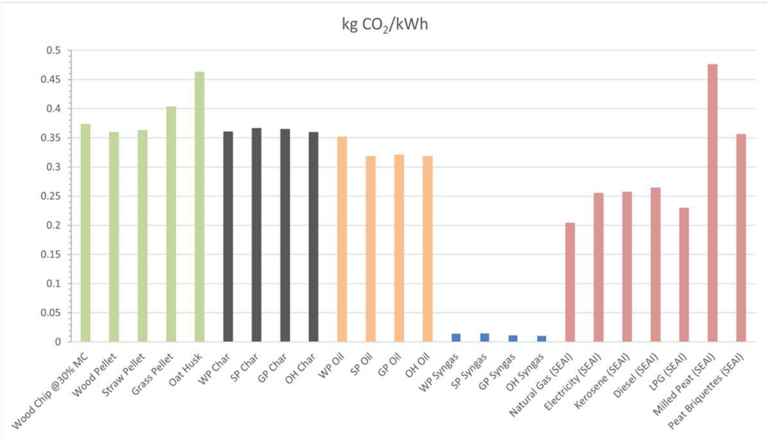

Figure 19: Carbon Emission Factors of IBC's vs Starting Biomass & Fossil Fuels

Figure 19 compares the carbon intensity of each IBC, biomass and conventional fuel on a kilowatt energy basis. IBC Syngas is incredibly low in carbon emissions due to its elevated levels of hydrogen and is therefore considerably cleaner than all other fuel options.

3.5.1 IBC Solid Char

The IBC char can be named differently depending on the processing temperatures used to create it. At temperatures up to 300 Celsius, it is commonly referred to as "torrefied (roasted) biomass" or "bio-coal" and usually contains up to 30% more energy per kg compared to standard dried biomass fuels.

As the processing temperature increases toward 600 Celsius, so does the energy density per kg as shown in Figure 18. The biomass becomes darker in appearance and brittle like charcoal. It is usually referred to as "carbonised biomass", "char" or "biochar". It is important to differentiate between char and biochar. For the purposes of this study, the char was envisaged to be used as fuel in a solid fuel boiler.

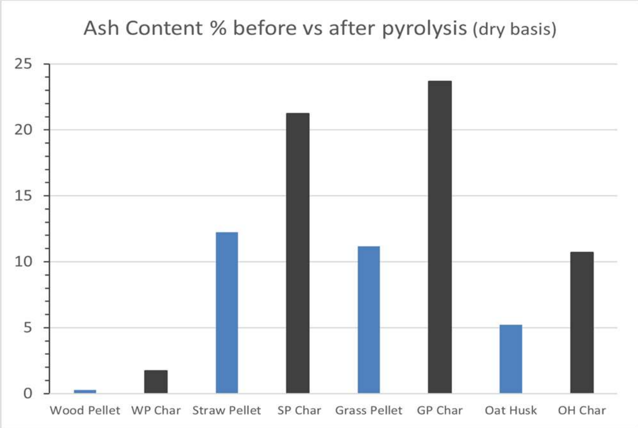

Figure 20: Comparison of pre & post pyrolysis ash content of biomass vs IBC chars

Across all biomass types (Figure 20), ash content significantly increases following pyrolysis. For instance, grass ash levels rise from ~11% to ~23% in its char form. This is expected, as pyrolysis removes volatile matter and concentrates inorganic residues in the remaining solid fraction. In practice, the effect of ash concentration will restrict the use of non-woody biomasses in boilers due to fouling. Perhaps IBC char blending could be a strategy to dilute the high ash content for boilers.

Low Initial Ash Biomass Yields Cleaner Chars

Wood pellets, with very low initial ash content (~1%), produce chars with correspondingly low ash levels (~2%). This makes them ideal for high-quality solid fuels where low ash is critical — for example, in boilers or stoves sensitive to slagging and fouling.

Ash Handling Considerations for End-Use Applications

Biomass types with inherently higher mineral content (e.g. straw, grass) lead to chars with ash levels above 20%, which may limit their usability in certain thermal systems. These findings highlight the importance of feedstock selection and post-processing (e.g. ash removal or blending) for practical deployment.

While fuel grade carbonised biomass was produced from wood, perhaps combustion is not the most beneficial use case for society as this would serve to increase total CO_2 emissions. The combustion of biomass, while considered carbon neutral by many, still produces CO_2 and contributes to global warming. 1 tonne of pure carbon fuel if combusted creates 3.6 tonnes of CO_2 emissions. What is interesting about the pyrolysis process is that the carbonised biomass becomes more environmentally stable with increasing processing temperatures. This creates an alternative possible use case as carbon sequestration media.

3.5.2 IBC Bio-Oil

In fuel applications, bio-oils can be used directly in industrial burners or modified engines designed to handle their higher viscosity and acidity compared to conventional fuels. Bio-oils can contain higher levels of moisture depending on how they are created which can alter combustion performance. In the *Grow Green, Burn Blue* project, bio-oils produced from non-forestry biomass were tested and found to have similar characteristics to heavy fuel oil. These qualities make bio-oils particularly suitable for hard-to-decarbonise sectors like cement manufacturing, where they can substitute for fossil-based kiln fuels, thus reducing emissions and promoting circularity. As an out-of-scope exercise, samples of bio-oil were provided to a cement producer who validated the suitability of the oil within their cement kiln and confirmed there were no identified obstacles to this use case on site. More standard applications such as in district heating or conventional engines or boilers is unlikely due to the properties of the fuel unless further refining is carried out.

3.5.3 IBC Syngas

IBC syngas is a renewable fuel gas produced through the thermochemical conversion of biomass, typically using a process like pyrolysis or gasification. During this process, biomass materials—such as agricultural residues, green waste, or non-forestry feedstocks—are heated in a low-oxygen or oxygen-free environment, causing them to decompose into a mixture of gases. The resulting syngas primarily consists of hydrogen (H_2), carbon monoxide (CO), and methane (CH_4), all of which are combustible and can be used directly for heat, electricity generation, or as chemical feedstock.

An unexpected outcome of the project is the sheer volume of IBC syngas produced. Initially this was anticipated to only be produced in low volumes. As process temperatures were increased, greater volumes of IBC syngas were produced. Syngas generated from non-forestry biomass was found to be richer in clean combustibles than initially anticipated, offering a low-carbon alternative energy source (fig 19) with potential integration into grid electricity or district heating systems. Storage of IBC syngas is not a practical option and therefore it needs to be converted to energy as it is being produced via a combined heat & power unit.

Dowmann produced Syngas with carbon intensities per kWh, 20 times lower than commercially available natural gas and 17 times lower than grid electricity. This highlights the potential impact of IBC Syngas as a power decarbonisation tool. Syngas can burn clear or with a blue flame depending on the gas composition. This characteristic gave the project its name, “Grow Green, Burn Blue”.

4. Methodology

The iSBEM and DEAP methodologies serve different purposes in building energy assessments within Ireland. iSBEM (Simplified Building Energy Model) is used primarily for assessing non-residential buildings, or, buildings other than dwelling, under the Building Energy Rating (BER) framework. It calculates energy performance and carbon emissions based on standardized input data, focusing on a building's compliance with Part L regulations for non-domestic properties. iSBEM considers factors such as building fabric, HVAC systems, lighting, and occupancy patterns.

On the other hand, DEAP (Dwelling Energy Assessment Procedure) is used for residential buildings (dwellings) in Ireland. It specifically assesses energy performance for dwellings, providing a Building Energy Rating (BER) label. DEAP considers the thermal properties of the building, heating systems, and renewable energy contributions. Unlike iSBEM, DEAP is tailored to the unique characteristics and energy usage patterns of residential properties.

In summary, iSBEM relates to non-residential buildings with a focus on broader energy compliance, while DEAP is specialized for residential buildings, offering detailed insights into household energy efficiency. Both focus on compliance with Part L.

4.1 Part L

Part L of the Building Regulations sets out requirements in relation to the conservation of fuel and energy. First published under Article 7 of the Building Regulations 1997, it has since been updated in 2022 to include the EPBD requirement for Nearly Zero Energy Buildings (NZEBs). A NZEB, as per the EPBD, is defined as "a very high energy performance, as determined in accordance with Annex 1. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby." Its goal is to limit the use of energy and related CO_2 emissions arising from the operation of buildings, while ensuring that occupants can achieve adequate levels of lighting and thermal comfort, as far as is practical. Ultimately, it is a commitment to the clean energy transition, energy efficiency and decarbonisation of the building stock.

For New Dwellings, the criteria used are

- Primary Energy Consumption and Related CO_2 Emissions
- Use of Renewable Energy Sources
- Fabric Insulation
- Air Tightness
- Heat Generation
- Building Services Controls
- Insulation of Pipes, Ducts, and Vessels
- Mechanical Ventilation Systems
- Limiting Heat Gains
- Performance of Completed Dwelling

For Existing Dwellings, the criteria used are

- Fabric Insulation
- Air Tightness
- Heat Generation
- Building Services Controls
- Insulation of Pipes, Ducts, and Vessels

4.1.1 Renewable Energy Technologies

To be Part L compliant, there is a minimum level of the energy used by the dwelling that must come from renewable technologies. It uses the ratio of primary energy from renewable technologies to the total primary energy, known as the Renewable Energy Ratio (RER).

The RER is considered alongside the Maximum Permitted Energy Performance Coefficient (MPEPC) and the Maximum Permitted Carbon Performance Coefficient (MPCPC) to determine compliance. Both EPC and CPC are calculated by comparing the dwelling's performance to that of a reference building. By diving either the primary energy consumption or the CO_2 emission rate by that of DEAP's reference building, the energy performance coefficient or carbon performance coefficient can be found (respectively.) The allowable MPEPC is 0.3 and the allowable MPCPC is 0.35.

If a combined heat and power (CHP) system that contributes to both the space and water heating is in use, then an alternative to the RER would be accepted. This is only accepted if the primary energy savings due to the use of CHP are equivalent to the RER of 0.20.

4.1.2 Building Fabric

Fabric insulation looks at how much the building envelope resists heat loss. The thermal transmittance (aka "U-value") is a measure of the rate at which heat passes through that component or structure when unit temperature difference is maintained between the ambient air temperatures on each side. It is expressed in units of Watts per square metre per degree Kelvin of air temperature difference ($W/m^2 K$). Part L prioritises elements directly or indirectly exposed to the outside air. Elements exposed to the ground, voids, and unheated spaces are considered when appropriate. Heat loss through elements that separate dwellings or other premises that can reasonably be assumed to be heated, is negligible.

4.1.3 Building Services

Building services refer to the systems within a building that manage heating, cooling, ventilation, lighting, and hot water supply. These services are designed to be energy-efficient, ensuring that they operate with minimal energy waste. This includes using appropriate controls to adjust system operations based on demand, insulating pipes and ducts to reduce energy loss, and commissioning systems properly to ensure they function as intended. In non-domestic buildings, metering is required to monitor energy usage, and regular maintenance is necessary to sustain long-term efficiency, ultimately promoting reduced energy consumption.

4.2 Modelling Software

4.2.1 iSBEMie

The Simplified Building Energy Model (SBEM) is a widely used software tool designed to assess the energy performance of non-domestic buildings, particularly in the context of regulatory compliance. In Ireland, SBEM plays a crucial role in evaluating the energy efficiency of new and existing non-domestic buildings to ensure they meet the standards set out by national building regulations. The tool simulates a building's energy usage based on its construction, systems, and occupancy patterns, providing an energy performance rating that helps in achieving compliance with the Building Energy Rating (BER) requirements.

In the Irish context, SBEM is instrumental in aligning with the European Union's Energy Performance of Buildings Directive (EPBD), which mandates that all buildings must meet specific energy performance criteria. The SBEM methodology is used to generate the BER, which is essential for the sale or rental of buildings, as well as for planning and building control purposes.

To facilitate the use of SBEM in Ireland, the iSBEMie software was developed. iSBEMie is an Irish-specific implementation of the SBEM tool, adapted to meet the climatic, regulatory, and construction practices in Ireland. This software allows users to input data specific to Irish building practices, including local weather conditions, typical construction materials, and system specifications. iSBEMie then uses this data to generate accurate BER assessments that comply with Irish regulations, namely the Irish Building Regulations Technical Guidance Document Part L, which deals with the conservation of fuel and energy in buildings. The latest version as of writing is version 5.6a. This version updates the primary emission factor and carbon emission factor for grid supplied electricity

iSBEMie is suitable for various applications related to the energy assessment of non-domestic buildings in Ireland, the main three being regulatory compliance, design optimisation, and energy audits.

For regulatory compliance, iSBEMie is used to generate Building Energy Ratings (BER) for new constructions, major renovations, and existing buildings that are being sold or rented. This is mandatory under Irish law.

For design optimisation, architects and engineers can use iSBEMie to explore different design options and optimize the building's energy performance before construction begins. This can include testing various insulation levels, HVAC system configurations, or lighting strategies.
For energy audits, iSBEMie can be used to evaluate existing buildings, identify areas for improvement, and recommend upgrades to enhance energy efficiency.

There are several stages to inputting a building in iSBEMie:

1) Enter general information about the building, the client who commissioned the calculation, and the assessor, and select the appropriate weather data.

2) Build up a database of the different forms of constructions and glazing types used in the fabric of the building.

3) After "zoning" the building (on the drawings), create the zones in the interface, and enter their basic dimensions, along with the air permeability of the space.

4) Define the envelopes of each zone, i.e., walls, floor, ceiling, etc. The envelopes' areas, orientations, the conditions of the adjacent spaces, and the constructions used all need to be defined.

5) Within each envelope element, there may be windows/rooflights or doors. The areas and types of glazing or door within each envelope element need to be entered.

6) Similarly, within the envelope elements or within the window/door, there may be additional thermal bridges which need to be defined.

7) Define the HVAC (heating, ventilation, and air conditioning) systems, the HWS (hot water systems), and any SES (solar energy systems), PVS (photovoltaic systems), wind generators, or CCHP (combined cooling, heat, and power) generators used in the building.

8) Define the lighting system and local ventilation characteristics of each zone and assign the zones to the appropriate HVAC system and HWS.

9) Run the calculation and assess compliance or generate a BER

iSBEMie uses a detailed methodology to calculate key factors that contribute to the Building Energy Rating (BER) assessment of non-domestic buildings in Ireland. The methodology involves simulating the building's energy performance based on a variety of inputs and assumptions. Here are some key factors and how iSBEMie calculates them:

Heating and Cooling Demand
iSBEMie calculates heating and cooling demand by modelling the building's thermal performance, considering factors such as insulation levels, building orientation, window-to-wall ratio, and local climate data. The software simulates heat losses through the building envelope to calculate the energy required to maintain a comfortable indoor temperature.

Energy Consumption of HVAC
The energy consumption of HVAC systems is determined by considering the efficiency of the installed systems (e.g., boilers, chillers, heat pumps) and how they are operated (e.g., temperature setpoints, operation schedules). iSBEMie uses predefined performance data for various HVAC systems and calculates the energy required to meet the heating and cooling demands, but these can be changed manually

Hot Water Energy Demand
Hot water energy demand is calculated by assessing the usage patterns of the building (e.g., number of occupants, type of building use) and the efficiency of the water heating system. iSBEMie estimates the volume of hot water needed and calculates the energy required to heat this water, adjusting for system losses and efficiencies.

Lighting Energy Use
iSBEMie calculates lighting energy use based on the type and efficiency of lighting systems installed, the layout of the building, and the lighting control strategies employed (such as occupancy sensors or daylight dimming). The software considers both the installed lighting power density and operational hours to estimate the total annual energy consumption for lighting.

Renewable Energy Contributions
iSBEMie accounts for the contribution of on-site renewable energy systems, such as solar photovoltaic panels or solar thermal systems. The software calculates the amount of renewable energy generated based on system specifications, orientation, and local climate data, and subtracts this from the building's total energy demand.

Overall Energy Performance
The overall energy performance is determined by summing the calculated energy consumption from heating, cooling, ventilation, hot water, and lighting, and then adjusting for any contributions from renewable energy systems. This total energy consumption is then used to calculate the Building Energy Rating (BER), which is expressed on a scale from A (most efficient) to G (least efficient).

Carbon Emissions
Carbon emissions are calculated by applying standard emission factors to the energy consumption figures, considering the type of fuel used for heating, cooling, and electricity. The software converts energy use into equivalent Carbon Dioxide (CO_2) emissions, which are then reported as part of the BER assessment.

iSBEMie, like all modelling tools, operates on a set of assumptions to simplify the complex task of energy performance simulation. These assumptions include:

- **Standardised Occupancy Patterns:** iSBEMie assumes typical usage patterns for different types of buildings (e.g., offices, schools, retail spaces) based on standardised profiles. This may not perfectly match actual occupancy in all cases.
- **Simplified Geometry Representation:** While iSBEMie requires detailed inputs, it still simplifies the building's geometry into zones, which may not capture every nuance of the building's physical structure.
- **Default Values:** If the Building Energy Rating calculation has made extensive use of default values, some of the recommendations may be based on uncertainties. Any assumptions made must err towards a less efficient plant and/or less precise control.
- **Uniform Thermal Properties:** The software assumes consistent thermal properties across similar construction elements, such as walls or windows, which may overlook minor variations in material performance.

4.2.2 Indicative buildings

Buildings of different case examples were pulled from the iSBEMie software. The buildings modelled were real buildings taken to be an example of their use cases.

Table 2: Reference demands of Indicative Buildings

Building	*Office*	*Community Centre*	*Library*	*Swimmin g Pool*	*Fire Station*	*Park (with café)*
Year Constructed	2007	2001	2012	1968	1901	2009
Floor Area (m2)	710	2734	1581	749	914	1258
Space Heating Demand (kWh/yr/m2)	28.22	72.17	13.56	13.56	523.69	179.89
Hot Water Demand (kWh/yr/m2)	2.38	65.95	14.62	14.62	802.76	141.86
Auxiliary Demand (kWh/yr/m2)	105.95	28.56	4.32	4.32	581.36	9.83
Space Heating Demand (kWh/yr)	20036.2	197312.78	21438.36	392243.81	164419.46	248857.56
Hot Water Demand (kWh/yr)	1689.8	180307.3	23114.22	601267.24	129660.04	18656.14
Auxiliary Demand (kWh/yr)	75224.5	78083.04	6829.92	435438.64	8984.62	448275.72

4.2.3 Domestic Energy Assessment Procedure (DEAP)

The DEAP (Dwelling Energy Assessment Procedure) methodology is Ireland's official tool for assessing the energy performance of residential buildings and generating Building Energy Ratings (BER). Managed by the Sustainable Energy Authority of Ireland (SEAI), DEAP is used for both new and existing dwellings. There are several key components to the DEAP Methodology, such as:

- **Data Collection:** The process begins with the collection of detailed information about the dwelling, including its dimensions, construction materials, insulation levels, window types, and air tightness. Information on the heating system, hot water generation, ventilation, lighting, and any renewable energy systems is also gathered.

- **Energy Calculations:** DEAP calculates the energy required to heat the dwelling, provide hot water, and power the lighting. It considers factors such as climate, occupancy, and usage patterns. The calculation includes the heat losses through the building fabric (walls, roof, windows) and gains from sunlight and internal sources.

- **Primary Energy Use and CO_2 Emissions:** DEAP converts the calculated energy usage into primary energy (which includes the energy used in production and delivery of the energy) and estimates the associated CO_2 emissions. This helps assess the overall environmental impact of the dwelling.

- **Building Energy Rating (BER):** The results are expressed as a Building Energy Rating, ranging from A1 (most efficient) to G (least efficient). The BER provides a clear indicator of the dwelling's energy efficiency, helping owners, buyers, and tenants make informed decisions.

- **Recommendations:** The DEAP assessment often includes recommendations for improving energy efficiency, such as upgrading insulation, improving heating systems, or installing renewable energy sources.

DEAP can be used for several applications. It is used to ensure new dwellings meet the energy performance standards set out in the Part L, and to determine the current energy efficiency and suggest improvements for existing dwellings. Homeowners may also use DEAP assessments to qualify for government grants aimed at improving energy efficiency.

<u>**Carbon Comparisons**</u>

Figure 21 provides a comparison of the different DH and individual heat supply solutions and the carbon content of the heat provided by each of these. This comparison considers the carbon content of the fuels used, the efficiency of heat production[6] and the losses (heat network and hot water cylinder losses). It should be noted that the use of IBC fuels for CHP plants shows a negative value this is due to the offsetting of grid electricity by this unit. As the grid decarbonises the carbon content of this heat source will increase.

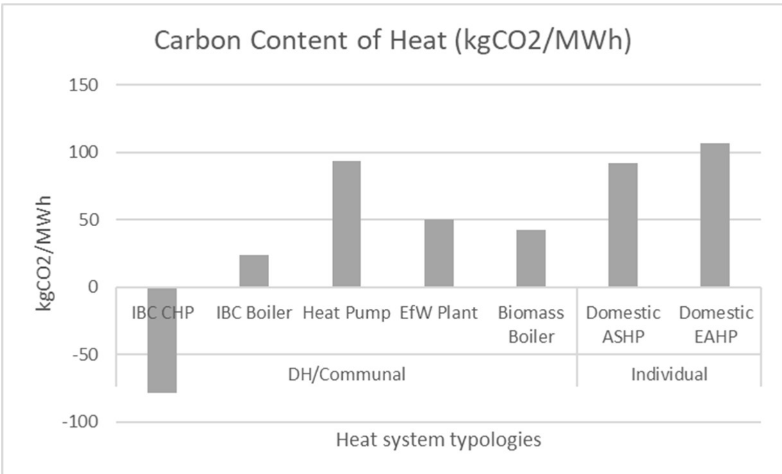

Figure 21: Carbon content of heat comparison graph

[6] The efficiencies used for individual exhaust air and air source heat pumps are from a UK study of over 750 heat pumps

5. Techno Economic Comparisons

This section of the report looks to compare individual building-level heat pumps with a site-wide communal network from a techno-economic perspective for new residential developments. It should be noted that the results from this analysis are likely to give a conservative estimate of viability for district heating due to several factors, these include:

- This analysis focuses mainly on residential developments and may not capture the full diversity of demand that exists in many areas. Generally, a mix of domestic and non-domestic building would result in a better economic case for a network

- It is being assumed that the primary heating plant of the DH network covers 50% of the full peak of demand – this is a conservative estimate as, the primary plant is typically sized to only cover approximately 1/3 of the peak with thermal storage and less capital-intensive backup plant used to cover peak periods

- The lifespan being investigated is 25 years in line with typical investment horizons – the full value of a DH network may not be realised within this timeframe since DH networks have a lifespan that is typical more than double this period

- DEAP models have been used to estimate the heat demands connected to the network – DEAP generally significantly underestimates the actual heat demand of new energy efficient buildings. This directly effects the heat density of the development which is one of the main drivers for the economic viability of heat networks

- The domestic peak heat demands were taken as being the rated capacity of the proposed heat pump for the purposes of sizing the DH network. It should be noted that this is likely an overestimation of the peak demand

5.1 Assumptions & Methodology

5.1.1 Heat Demand

5.1.1.1 Domestic Heat Demand

Annual domestic heat demands were calculated using DEAP software. The demands for the houses and apartments used in this analysis are set out in Table 3. It was assumed that the dwellings would be built to nZEB standard. It should be noted that using DEAP as a means of estimating actual heat demand is likely a conservative estimate due to the commonly acknowledged existence of a performance gap between modelled and as-built dwellings (where models of buildings with a high energy efficiency rating typically underestimate heat demand).

Detailed dimensions were not available for the dwellings for the Dublin-based site on which the DH analysis is based. However, detailed dimensions for similar dwellings on which the same developer is working were used to estimate the annual heat demands. These annual demands for the most relevant dwelling types are shown in Table 3.

Table 3: Annual Domestic (House) Heat Demands from DEAP Modelling

Dwelling Type	Bed	Floor Area (m2)	Heat Demand (MWh/yr)
Type A	4 Bed	79.50	6.946
Type E	3 Bed	90.05	7.075

These relevant house types were used to develop a weighted average heat demand per house. The weighted average heat demand of 6,989 kWh/yr per house was used for this analysis.
The Dublin-based site on which the DH analysis is based also has a small number of apartments on it. The geometry of these apartments was not available at the time of writing this report and hence indicative heat demands from DEAP models for similar sized nZEB apartments have been used to inform this analysis. Table 4 shows that assumed annual heat demand per apartment type. An average figure of 3,056 kWh/yr per apartment was used for this analysis.

Table 4: Annual Domestic (Apartments) Heat Demands from DEAP Modelling

Dwelling Type	Floor Area (m^2)	Heat Demand (MWh/yr)
Apartment	51.1	2.774
Apartment	65.6	3.047
Apartment	66.6	3.066
Apartment	80.5	3.338
	Average	**3.056**

5.1.1.2 Non-Domestic Heat Demand

Non-domestic heat demands were estimated using NEAP/SBEM models for various forms of existing non-domestic buildings as set out in Table 5. These building types include offices, community centre, library, swimming pool, and fire station.

Table 5: Heat Demands Calculated for Non-Domestic Buildings Using SBEM/NEAP

Building	Office	Community Centre	Library	Swimming Pool	Fire Station
Year Constructed	2007	2001	2012	1968	1901
Floor Area (m2)	710	2734	1581	749	914
Space Heating Demand (kWh/yr/m2)	28.22	72.17	13.56	13.56	523.69
Hot Water Demand (kWh/yr/m2)	2.38	65.95	14.62	14.62	802.76
Space Heating Demand (kWh/yr)	20,036.2	197,312.78	21,438.36	392,243.81	164,419.46
Hot Water Demand (kWh/yr)	1,689.8	180,307.3	23,114.22	601,267.24	129,660.04

5.1.1.3 Peak Heat Demands

The domestic peak heat demands were taken as being the rated capacity of the proposed heat pump for the purposes of sizing the DH network. It should be noted that this is likely an overestimation of the peak demand but provides a reasonable estimate in the absence of the expected peak heat demand figures developed based on building heat loss.

The peak demand for the non-domestic buildings was calculated using full load equivalent (FLEQ) hours. These equivalent hours represent the relationship between the peak and the annual demand for different types of buildings. For the buildings listed above the FLEQ of 2,000 hours per year was assumed to estimate the peak demand for each individual non-domestic building.

Diversity factors were applied Diversity (a.k.a. Coincidence) factors are an important consideration when sizing DH network. Diversity results from customers not requiring their respective maximum capacity heat demands at the same time. Diversity has a bigger impact on hot water peak demands than on space heating peak demands due to the longer durations for which space heating is generally required. This can be seen in the diversity (coincidence) factors for domestic DHW and SH shown in the figure below. The diversity factor associated with DHW (blue line) comes from the Danish standard DS439. The diversity factor associated with the space heating demand comes from CIBSE CP1 2020 (District Heating Code of Practice).

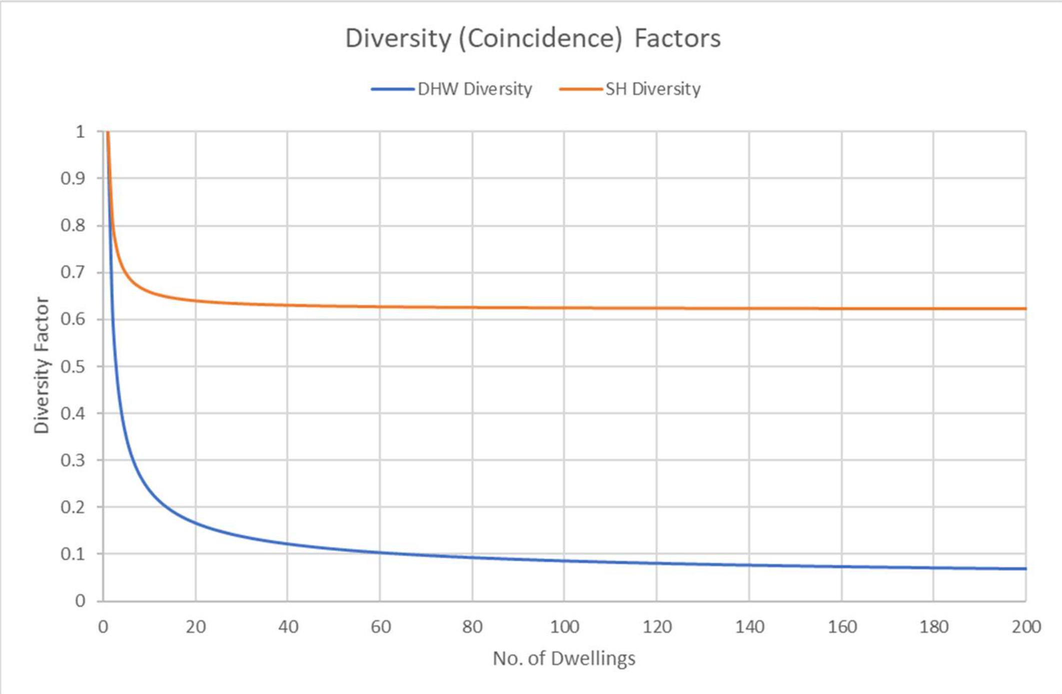

Figure 22: DHW and Space Heating Diversity Factors per No. of Dwellings (Source: Codema Image based on methodology from Danish Standard DS439 and CIBSE CP1 2020)

It should be noted that in developments where there is a mix of building types e.g. residential mixed with various commercial building then the different between the aggregated individual heat pump peak demand and the DH peak demand is likely to be even greater.

5.1.2 Costing

Table 6 provides a summary of the costs incurred from installing the various types of heating system. These costs can be grouped into capital costs, replacement costs, installation costs, and operational costs.

Depending on who is paying for the installation of the heating system these different costs groups are of varying importance e.g. developers are mainly concerned with the upfront capital and installation costs. If you are a resident (owner occupier of the building), typically you would also have a greater interest in the operational and maintenance costs which you will paying on an ongoing basis. It is assumed in this analysis that the gains in terms of building energy rating based on having an efficiently operating system are sufficient to influence the investment decisions of the developer and that therefore the total cost of ownership is the most suitable metric to determine the most cost-effective solution for both developer and resident alike.

Table 6 – Renewable Heating Expenses

Med-High-Rise Scenario		Capex	Repex	Opex	Total
Individual	ASHP/EAHP (Individual)	€12,550	€14,724	€19,599	€46,874
Communal/ District Heating	Biogas CHP (DH)	€8,377	€8,538	€11,917	€28,832
	Biogas Boiler (DH)	€5,720	€5,881	€20,731	€32,332
	Heat Pump (DH)	€6,333	€6,493	€11,889	€24,715
	EfW Plant (DH)	€6,910	€7,070	€6,263	€20,244
	Biomass Boiler (DH)	€5,720	€5,881	€14,298	€25,899

5.1.2.1 Capital Costs

Cost information for equipment to be installed within the building was obtained for the residential buildings (apartments and houses) from an Irish installer[7] and were based on building data for a real planned development. This cost covered heat pump units (both air-source units for houses and exhaust air units for apartments), radiators and controls and ducting.

Cost for the different heat production options for the communal DH network were taken from the Danish Energy Agency Technology Catalogue. These capital cost assumptions for heat production plant can be seen in Table 7. The capital cost for Biogas CHP and Biogas boilers were based on prices for wood pellet CHP and boilers. It should be noted that it is typical for the primary heating plant in a DH or communal network to be sized to cover only a percentage of the peak heat demand with thermal storage increasing its overall contribution. Typically, this plant would be sized to cover approximately 1/3 of the peak but for this analysis the conservative estimate of sizing for 50% of the peak has been assumed for DH/communal analysis.

Table 7: Heat Production Unit Capital Cost per kW for Communal / DH Scenarios

DH Heat Production Capex	(€/kW)
Biogas CHP	3,201
Biogas Boiler	755
Heat Pump	1,319
EfW Plant	1,850
Biomass Boiler	755

Network Cost

The network costs were calculated using the diversified peak loads, expected network temperature difference (between the flow and return pipe) and the allowable velocity for difference diameter DH pipes. A hydraulic analysis of each pipe in the network was undertaken to determine the size of pipe required for each length of pipe in the network and the associated cost. The purpose of this analysis is to ensure that the heat demand can be served and that limiting velocities (or pressure drops) are not exceeded while also keeping the pipes as small as possible to reduce capital cost, reduce heat losses and help maintain the required pressures. Keeping velocities (or pressure drops) below these limiting values ensures:

[7] Via Unitherm Heating Systems Ltd

- The dynamic head losses (pressure drop) are minimised reducing the need for excessive pumping energy as well as the increase in pump capital costs that come with a need to be able to supply at higher pressure.
- The need to carry out a transient pressure surge analysis is avoided. Pressure surges also known as water hammer can cause severe damage to the pipes.
- Mitigate against flow induced movement of the pipework.

Suitable pipe diameters calculated using the Q=m.Cp.dT equation. Where Q is the capacity in kW, 'm' is the mass flow rate in kilograms per second (kg/s), Cp is the specific heat capacity of water in kJ/kg°C (of 4.18 kJ/kg °C based on expected operating temperatures), and dT is the temperature, and the temperature difference in degrees Celsius (°C) between the flow and return. For this system it was assumed that the network dT was 25C.

The table below provides some typical allowable velocities for different pipe diameters for steel carrier pipes which can be used to determine suitable pipe sizes.

Table 8: Allowable Max Flow Rates for Steel DH Pipes of Different Diameters

Nominal Pipe Diameter (mm)	***Max Allowable Velocity (m/s)***
20	0.65
25	0.7
32	0.75
40	0.85
50	0.95
65	1.1
80	1.25
100	1.5
125	1.75
150	2
200	2.5
250	2.5
300	3
350	3
400	3
>450	3.5

The figure below outlines the calculated pipe sizes required for the low-density scenario analysed.

The network cost includes for the flow and return pipes. They also include for supply, delivery, offloading, installation (incl. allowance for fittings, joints and termination seals) and hydraulic testing (10% N.D.T.) of the network.

Emitter costs

As large-scale heat pumps can supply heat at a higher temperature without compromising on efficiency, this means that higher supply temperatures can be used for DH/Communal systems. This in turn means that smaller emitters can be used when compared with individual heat pumps. This is discussed in greater detail in Section 3.4. This results in a Capex reduction for emitters fed from the DH/communal system of €920 and €2,073 per dwelling for steel and aluminium radiators respectively.

Figure 23: Map Showing DH Pipe Diameters - Low Density Residential Development Example

5.1.2.2 Replacement Costs

The annual replacement costs for various items of plant have been calculated using the capital cost of each and dividing it by the expected lifespan. The expected lifespan for the individual building plant come from CIBSE Guide M[8] and the lifespan for the DH heat production plant came from the Danish Energy Agency Technology Catalogue[9].

5.1.2.3 Installation Costs

Installation costs for different systems have been based on cost estimates provided by installers where possible. Wherever installers could not provide information, available industry standard cost guide information (hourly labour rates and indicative number of hours required for installation) was used for each specific element e.g. heat exchangers, heat pumps, etc. For the large-scale DH heat production plant installation costs from the Danish Energy Agency Technology Catalogue were used.

5.1.2.4 Operational Costs

In this analysis the main operational costs considered were the cost of heat production which is driven by fuel costs and the efficiency of the heat production units and the maintenance costs. It should be noted that the heat pump efficiencies are based on real world measured efficiencies for the ASHPs and for the DH heat production units. The exhaust air heat pump efficiencies are based on metered data (SPF) from a study of approximately 750 heat pumps in the UK.

Heat Production Prices

Table 9 shows the heat production prices for the different forms of heat production. The fuel costs for the individual building solutions are taken from the SEAI domestic fuel price comparison data for July 2024[10]. The fuel prices for the larger communal heat production are taken from the SEAI commercial fuel price comparison for July 2024[11]. In the case of the electricity prices estimates of annual

[8] https://www.cibse.org/knowledge-research/knowledge-portal/guide-m-maintenance-engineering-and-management-2014-pdf

[9] https://ens.dk/en/our-services/technology-catalogues/technology-data-generation-electricity-and-district-heating

[10] https://www.seai.ie/publications/Domestic-Fuel-Cost-Comparison.pdf

[11] https://www.seai.ie/publications/Commercial-Fuel-Cost-Comparison.pdf

electricity demand were made to select the correct price band. The % losses shown in the table relate to the losses from the DH network[12] and the HIU[13] for the communal solution and the heat loss from the hot water cylinder[14] for the individual building solutions (i.e. heat pump options). These percentages are shown as a percentage of overall heat demand.

It can be seen from Table 9 that Energy-from-Waste option has the lowest cost of heat production for the heat sources analysed. This is mainly down to the relatively small impact of taking high-grade heat from the electricity producing turbines in a WtE plant and the economies of scale of such a system. IBC fuel being burnt in a boiler represents the most expensive form of heat generation this is due to using such a high-exergy fuel for heat production.

Table 9: Heat Production Price Calculations

Heat Source	Fuel	Efficiency	Fuel Price (c/kWh)	Heat Losses (%)	Heat Production Price (c/kWh)
Communal/District Solution					
IBC CHP	IBC Fuel	80% (40% Heat, 40% Elec)	17	15%	11.992
IBC Boiler	IBC Fuel	85%	17	15%	23.52941176
Heat Pump	Elec	320%	32.52	15%	11.95588235
EfW Plant	Elec (Turndown)	600%	23.42	15%	4.592156863
Biomass Boiler	Biomass	70%	8.99	15%	15.1092437
Individual Building Solution					
Domestic ASHP	Elec	309%	37.94	10%	13.64257461
Domestic EAHP	Elec	294%	37.94	19%	15.93180482

5.1.2.5 Main Differences Between District Heating and Individual Heating System Costs

One of the main differences in cost between DH and individual heating systems is the lower operating costs of the DH/communal network. This driven by the higher het production efficiency, lower maintenance costs of these communal networks. One of the other differences is that the cost of individual heat pumps does not reduce at the same rate as communal/DH solutions with increased density/number of dwellings. It was also noted that that in the information provided by suppliers that when considering the whole heating system that exhaust air heat pumps are more expensive than air source heat pumps this is mainly due to the cost of the ducting required in each dwelling to allow the EAHP to move worm air around the premises.

5.2 Analysis

5.2.1 Scenarios Analysed

As part of this analysis different dwelling density scenarios were analysed. These scenarios are set out below:

- original scenario based on planned development,
- duplex scenario (looking at 2-storey apartments on the same site,
- low-rise scenario (looking at 4-storey apartment blocks on the same site),
- med/high rise scenario (6 storey apartment blocks on the same site).

Each of the density scenarios looked at individual heat pumps and district heating networks supplied using the following heat sources:

Individual Heat Pumps:

- Air-source heat pumps in houses

[12] Assumed to be 10% for houses and 5% for apartments due to their shorter pipe length per dwelling
[13] Based on a standard 1kWh per day
[14] Based on heat loss calculation method used in DEAP4.1

- Exhaust air heat pumps in apartments

District Heating:

- IBC Combined Heat & Power Plant
- IBC Boiler
- Large-scale Heat Pump
- Energy-from-Waste Plant
- Biomass Boiler

5.2.2 Results

The results from this analysis are based on the total cost of ownership over a period of 25 years. This includes capital costs (Capex), replacement costs (Repex), and operational costs (Opex i.e. fuel and maintenance costs).

This section of the report looks to compare the results for individual building-level heat pumps with a site-wide communal network from a techno-economic perspective for new residential developments. It should be noted that the results from this analysis are likely to give a conservative estimate of viability for district heating due to several factors, these include:

- This analysis focuses mainly on residential developments and may not capture the full diversity of demand that exists in many areas. Generally, a mix of domestic and non-domestic building would result in a better economic case for a network
- It is being assumed that the primary heating plant of the DH network covers 50% of the full peak of demand – the primary plant is typically sized to only cover somewhere in the region of 1/3 of the peak with thermal storage and less capital-intensive backup plant used to cover peak periods
- The lifespan being investigated is 25 years in line with typical investment horizons – the full value of a DH network may not be realised within this timeframe since DH networks have a lifespan that is typical more than double this period
- DEAP models have been used to estimate the heat demands connected to the network – DEAP generally significantly underestimates the actual heat demand of new energy efficient buildings. This directly effects the heat density of the development which is one of the main drivers for the economic viability of heat networks
- The domestic peak heat demands were taken as being the rated capacity of the proposed heat pump for the purposes of sizing the DH network. It should be noted that this is likely an overestimation of the peak demand

The dwelling per hectare figures is based on a similar layout to that shown in Figure 24. the boundary used in this map (i.e. the red boundary including roads where main DH distribution pipes run, the buildings connected and the green areas to the front and back of these buildings). It should be noted that were a large green area within this boundary the dwelling density would drop significantly but the viability would remain the same. This is also an important consideration of using the findings as an indication of DH viability for other sites. The area of the boundary below was measured using QGIS software and found to be 1.48 hectares this is the area used for calculating the dwelling density figures.

Figure 24: Development Layout on Which Analysis is Based

The graphs below show the dwelling density at which communal heating networks (using different heat sources) becomes the more cost-efficient option compared with individual heat pumps (air-source heat pumps for houses and exhaust-air heat pumps for apartments). Figure 25 below is informed by the information shown in Table 10

It can be seen from this graph that the individual heat pump option is a better solution for any residential development (of similar layout as that shown in Figure 24) with a dwelling density of less than circa 10 dwelling per hectare. All district heating options outperform individual heat pumps when the dwelling density reaches circa 40 dwellings per hectare. The communal heat pump outperforms the individual heat pumps for dwelling densities above 25 dwellings per hectare.

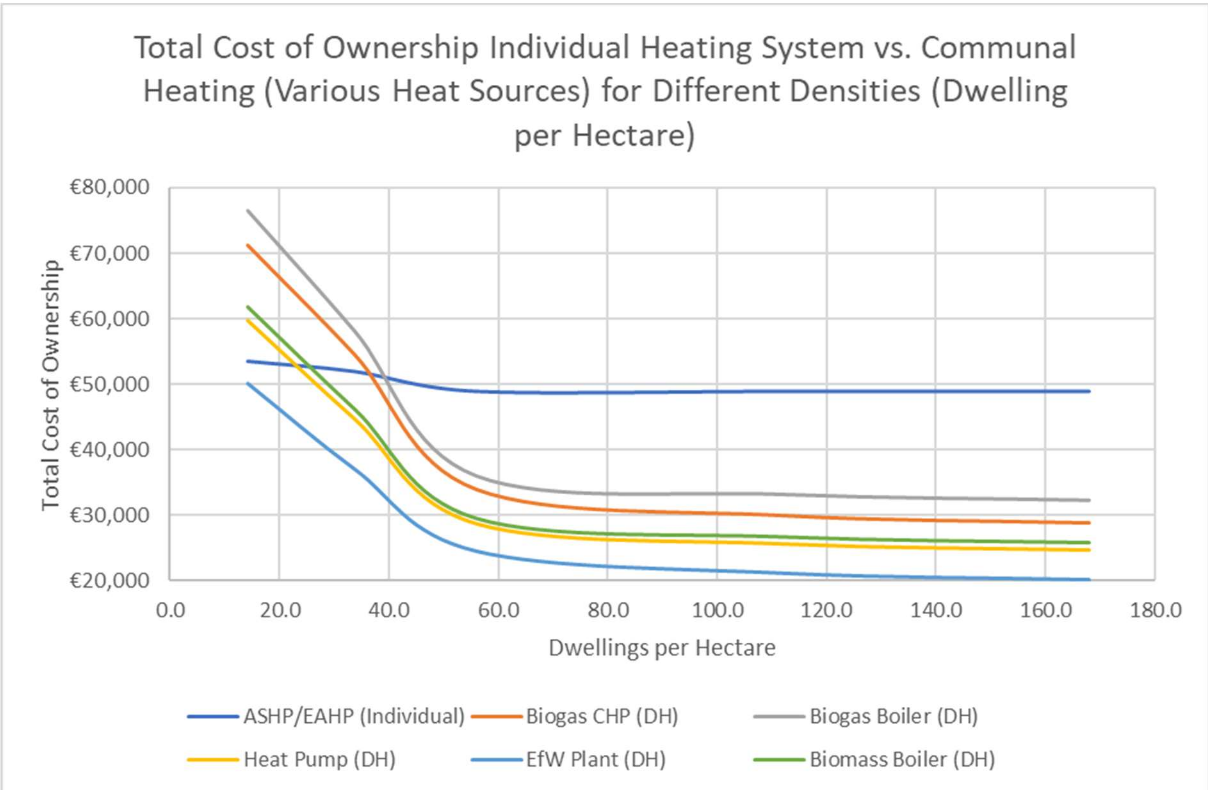

Figure 25: Total Cost of Ownership for Different Dwelling Density and Heat Source Scenarios

Table 10: Total Cost of Ownership for Different Dwelling Density and Heat Source Scenarios

Total Cost of Ownership per Dwelling (25 years)		Very Low Density	Low Density (Actual Development)	Low-Rise Apartments	Med-Rise Apartments	Med-High Rise Apartments
	Storeys	2	2	2	4	6
	Dwelling Types	Houses	Mix (House & Flat)	Apartments	Apartments	Apartments
	Dwellings per Hectare	14.2	33.7	56.0	112.0	168.0
Individual	ASHP/EAHP (Individual)	€53,447	€51,894	€48,880	€48,880	€48,880
Communal/ District Heating	Biogas CHP (DH)	€71,271	€54,533	€33,944	€29,956	€28,832
	Biogas Boiler (DH)	€76,436	€58,075	€36,020	€33,207	€32,332
	Heat Pump (DH)	€59,669	€44,663	€28,731	€25,647	€24,715
	EfW Plant (DH)	€50,062	€37,032	€24,570	€21,230	€20,244
	Biomass Boiler (DH)	€61,724	€46,178	€29,587	€26,774	€25,899

Carbon Reduction Potential

Table 11 shows which of the heat production options have the greatest carbon reduction potential. The use of IBC fuel in CHP plants provides a carbon negative heat solution. This is primary due to offsetting the emissions associated with on-site electricity use based on current electricity grid emissions factors. Over time this level of carbon abatement is likely to reduce for the IBC CHP as the electricity grid becomes cleaner.

Table 11: Carbon Content of Heat Produced

Heat Source	Fuel	Efficiency	Emmissions Factor (kgCO2/MWh)	Heat Losses (%)	Carbon Content of Heat kgCO2/kWh
Communal/District Solution					
IBC CHP	IBC Fuel	80% (40% Heat, 40% Elec)	17.05	15%	-78.32138408
IBC Boiler	IBC Fuel	85%	17.05	15%	23.59861592
Heat Pump	Elec	320%	254.8	15%	93.67647059
EfW Plant	Elec (Turndown)	600%	254.8	15%	49.96078431
Biomass Boiler	Biomass	70%	25	15%	42.01680672
Individual Building Solution					
Domestic ASHP	Elec	309%	254.8	10%	91.62171881
Domestic EAHP	Elec	294%	254.8	19%	106.9958848

Inclusion of Non-Domestic Buildings in Residential Developments

While non-domestic buildings do not form part of the development used as the basis for this analysis. It is important to note that developments which do include a more diverse range of buildings will likely improve the case for DH. It therefore can be said that the analysis performed represents a conservative estimate of DH viability for the stated dwelling densities. As part of the analysis Codema also performed an analysis to identify which of the three non-residential heat demands considered (office, retail and leisure centre) are most preferred as an accompanying heat demand to residential heat in a development. This analysis was performed using hourly heat demand profiles[15]. The preferred accompanying heat demand was determined based on which combination profile had the lowest peak demand (kW) whilst delivering the same heat demand (kWh) across the day. The results of this analysis can be seen in the graphs below.

It can be seen from these graphs that residential heat demand is best paired with leisure centre heat demand giving a combined peak demand of 149.9kW. The second-best of the three non-domestic heat demand analysed to pair with residential heat demand is retail heat demand with a combined

[15] Based on a combination of metered data and thermodynamic software

peak of 171.1kW. The least beneficial of the three non-domestic heat demands analysed to combine with residential heat demand is office heat demand with a combined peak of 186.4kW.

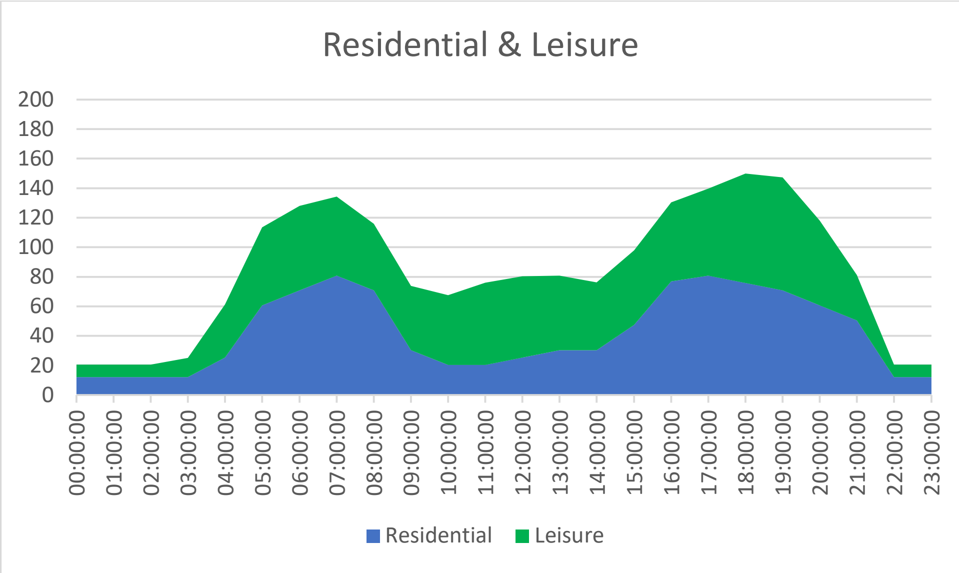

Figure 26: Combined Hourly Profile for Residential & Leisure Centre Heat Demand

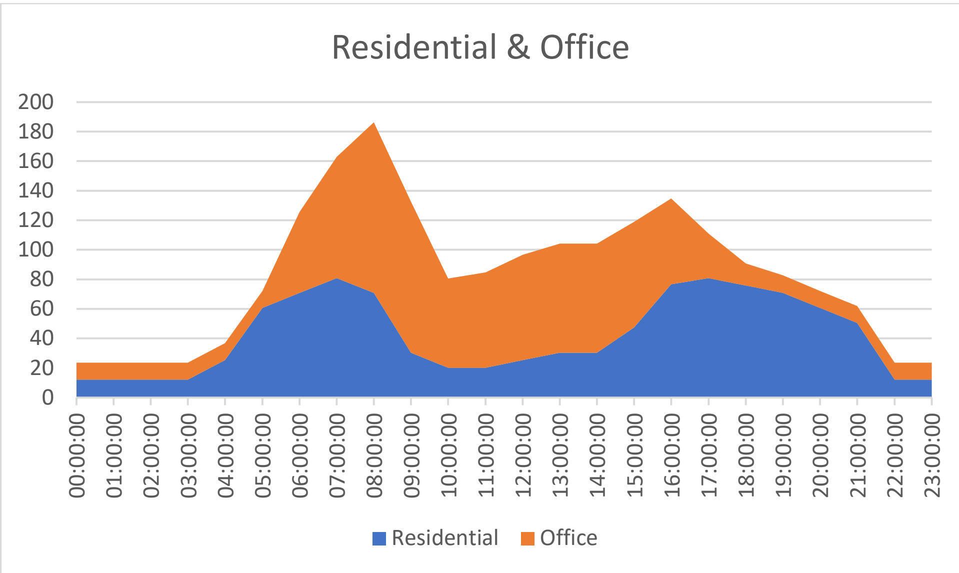

Figure 27: Combined Hourly Profile for Residential & Office Heat Demand

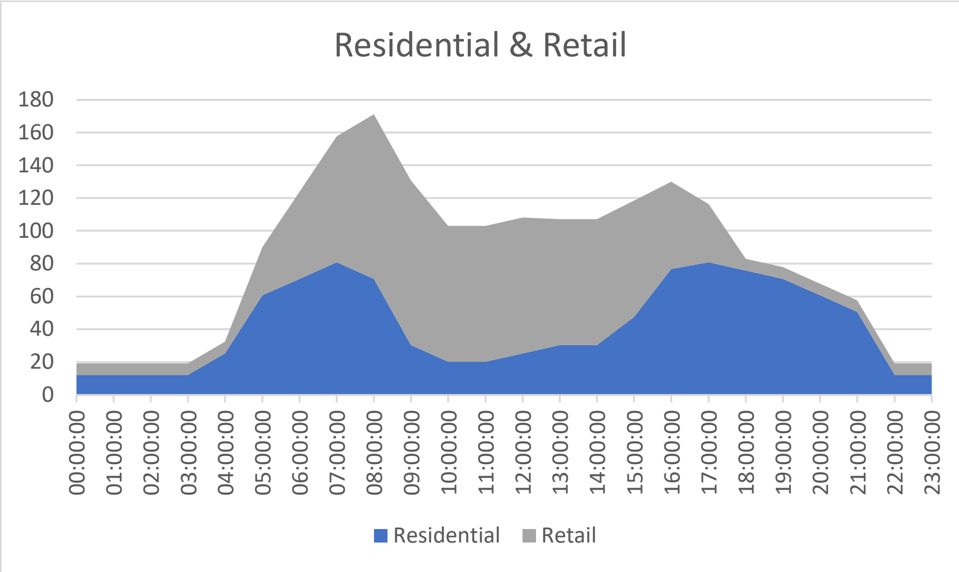

Figure 28: Combined Hourly Profile for Residential & Retail Heat Demand

5.3 Conclusions

Individual heat pump option is a better solution for the occupants of a residential development (of similar layout as that shown in Figure 24 above) with a dwelling density of less than circa 10 dwelling per hectare (see Table 12 below for description of relevant dwelling densities). All district heating options outperform individual heat pumps when the dwelling density reaches circa 40 dwellings per hectare. The communal heat pump outperforms the individual heat pumps for occupant of developments with dwelling densities above 25 dwellings per hectare. It should be noted that these figures are based on an assumed investment horizon of 25 years. This again is a conservative estimate for a heat network which has a much longer lifespan of 50 – 100 years+.

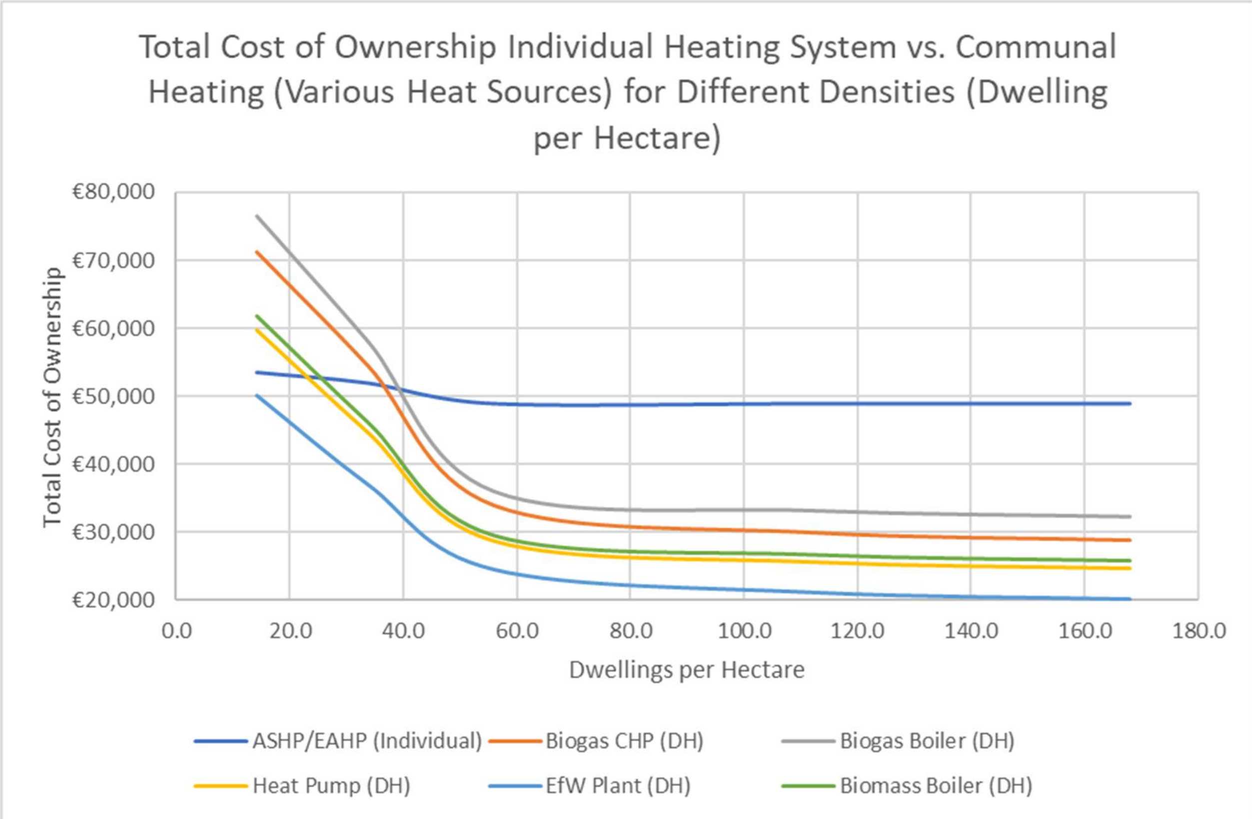

Figure 29: Total Cost of Ownership for Different Dwelling Density and Heat Source Scenarios

Table 12: Description of dwelling densities typical to Ireland

Density of Development (dwellings per hectare)	Description of typical development that corresponds to this density
10	Rural villages, ribbon developments, or outer suburban fringe of mostly detached houses (usually 1 -2 storeys) with large front and back gardens, parking spaces, driveways and garages
25	Suburban/ housing estate development of mostly semi-detached houses with some detached or short terraced housing (mostly 2 storeys) with medium to large rear gardens.
35	Moderate residential density with a mix of terraced and semi-detached houses; some duplexes or maisonettes (typically 2-3 storeys)
40	Compact development of mostly terraced and semi-detached houses; some duplexes or maisonettes; occasional small apartment blocks (usually 2-3 storeys) with small private gardens or patios
50	High density residential development of low to mid-rise (2-4 storeys) with a mix of terraced housing, duplexes and low-rise apartment blocks with balconies or communal courtyards.

The economic case for district heating is typically improved by connecting different forms of heat demand to the DH network in combination with residential heat demand to improve the heat networks heat demand diversity. Of the three non-domestic heat demands considered, leisure centre heat demand provides the best opportunity for combining non-domestic heat demands with residential heat demand followed by retail heat demand and office heat demand.

Figure 30 provides a comparison of purely capital expenditure. This is what developers who are less concerned with how the heating systems will cost to run and maintain would typically look at as their focus is on developing the site for the lowest cost. This does not fully reflect the potential of the DH/communal option to improve the dwelling BER rating due to its more efficient operation. It can be seen from this graph that from a developer's perspective DH becomes the most cost-effective option at between 35 and 50 dwellings per hectare. A description of these dwelling densities can be found in Table 12.

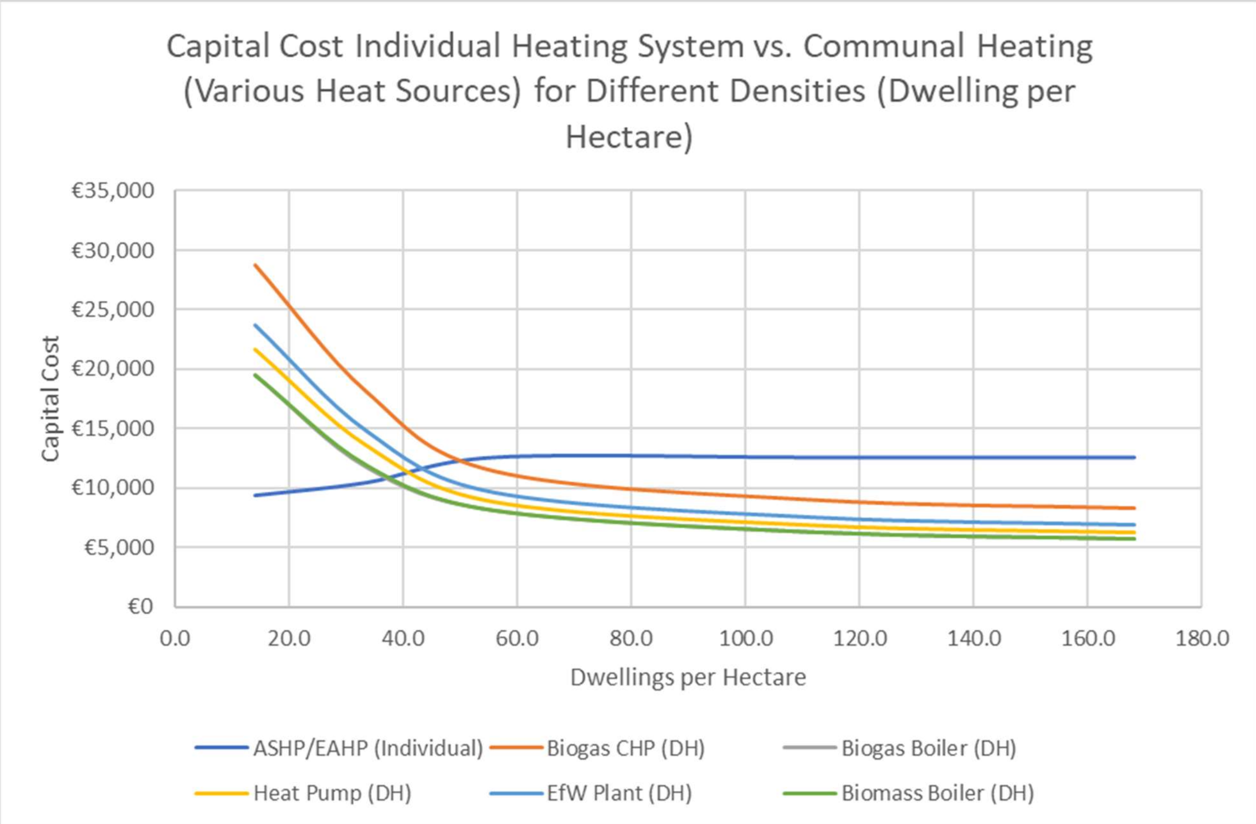

Figure 30: Capital cost comparison of individual heating systems vs communal heating systems for different dwelling densities

6. Policy Recommendations

DEAP/NEAP Barriers

Current DEAP and NEAP models do not include IBC fuels as an option for heating. It is recommended that early discussions are had with SEAI to present the test results from the IBC analysis to facilitate its potential inclusion in future version of the DEAP and NEAP software. Robust test results from analysing the fuel will be required to facilitate the inclusion of IBC fuels in this software.

Currently, the Dwelling Energy Assessment Procedure (DEAP) in Ireland lacks a mechanism to accurately assess the efficiency of large-scale heat pumps used in communal heating systems as the standard used for defining efficiency in HARP is based on a standard that only covers domestic-scale heat pumps (EN16147) rather than also allowing the standard for larger heat pumps (EN14825). The default efficiency values used in DEAP underestimate the performance of these systems, creating an unfair disadvantage when compared to smaller, individual heat pumps listed in the HARP database. The quickest way to address this barrier is to allow manufacturers to submit third-party verified efficiency data for large-scale heat pumps to be used in DEAP assessments (as a drop-down option from the HARP database).

CAPEX vs Total Cost of Ownership

This analysis shows that there is a disconnect between the value of a communal heating solution to the owner/operator and the developer. Funding mechanisms should be explored to put equipment for communal and DH systems on an equal footing with heat pumps in terms of grants and tax rebate schemes to help address this imbalance and help facilitate meeting national targets for Dh set out in the national Climate Action Plan.

Some of the options that could be explored include:

- Grant funding for heat network installations
- Tax rebate options for DH equipment e.g. €1 tax rebate for every €2 spent on district heating capex; accelerated tax depreciation for investment in district heating equipment; or a reduced rate of VAT equivalent to measures introduced for heat pumps or solar panels

HIU Standards

Ireland should consider adopting reputable European HIU standards such as Sweden's FVU, Germany's AGFW FW 524 or Denmark's DS439 as alternative options to the UK's BESA standard. These standards are widely used across Europe and support reliable, efficient heat network performance without a de facto mandation of specific components like PICVs.

If adopting these standards further considerations should also include ensuring system-level hydraulic balancing, return temperature optimisation, and alignment with low-temperature network design, to maintain high performance under Irish operating conditions

7. Decision Framework for Low Carbon Heating Solutions

The purpose of Figure 31 is to help guide and narrow in potential system design approaches for different sized developments with a view to minimising the total cost of ownership as well as carbon emissions.

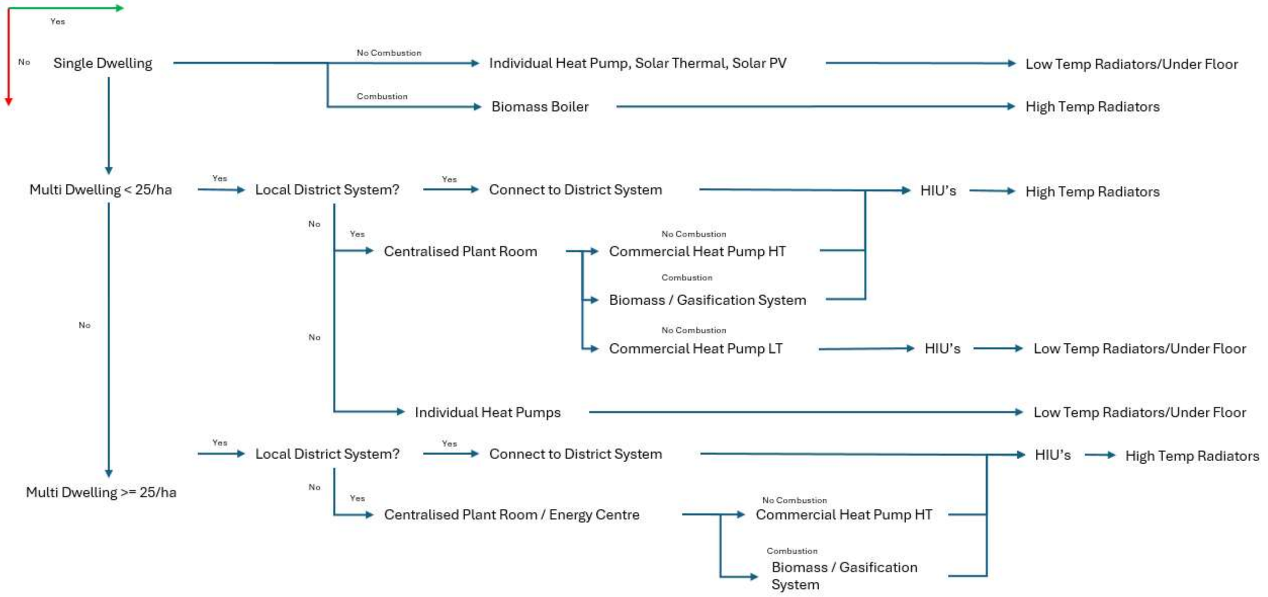

Figure 31: Low Carbon Heating Solutions - Flow Chart of Recommended Design Approaches for Different Dwelling Densities

First, determine site type, then prioritise lower carbon, higher temperature solutions.

(1) <u>Single Dwelling:</u>

a) *<u>No Combustion Route (Preferred for Low Carbon):</u>* Choose Individual Heat Pump, Solar Thermal, or Solar PV → Low Temperature Radiators/Underfloor Heating.

b) *<u>Low Carbon Combustion Route:</u>* Opt for Biomass Boiler (ensure sustainably sourced fuel) → High Temperature Radiators.

(2) <u>Multi Dwelling (<25 dwellings per hectare):</u>

a) *<u>Local District System Available:</u>* Connect to District System (ensure renewable or low carbon heat source) → Heat Interface Units (HIUs) → High Temperature Radiators.

b) *<u>No Local District System:</u>*

   a. <u>Centralised Plant Room:</u>

      i. No Combustion (Preferred): Choose Commercial High-Temperature Heat Pump.

      ii. Combustion Option: Biomass/Gasification System (with sustainably sourced biomass).

      iii. Alternative No Combustion: Commercial Low-Temperature Heat Pump → HIUs → Low Temperature Radiators/Underfloor Heating.

   b. <u>No Centralised Plant Room:</u> Choose Individual Heat Pumps → Low Temperature Radiators/Underfloor Heating.

(3) <u>Multi Dwelling (≥25 dwellings per hectare):</u>

a) *Local District System Available:* Connect to District System (ensure renewable or low carbon heat source) → HIUs → High Temperature Radiators.

b) *Centralised Plant Room/ Dedicated Energy Centre:*
    i. No Combustion (Preferred): Commercial High-Temperature Heat Pump.
    ii. Low Carbon Combustion: Biomass/Gasification System (with sustainably sourced biomass).

A Appendix: Scenario Results

The tables and graphs below set out the results from the different dwelling density scenarios; original scenario based on planned development, duplex scenario (looking at 2-storey apartments on the same site, low-rise scenario (looking at 4-storey apartment blocks on the same site), med/high rise scenario (6 storey apartment blocks on the same site).

The project lifespan assumed for calculating the Repex and Opex figures was 25 years. This is a typical investment horizon over which projects are assessed.

Table 13: Original Development Non-Discounted Techno-Economic Results

		Capex	Repex	Opex	Total
Individual	ASHP/EAHP (Individual)	€10,477	€12,171	€29,246	€51,894
Communal/ District Heating	Biogas CHP (DH)	€18,122	€16,332	€19,699	€54,153
	Biogas Boiler (DH)	€11,742	€9,953	€36,001	€57,695
	Heat Pump (DH)	€13,592	€11,423	€19,648	€44,663
	EfW Plant (DH)	€14,767	€12,809	€9,243	€36,820
	Biomass Boiler (DH)	€11,910	€9,953	€24,104	€45,966

Table 13 and its contents have also been displayed in graphic form in Figure 32.

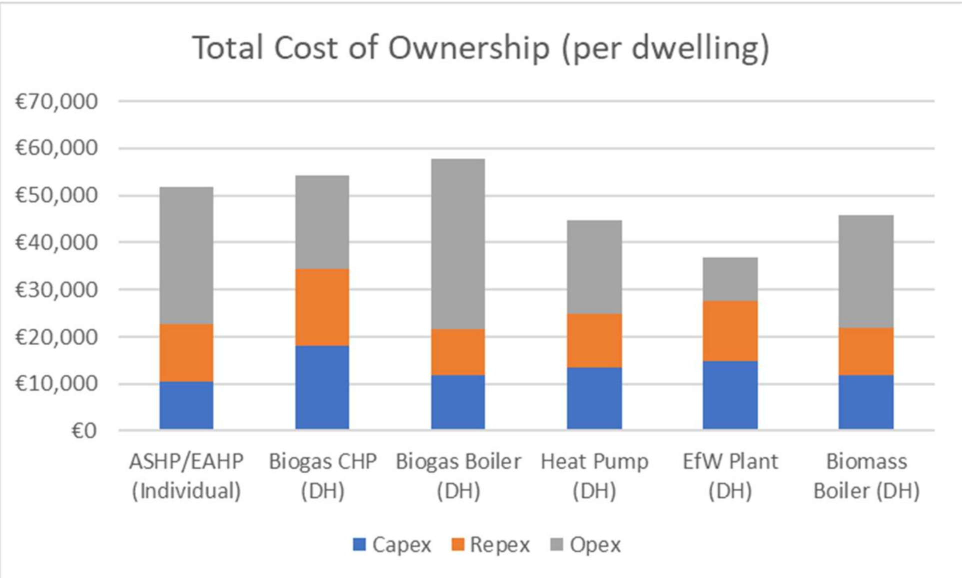

Figure 32: Original Development Total Cost of Ownership (per dwelling) Graph

Table 14: Duplex/2-Storey Apartment Development Non-Discounted Techno-Economic Results

		Capex	Repex	Opex	Total
Individual	ASHP/EAHP (Individual)	€12,609	€14,724	€21,547	€48,880
Communal/ District Heating	Biogas CHP (DH)	€11,489	€10,538	€11,917	€33,944
	Biogas Boiler (DH)	€8,120	€7,169	€20,731	€36,020
	Heat Pump (DH)	€8,896	€7,946	€11,889	€28,731
	EfW Plant (DH)	€9,629	€8,678	€6,263	€24,570
	Biomass Boiler (DH)	€8,120	€7,169	€14,298	€29,587

Table 14 and its contents have also been displayed in graphic form in Figure 33.

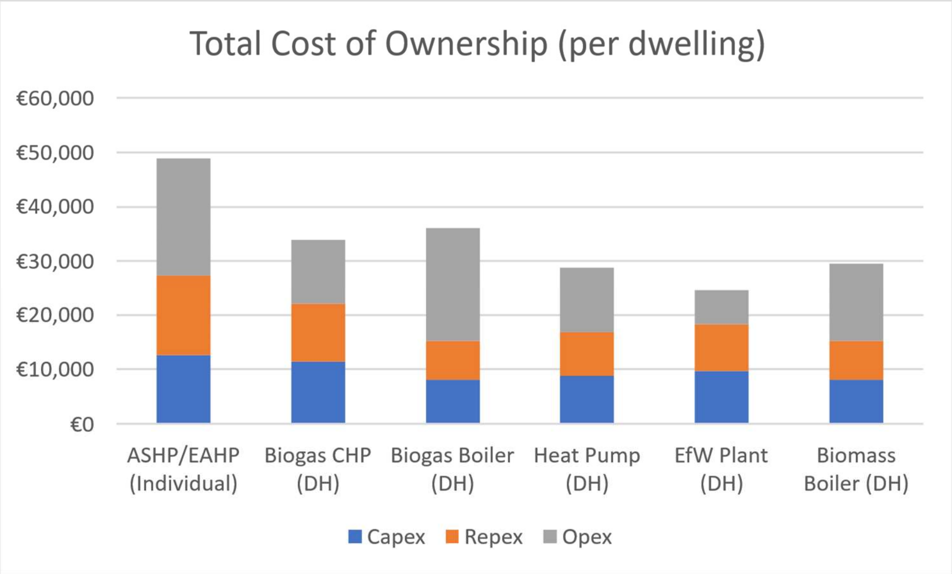

Figure 33: Duplex/2-Storey Apartment Development Cost of Ownership (per dwelling)

Table 15: Low-Rise (4-Storey) Apartment Development Non-Discounted Techno-Economic Results

		Capex	Repex	Opex	Total
Individual	ASHP/EAHP (Individual)	€12,609	€14,724	€21,547	€48,880
Communal/ District Heating	Biogas CHP (DH)	€9,075	€8,964	€11,917	€29,956
	Biogas Boiler (DH)	€6,293	€6,183	€20,731	€33,207
	Heat Pump (DH)	€6,934	€6,824	€11,889	€25,647
	EfW Plant (DH)	€7,539	€7,428	€6,263	€21,230
	Biomass Boiler (DH)	€6,293	€6,183	€14,298	€26,774

Table 15 and its contents have also been displayed in graphic form in Figure 34.

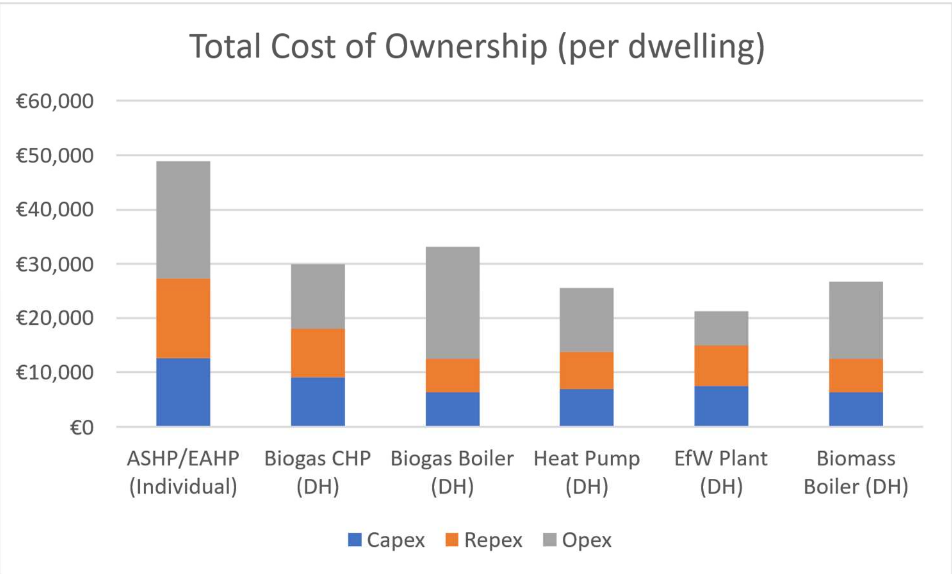

Figure 34: Low-Rise (4-Storey) Apartment Development Cost of Ownership (per dwelling)

Table 16: Medium-High-Rise (6-Storey) Apartment Development Non-Discounted Techno-Economic Results

Med-High-Rise Scenrio		Capex	Repex	Opex	Total
Individual	ASHP/EAHP (Individual)	€12,609	€14,724	€21,547	€48,880
Communal/ District Heating	Biogas CHP (DH)	€8,377	€8,538	€11,917	€28,832
	Biogas Boiler (DH)	€5,720	€5,881	€20,731	€32,332
	Heat Pump (DH)	€6,333	€6,493	€11,889	€24,715
	EfW Plant (DH)	€6,910	€7,070	€6,263	€20,244
	Biomass Boiler (DH)	€5,720	€5,881	€14,298	€25,899

Table 16 and its contents have also been displayed in graphic form in Figure 35.

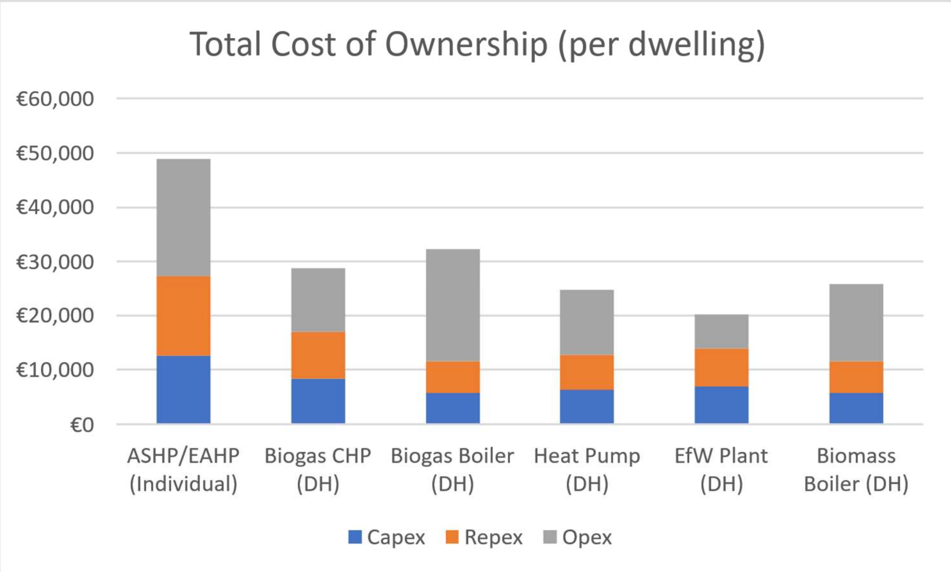

Figure 35: Medium-High-Rise (6-Storey) Apartment Development Low-Rise (4-Storey) Apartment Development

B Appendix: Technical Information on Heating System Design

Table 17: Heating System Design Internal Temperatures as per SR50

Room Type	Design Temperature
Bathroom	22°C
Bedroom	18°C
Bedroom /Study	21°C
Bedroom/En-Suite	18°C
Bedsitting	21°C
Breakfast	21°C
Cloak Room	18°C
Dining Room	21°C
Dressing/WIW	21°C
Games Room	21°C
Hall	18°C
Kitchen	18°C
Kitchen/Dining	21°C
Landing	18°C
Living Room	21°C
Lounge Sitting	21°C
Storeroom	16°C
Study	21°C
Toilet	18°C
Utility Room	18°C
Sunroom/Conservatory	22°C
Gym	18°C
External	-3°C

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