A GUIDE TO DISTRICT HEATING IN IRELAND

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A Guide to District Heating in Ireland

Produced by Codema and BioXL on behalf of the Irish Bioenergy Association (IrBEA)

Funded by the Sustainable Energy Authority of Ireland's Research, Development and Demonstration Programme 2016, with support from the European Union and National Development Plan.

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October 2016

Special thanks to those involved in the case studies and feasibility analyses for their time and openness in providing the required data, they are;

- Tim Mc Swiney and Sandy Mc Swiney, Kerry County Council
- JJ Lenehan, Teagasc
- Peter Keavney and Diane Egan, Galway City Council
- Gearóid Dorchaí and Donal MacEiteagain, Udarás na Gaeltachta
- Fred Tottenham, Mott MacDonald
- David Palmer, Campbell-palmer partnership
- Adrian Quinn and Kevin Cullen, Cork City Council
- Fintan Lyons, Kaizen Energy

Disclaimer

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Acronyms

DH – District Heating
GHG – Greenhouse Gases
EU – European Union
ETS – Emissions Trading Scheme
RES – Renewable Energy Sources
CHP – Combined Heat and Power
COP –Coefficient of Performance
NEEAP – National Energy Efficiency Action Plan
NREAP – National Renewable Energy Action Plan
REFIT – Renewable Energy Feed-In Tariff
SEAI – Sustainable Energy Authority of Ireland
RHI – Renewable Heat Incentive
4GDH – 4th Generation District Heating
DHW – Domestic Hot Water
SH – Space Heating
WtE – Waste to Energy
RE – Renewable Energy
BER – Building Energy Rating
GJ – Gigajoule
PJ - Petajoule
kWh – kilowatt hour
MWh – Megawatt hour
GWh – Gigawatt hour
KCC – Kerry County Council
TEA – Tipperary Energy Agency
NPV – Net Present Value
IRR – Internal Rate of Return

Executive Summary

The Irish Bioenergy Association (IrBEA) has commissioned this work recognising the role of district heating in enabling biomass and other low-carbon energy solutions within the energy system. In particular, the expectation of a renewable heat incentive and the expected increase in demand for renewable heat solutions makes it timely to provide guidance for district heating. This project has been funded by the Sustainable Energy Authority of Ireland (SEAI) Sustainable Energy Research, Development and Demonstration (RD&D) 2016 Programme. The objective of this guide is to understand District Heating (DH) and its benefits and to present learnings for the Irish context from case studies of existing systems and techno-economic analyses of planned systems carried out during this project.

Ireland has one of the lowest shares of DH in Europe at less than 1% of the heat market. DH can play a key role in improved energy efficiency and emissions reduction through the use of low carbon energy resources, improvements in energy conversion efficiency through, for example, CHP (Combined Heat and Power) and capturing low value heat resources which would otherwise go to waste. Advances in DH technology, particularly in smart controls and integration opportunities with the electricity sector are further increasing the possibilities for application of DH. As heat rather than fuel is supplied to end-users, a DH network offers flexibility in fuel choice and the ability to adapt to changes in the economic and policy landscape which may see different combinations of energy resources used at different times over the lifetime of a DH network.

This guide to DH in Ireland outlines the fundamentals of DH systems, the various existing DH network types and structures, and the many technical, economic and societal benefits of DH systems. The guide also outlines the existing barriers to realising these benefits, with one of the most prolific barriers being the lack of guidelines, regulations, policies, frameworks or standards for DH which creates high risk and uncertainty when planning DH systems in Ireland.

Public bodies are identified as key enablers of DH, particularly where larger scale co-ordination of projects is required among diverse stakeholders. The development of DH will require coordinated, local-level action to effectively plan for successful wide-spread DH implementation. This guide outlines the key steps required for DH growth and gathers together useful information for planning and design of DH networks, referencing many resources for best practice from the UK, Denmark and elsewhere.

The experience of interacting with projects on the ground in Ireland, both existing and planned, has led to some useful learnings and input to this DH guidance. Many findings are based on the feedback from owners and operators of the existing schemes, or those in the process of developing a new area. These learnings, which in many cases are proving to be some of the barriers to more widespread uptake of DH in Ireland, are summarised in the next section.

Most barriers to development of DH are non-technical, as the technologies used are themselves not new or innovative. The findings also highlight the many societal benefits of utilising high efficiency technologies and renewable energy sources in DH systems, such as security and flexibility of supply, reduced carbon emissions, decrease in fossil fuel imports and greater use of local heat resources which boosts the local economy.

Key Findings of Case Studies and Techno-Economic Analyses

Industry Maturity

- There is a lack of culture and knowledge around DH as a utility. This applies to consumers generally, but also to those involved in the supply chain for DH from concept through to operation.
- Flaws in both the design and installation in existing systems will lead to energy losses, additional costs and longer term maintenance concerns.
- There is a need for additional skills and training appropriate to design and fit the various components of a DH scheme.
- Need for reliable third parties to operate and maintain a DH network.

New Consumer Connections

- Consumer behaviour is an important variable in the success of DH infrastructure.
- Timing or budget issues may prevent connection to the DH system over the short to medium term. In other instances, there may be technical considerations to resolve.
- Typical commercial lease terms need to account for DH services
- Situations were identified where new customers could feasibly connect to existing DH networks, but have not taken up this opportunity.
- There are mandatory and voluntary methods employed in other countries to encourage rational uptake of DH schemes which should be further explored.

Planning Policy Issues

- There are no energy planning practices carried out at a local authority level in Ireland and there is insufficient guidance on this process at a national level.
- Buildings are not necessarily rewarded with a high Building Energy Ratings (BER) for using a DH supply.
- There are limitations to Part L compliance under the building regulations, which do not give sufficient recognition to DH solutions.
- DH pipes should be considered and treated the same as any other underground pipe or cable and be exempt from planning permission in most circumstances under the Planning and Development Act.

Pricing Challenge

- There is a need for independent guidance and regulation of heat pricing.
- Owners and operators of DH schemes have a challenge to determine a fair heat price, and are working in a quasi-monopoly supply situation.
- Different owners operate on different pricing models and expectation of a return on investment. Publicly owned schemes tend to price at or below the real cost of supply.
- Notwithstanding the different financial expectations, privately managed schemes can supply heat at rates lower than publicly-owned subsidised schemes.

Long Term Investments for DH Infrastructure

- It is not appropriate to compare DH to other solutions under the same short-term economic analysis, when the benefits accrue over a much longer investment period.
- The expected useful life of DH piping is over 50 years, whereas a typical 20-year project life is attached to energy generation assets.
- DH should be considered in the same way as other long-term infrastructure investment, such as motorways or electricity distribution assets.
- Public private partnerships, long-term bonds or other financial options need to be considered to address the long-term funding requirements for DH networks.

Commercial Viability

- A range of viable existing and planned DH systems across a range of scenarios are identified in this guide, and highlights the viability of systems outside the Dublin area.
- Heat density is a key criterion for commercial viability, where sufficient load is required to justify the network costs and heat losses over long pipe runs.

- The diversity of connected heat loads and connection of anchor loads such as hospitals, leisure centres or large retail has a positive effect on DH system viability.

Synergy with Renewable Heat and DH

- All DH sites analysed either used or expressed interest to use renewable heat sources and had built or planned a DH system based around the concept of low carbon or carbon neutral heat supply.
- With natural gas prices at a 10 year low, it has proved commercially more attractive to use natural gas and leave biomass boilers or other renewable energy equipment idle in some existing systems. Thus, at present, scheme owners find it necessary to justify the higher costs for renewable heat supply.
- Renewable heat supply needs to be supported and incentivised to ensure that this is a cost-effective option for new planned DH networks.
- The cost challenge and other barriers to renewable heat are acknowledged by the Department of Communications Climate Action and Environment who are currently designing a renewable heat incentive (RHI) to address this gap.

Introduction

District heating is a method of heating towns and cities which has been in widespread use in Europe since the 1930s. Since the first generation of systems were put in place, the technology, methods and practices surrounding the effective use of DH systems have improved dramatically. Scandinavian countries are leading the way and finding innovative ways to use and improve DH networks in order to decrease emissions levels, increase efficiencies and decrease fossil fuel use in the energy system.

DH in Ireland on the other hand has been much slower to find its place in the heating market, and Ireland has one of the lowest shares of DH in Europe at less than 1%[1]. 39% of Ireland's total final consumption of energy is used to meet heat demands[2], and this heat is primarily supplied by individual oil and gas boiler systems. Replacing every individual fossil fuel based heating system in the country with a sustainable alternative is an overwhelming task, but using centralised high efficiency DH networks in suitable areas can greatly contribute to the integration of high levels of low carbon energy sources in the heating sector.

Energy efficiency and low carbon sources in the heating sector will become even more important in light of the new binding targets to reduce greenhouse gas (GHG) emissions to 2030, which were announced by the EU recently for each member state. As part of an overall EU wide 40% GHG emission reduction strategy which the EU committed to at COP21, Ireland has a binding national target of 20.4%[3] reduction compared to 2005 emission levels. The new GHG targets are aimed at the non-Emissions Trading Scheme (ETS) sectors, which cover transport, buildings, agriculture, waste, land-use and forestry.

Of these sectors, transport and buildings are the largest contributors of emissions from fossil fuel consumption, and heating is the largest energy use in buildings. For example, 75% of the average household's final energy consumption is used for space and water heating[4]. There now needs to be a stronger focus on energy efficiency and renewable fuel sources in the heating sector in order to reduce energy related GHG emissions and contribute to meeting Ireland's binding EU 2020 and 2030 targets.

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[1] EcoHeatCool estimates Ireland's DH sales to be 0.1PJ/year. Source: EcoHeatCool (2006) *Possibilities with More district heating in Europe.*
[2] SEAI. (2015) *Energy in Ireland 1990-2014*.
[3] The GHG target is 30%, but there have been allowances for land-use and ETS flexibility, which will reduce the overall target to approximately 20.4%.
[4] SEAI. (2013) *Energy in the Residential Sector 2013*.

Context

District heating can have a direct positive effect on the emissions from the heating sector, and an indirect positive effect on emissions from the electricity sector when optimised within an overall smart energy system. When utilising waste heat and low grade heat sources, DH systems also allows more valuable sustainable resources to be allocated for use in the transport sector. DH can therefore play a key role in reducing energy related emissions across all sectors and help to meet EU, national and local level climate change targets.

Policy

The importance of tackling the causes of climate change and limiting its impacts is now recognised worldwide, and there is overwhelming consensus amongst climate and environmental scientists that human activity and subsequent man-made GHG emissions are causing the rapid change in the earth's climate. The COP21 meeting held in 2015 in Paris, saw countries worldwide pledge their own emission reduction targets and agree on global emission reductions, with 174 countries signing the agreement in New York in 2016.

EU Policy

The EU 2020 climate and energy package set the so-called EU-wide '20-20-20' targets for energy and emissions for the EU; 20% energy efficiency, 20% renewable energy and 20% emission reductions by 2020 (from 1990 levels). These targets were translated down to individual member state targets, with Ireland set a non-binding 20% energy efficiency target, binding targets of 20% non-ETS GHG emission reductions and 16% renewable energy share of gross final energy consumption by 2020. The Irish National Energy Efficiency Action Plan (NEEAP) and the National Renewable Energy Action Plan (NREAP) outline how these targets are to be achieved.

With 2020 fast approaching, the EU 2030 climate and energy framework is now overshadowing the 20-20-20 targets, particularly when planning large-scale infrastructural projects. As mentioned in the introduction, the EU has now set Ireland a new GHG emission reduction target of 20.4% by 2030, after flexibility allowances for land-use and the ETS sectors are taken into account. The ETS sectors include power generation, aviation and large energy-intensive industry; therefore the non-ETS sectors cover transport, buildings, agriculture, waste, land-use and forestry. From an energy-related emission perspective, the transport and buildings sectors are the largest contributors. These new targets mean there should now be a renewed focus on these sectors and reduced focus on the electricity sector, as this is dealt with on an EU-wide basis under the ETS sector carbon trading system and emission targets.

National Policy

Under the NREAP, sectoral targets were established for electricity, heat and transport sectors of 40%, 12% and 10%, respectively. In order to meet the heating targets, policies and measures were put in place, such as ReHeat, the Combined Heat and Power (CHP) deployment scheme and the Greener Homes Scheme, all of which were cancelled due to budgetary constraints around 2011. There has been a Renewable Energy Feed-In Tariff (REFIT) available for renewable CHP, but this has been ineffective in increasing the number of heating schemes supplied by CHP. The REFIT2 and REFIT3 schemes are currently closed and consultation is ongoing on the future of renewable heat and renewable electricity supports.

According to the Sustainable Energy Authority of Ireland (SEAI) report *'Energy Forecast for Ireland 2020'*, projections show that even with an optimistic view of the impact of current heat policies and measures, the renewable heat target is unlikely to be met by 2020.

The NEEAP targets reductions in heat energy through increased rates of building energy efficiency retrofit and introduction of higher building energy standards. Part L of the 2011 Building Regulations requires 10kWh/m^2/yr of renewable heat, or 4kWh/m^2/yr of renewable electricity, or a combination of both, to be installed in new dwellings. These building energy regulations, along with higher insulation and energy efficiency requirements, have had a positive effect on emissions from new dwellings.

The Department of Communications, Energy and Natural Resources[5] outlines the pathway to 2030 in the report *"Irelands Transition to a Low Carbon Energy Future 2015-2030"*. The document sets out a framework for climate change and energy policy, which includes a vision for 80-95% GHG reductions compared to 1990 levels by 2050. For heating sector solutions, the framework envisions electricity and bioenergy will increase in the home heating and transport sectors. It also states that there will be a comprehensive heating strategy and a policy framework developed to encourage DH development. A Renewable Heat Incentive (RHI) is expected to be introduced in the coming year, consultation is currently ongoing.

Scope

This guide gives a general introduction to DH, DH policy and supports in Ireland, and how to go about initiating a DH system, while this guide is generally aimed at public sector bodies, much of the content is also applicable to the private sector. A thorough literature and research review has been carried out to inform the contents of this guide. The guide analyses current and potential DH sites in Ireland to further highlight how DH works within the context of the Irish energy sector.

The analyses in this guide include case studies of three existing and operational DH systems in Ireland. These were chosen based on access to information and availability of site visits within the project period, and an effort was made to show a variety of DH system types. Three sites with potential for successful DH implementation were also chosen for a Techno-Economic Analysis (TEA). Again, these were chosen based on accessibility to the required data, and the variety of DH system options, i.e. public/private ownership, small/medium scale, new/retrofit systems etc.

This report focuses on district heating and does not include analysis of district cooling, due to the fact that Ireland has a far higher heating demand than cooling demand, the cooling load in Ireland has yet to be accurately estimated, and initial growth of district energy systems in Ireland will need to be based on the economics of selling heat rather than cooling.

[5] Now known as the Department of Communications, Climate Action and Environment.

What is District Heating?

DH is a method of delivering thermal energy in the form of hot water through a network of highly insulated pipelines. In this way, *heat* rather than *fuel* is delivered to buildings. This works in much the same way as the electricity system; energy is produced at large plants and transported over a network, and usage is metered at each building. Like the electricity grid, large systems have transmission and distribution networks, and energy feeds into the network from a variety of sources and technologies. This means there is no actual fuel delivered to buildings and no heating plant is required in each building, therefore no gas, oil or coal deliveries or connections, and no open fires, gas or oil boilers and flues are required. A heat exchanger at each building transfers the heat energy from the DH network to the building's own water based heating system, and heat is supplied for both space heating (SH) and domestic hot water (DHW).

DH systems have the ability to distribute heat from many different sources, including heat sources that are typically seen as a by-product and usually go to waste, like the waste heat[6] from electricity production and industry. It is estimated that there is enough heat currently going to waste from electricity production and large industries in Europe to meet all of Europe's heating demands[7]. Once a DH system is established, it is possible to connect many sources of heat, for example, the DH network in Aalborg, Denmark, is mainly supplied by waste heat from a large cement producer, but also recycles waste heat from the local crematorium. High levels of recycled heat and renewable sources serve to lower the emissions from a DH system and the cost of heat to the end consumer.

In Denmark, DH is seen as a key technology in the decarbonisation of the Danish energy system, as it has whole energy system benefits, not just heating sector benefits. Using new operational and technological advancements, and integrating high levels of waste heat and renewables, is all part of, and is aiming toward, what is termed as '4th generation' DH (4GDH).

The progression of DH technology and system operation to 4GDH is explained in Figure 1. The new 4GDH systems currently being developed introduce DH into an overall smart energy system, connecting the electricity and heat markets, and utilising waste heat, renewable heat and electricity, thermal storage and prosumers[8] of heat, all within a system with lower temperatures and higher efficiencies.

4GDH connects the heat and electricity markets by allowing integration of higher shares of renewables on the electricity grid. With a combination of heating units powered by electricity and CHP units producing electricity, DH systems can coordinate these units to consume electricity in hours of high renewable feed-in to the grid, and to produce electricity in hours of low renewable feed-in to the grid, utilising thermal storage when there is no demand for heat. Thermal storage is a low cost way to store electricity for later use in the heating sector.

[6] For clarification, 'waste heat' is not 'heat generated from burning waste', but heat which is currently going to waste as a by-product of other industry. Waste to Energy plants produce electricity, and unless operating in CHP mode, will also have waste heat as a by-product of electricity generation.

[7] Heat Roadmap Europe, EU Horizon 2020 project

[8] 'Prosumers' is a term used for consumers who produce energy and feed excess back into an energy system.

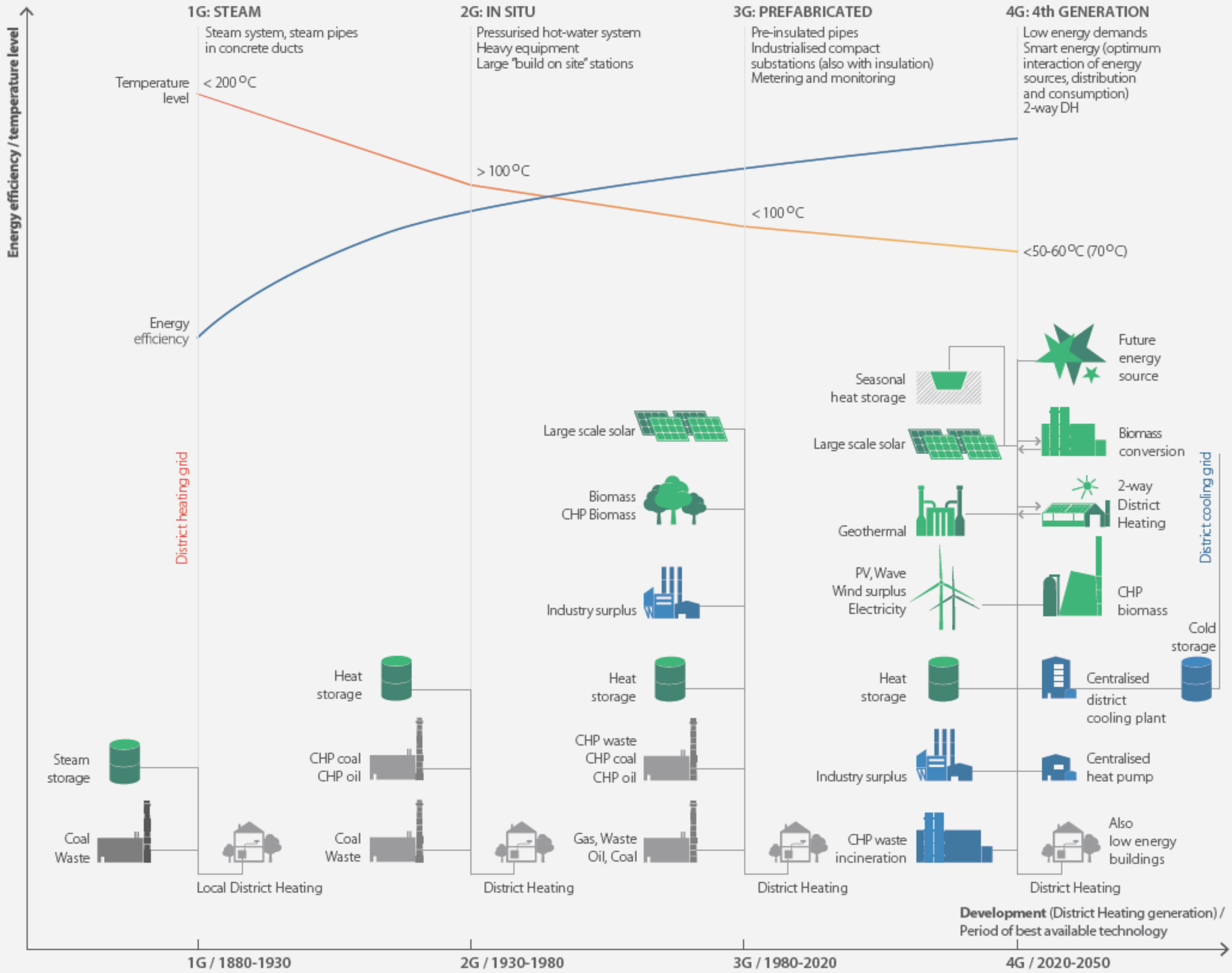

Figure 1: Evolution from 1st to 4th generation DH systems (Source: Aalborg University)[9]

The European Commission has conducted in-depth studies of DH and the role it can play in the decarbonisation of the heating sector. A 2012 report from the Joint Research Centre states:

"DH is a highly reliable and resilient heating solution. The end user has only a simple consumer unit with no combustion chamber or flue requiring annual maintenance, or potentially hazardous on-site fuel storage or delivery. The service is run by professionals and has intrinsic storage in the network sufficient to cover brief CHP outages, while the peaking boiler plants may be run to cover any longer outages. Moreover, the supply of heat can evolve over time towards a mix of zero carbon indigenous sources without requiring any action by the building owner or occupier. It follows that district heating is a robust solution that is unlikely to be superseded." [10]

– European Commissions Joint Research Centre.

There are many EU funded projects which concentrate on implementing and improving the use of DH in Europe, many of which have developed numerous resources for DH development. Links to some of these projects are found below:

- Celsius Smart Cities (http://celsiuscity.eu/) collaborates throughout the whole spectrum of planning, implementing and optimising new and existing smart infrastructure solutions for heating and cooling. The broad knowledge transfer spans topics such as technical best practice solutions,

[9] 4GDH Centre, Aalborg University. *4GDH Definition.*

[10] Andrews. et al. (2012) *Background Report on EU-27 District Heating and Cooling Potentials, Barriers, Best Practice and Measures for Promotion*.

fuel management, business models and gaining customer trust. Dublin avails of the support, advice and guidance by following the project as a 'Celsius City' member.

- **Heat Roadmap Europe 1, 2 and 3** (http://www.heatroadmap.eu/) have investigated the role of district heating and quantified the importance of implementing energy efficiency measures on both the demand and supply side of the heating sector for the EU27 region, and translated the methodology from an EU level to member state level, by quantifying the impact of implementing low-carbon energy efficiency measures in the heating sector of five member states, accounting for approximately 25-30% of the total heating and cooling demands in Europe.

- **SmartReFlex** (http://www.smartreflex.eu/en/home/) aims to increase the diffusion of smart and flexible district heating and cooling systems, basing on high shares of renewable energy sources in European cities.

- **HeatNet –** HeatNet is an Irish led INTERREG V NWE[11] project focusing on developing DH in north-west Europe, where the shares of DH supply are much lower in comparison to the rest of Europe. A living lab will be created in South Dublin where the first phase of a 4GDH system will be developed.

[11] The HeatNet project has been approved subject to clarification.

Definitions of DH Network Types

District heating systems can be different sizes, with different types and numbers of customers, and different supply sources, and with these different systems come different barriers, opportunities and levels of difficulty to implement. In Europe, the term district heating is generally only used for networks serving neighbourhoods, towns or cities. DH CHP systems serving one or few buildings are not considered DH systems but called 'residential CHP'[12]. It is therefore useful to define the different types of DH systems in operation in order to clarify the different planning and development characteristics which need to be considered.

Communal Heating Systems

These are **single buildings served by a single centralised heating system with multiple customers**, generally apartment blocks or blocks with a mixed use of commercial, offices and residential spaces. These are micro-scale DH systems, and generally do not have issues with connection of customers as all customer units are connected during construction by the site developer. The centralised heating plant is generally located in the basement of the building and therefore no large transmission pipeline is required and only small diameter distribution piping is needed within the building. All maintenance and billing is managed by the facilities management. Examples: Lansdowne Gate Apartments, Dublin, Heuston South Quarter development, Charlestown Shopping Centre (see Case Study chapter).

Localised Heating Systems

These are **multiple buildings with either a single or multiple customer/s connected to a single centralised heating system within a single small development or confined area**, usually with the same property owner or developer. These small scale systems generally do not expand or connect buildings outside the development, although some may connect to a neighbouring building if the economics of the system can be improved.

The pipeline network is generally on the developer's own land and no way leaves[13] are required. Again, a facilities management company or an Energy Services Company (ESCO) will maintain the centralised heating unit, and will meter and bill the customer/s. Planning such a defined system means the pipelines can be sized and planned knowing exactly where and how much heat is required, and negates planning for future predicted system expansion. There can be issues with such systems when all buildings on the development are not ready to connect at the same time, and the system may need to run at a much lower efficiency at the initial stages of development.

Many localised heating systems are public sector developments, such as college campuses, where it is mainly public sector buildings/customers connected. This makes it easier to implement as there is less risk of disconnection and heat payments are reliable. Examples: campuses such as Teagasc Grange Research Centre, UCD, UCC and DIT Grangegorman; local authority social housing estates such as Cork City Council's DH system at The Glen, etc. Localised systems also include large industrial sites, such as St. James Gate Guinness Brewery Site, where a large industrial site with large heat and power demands is supplied by an onsite energy centre.

District Heating Systems

DH systems are supplied by one large or multiple heating centres/sources over a transmission network supplying multiple buildings and multiple customers in a neighbourhood, town or city. These medium to large scale systems typically involve many stakeholders as there are many different building owners and customers involved, and will supply a range of new and existing building stock.

[12] Frederiksen, S. and Werner, S. (2013) *District Heating and Cooling*. Lund: Studentlitteratur AB.

[13] Way leaves are permissions required to access other land/properties outside the developer's ownership, in this case for the routing of pipelines.

They are generally planned and championed at a municipal level and form part of a district-level strategic energy plan. A district heating company is set up to manage and maintain the system, which is either a public or private sector entity. These systems typically utilise cheap sources of waste heat from a local industry or electrical power plant, have large thermal storage units and large back-up boiler systems. Many district-wide systems will have 10s of kilometres of transmission pipeline, which requires way leaves, road opening licenses and possibly planning. The pipes generally pass through areas with many other services in the ground.

These systems will often connect and supply existing communal and localised heating systems, or DH 'nodes', when they come into a feasible connection distance to the DH transmission network. The closest example of this type of a DH system in Ireland is the Mitchels-Boherbee neighbourhood DH system in Tralee, which is currently at the first phase of a planned district-wide network. This system was championed by the local authority, connects a range of different building types and customers, and is planned to expand to connect surrounding buildings, as part of an overall local authority energy plan.

Example: District Heating in Copenhagen

DH has been in use at small scales in Copenhagen since 1903, but increased significantly from 1979 when the National Heat Supply Act was introduced, and continues to extend to new areas where natural gas is currently in use. The heat transmission companies are owned by the municipalities they serve and the 20 heat distribution companies are owned by either the municipality or the consumers. All these companies work together to increase efficiencies and improve the cost-effectiveness of the system as they all have the same objective; to find the cheapest way to supply heat to their customers.

The system serves 75 million square metres of heated floor area and the transmission system is over 160km long. The DH companies sell 8,500 Giga-Watt hours (GWh) of heat annually, which is a lot more than the 5,000 GWh of total heat demand in Dublin City, and the Copenhagen system is expected to connect another 1,000GWh of heat demand in the near future. The system distributes heat from two large CHP plants, three waste-to-energy (WtE) plants, and more than 50 peak boilers and small heat producers. The system is constantly improving, and is moving towards 4GDH by replacing the gas and coal for CHP with straw and wood fuels, lowering the supply temperatures, integrating heat pumps and electric boilers, and increasing the thermal storage capacity[14].

[14] State of Green (2016). *District Energy: Energy Efficiency for Urban Areas*. Denmark: State of Green.

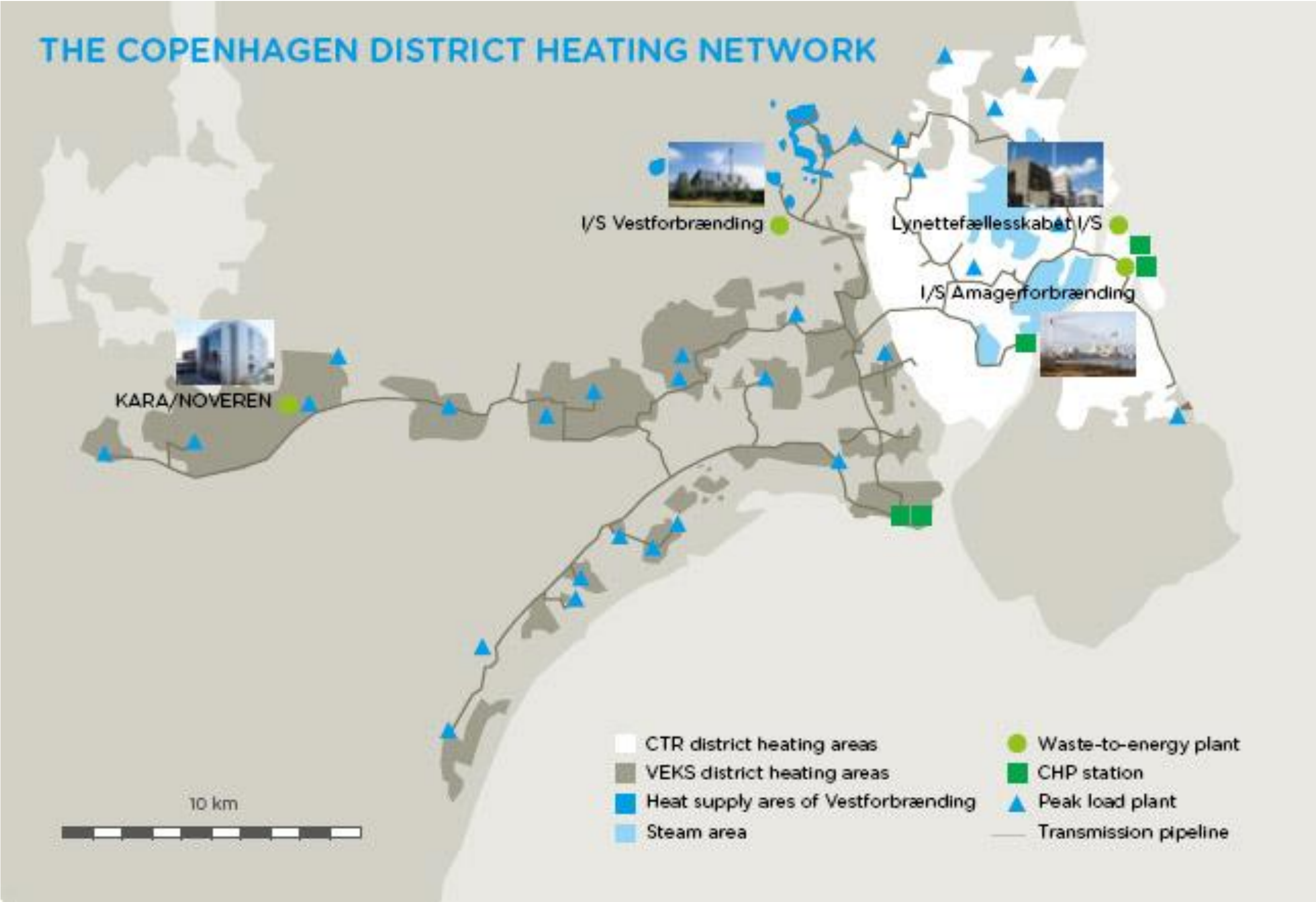

Figure 2: Copenhagen DH system (Source: Ramboll)

Why DH?

There are numerous direct and indirect benefits for Ireland if DH systems are developed in areas with suitable heat demands. There are technical, economic and societal benefits to be gained from the use of DH.

Technical benefits

Efficiency

Traditional electricity generation has low efficiencies due to high losses, mainly in the form of heat. Older existing power generation plants are typically 30-45% efficient. Some of the highest efficiencies in traditional power generation are found in new combined cycle gas turbines (CCGT), at approximately 55% electrical efficiency. In comparison, if the same CCGT plant was to run in CHP mode, the overall efficiency would increase to 90%, split into approximately 50% electrical efficiency and 40% heat efficiency[15]. As can be seen, there is a drop in the electrical efficiency in order to extract useful heat, but overall the fuel-input-to-energy-output ratio is greatly increased. When comparing CHP (at 90% efficiency) to producing both electricity (55% efficiency) and heat (90% efficiency) separately[16], the CHP plant will use 35 fewer units of fuel to produce the same amount of heat and electricity.

Using decentralised CHP also means that it is likely that the electricity generation will be located closer to heat demands in order to deliver heat, and therefore will also deliver electricity closer to electricity demands and reduce losses on the electrical grid.

When DH is retrofitted into existing buildings, it replaces the existing gas or oil boiler which may be old and inefficient. The building owner no longer has to worry about the efficiency of their own heating plant, as heat energy is delivered directly to their system through a heat exchanger. The central heating plants are maintained regularly by the DH company to ensure optimum efficiency, whereas domestic boilers will have an annual inspection at most.

Integration of more renewables into the energy system

Like Denmark, Ireland has a large percentage of renewable electricity supplied by wind power, which is a fluctuating source and needs to be balanced or stored at certain times by other units connected to the grid. As mentioned previously, advances in DH operations and technologies towards 4GDH means more renewable energy can be integrated into both the electricity and heating systems. Many DH systems use solid biomass, municipal waste, including organic waste. It is a key enabling technology for biomass and other forms of renewable heat.

DH grids allow greater integration of renewables on the electricity grid by helping to balance energy input from renewables, and therefore reduce the need for curtailment and negative pricing. DH can achieve this by using large scale heat pumps or electric boilers when there is a surplus of RE on the grid and utilising thermal storage to store this energy in the form of heat for later use on the DH network. The DH system can also turn CHP units on/off when balancing of renewables is required, and again makes use of thermal storage. Thermal storage is a very cheap and effective way of storing energy as thermal energy and using it to offset fossil fuel use in the heating sector. Unlike electrifying the heating sector, utilising renewable electricity in DH systems in the way described does not require additional electrical capacity on the grid.

There are many examples of large solar thermal plants connected to DH systems, some of which make use of seasonal thermal storage to store this heat during summer for use in winter. Marstal, a town on the island of

[15] Different ratios of heat-to-electricity output are found for different types/size of gas engine, and if operating in back-pressure mode.
[16] Using high efficiencies found in new heat and electricity generation technology rather than comparing to existing older technologies.

Aero, Denmark, currently supplies close to 100% renewable heat to the residents, and includes over 33,000m^2 of solar thermal production.

New buildings built to high energy efficiency standards, such as near-zero energy buildings and passive house, will have a lower heating temperature requirement than the older building stock. DH is also a solution in these cases, as renewable energy sources such as geothermal and solar thermal heat become more compatible, and low-grade waste heat sources, that is, waste heat at lower temperatures from sources such as breweries, laundrettes, data centres, bakeries etc, can be used to supply cheap space heating to these buildings.

Economic benefits

Cheaper heat and cheaper plant

With the higher efficiencies related to sizing and maintaining one large energy plant to cover multiple building heat demands as opposed to multiple individual boilers, coupled with cheaper sources of heat production, and negotiating cheap prices for industrial waste heat, the overall customer price for heat can be reduced. There is an incentive for customers to connect to DH systems if it is cheaper than the alternative. For example, the Copenhagen DH system saves its customers on average €1,400 annually[17].

Due to economies of scale, a larger heating plant costs less per unit output than equivalent costs of numerous small plants. Having a DH system available to connect to also means developers and house owners need not invest in individual heating plant and hot water tanks, and only need a comparably low-cost heat exchanger, which also has much lower maintenance requirements. When comparing typical heating system installation costs of a 3,000m^2 office building supplied by a traditional gas boiler system versus a DH system, the capital cost savings are estimated to be over €30,000[18]. The replacement of boilers with heat exchangers saves on space within the building, increasing the useful space and value of the property.

Indigenous supply

Creating a network that can utilise more local resources, such as waste heat, CHP heat, and renewable heat including biomass, and a variety of different heat sources, means there is increased security of supply and less money is used to pay for imported fossil fuels. Ireland has one of the highest import dependencies for fuel in Europe at 85%, costing an estimated €5.7 billion a year[19], and leaves Ireland at great risk if there was a crisis in the gas or oil markets. The flexibility offered by DH supply means it is possible to switch to another heat source, and to continually connect new secure local sources to the network. This also offers increased price stability and security for customers.

Social benefits

Emissions

Fossil fuel heating systems based on coal, oil, gas and peat produce GHGs and other particle emissions, vented through chimneys and flues, and released into the local environment. These emissions can affect local air quality and health, depending on the technology used. Replacing these sources of heat production with 'clean' sources, reduces the direct health impacts of poor local air quality, and importantly, lessens the impact on global temperatures. Reducing CO_2 emissions will also contribute to mandatory emissions targets, and lessen the impact of financial penalties associated with not meeting these targets.

[17] C40 Cities. (2011) *Case Study: 98% of Copenhagen City Heating Supplied by Waste Heat*.
[18] RPS. (2016) *Technical Information Pack for Developers: Dublin District Heating.* Dublin: Dublin City Council.
[19] SEAI (2016) *Energy Security in Ireland: A Statistical Overview*.

Local jobs

There will be increased local employment during construction of DH networks, energy centres and customer interfaces, as well as long-term local employment in the operation and maintenance of all system components. In the Swedish city of Helsingborg, the DH system employs 1,358 people full time, and increases local purchasing power by €20 million per year[20]. There are also established positive employment impacts created through the development of new supply chains for the supply of sustainable indigenous biomass.

In 2012, IrBEA published a study on the socio-economic benefits of developing the bioenergy sector in Ireland over the coming years to 2020. The independent study confirmed the substantial economic benefits that can accrue by meeting the 2020 bioenergy targets, including over 3,600 new permanent jobs in the bioenergy sector.

Customer benefits

There are many additional benefits to the DH consumer on top of the financial benefits already mentioned. Due to the lower costs of heat, supplying DH to residential areas that have low building energy efficiencies and high levels of unemployment can reduce the risk of energy poverty. Fossil fuel is usually burned onsite within the consumers' own boiler unit. This creates a risk of carbon monoxide poisoning in all buildings, particularly in homes where the boiler is located inside the house. DH supply negates the need to burn or store any fossil fuels onsite, thus reducing health and safety risks. The heat exchanger which connects the customer to the DH network has very low noise levels and no flue gases. The heat exchanger has very low maintenance costs, as there are very few mechanical moving parts. With a DH connection, customers do not need to time heating to fill hot water tanks or to turn on electric immersions, as hot water is available on demand with no run-up times required. The customer does not require any fuel storage tanks or fuel deliveries.

Disadvantages of DH

There are also disadvantages to DH. When a customer invests in a DH connection, they are signing up to be supplied by the local DH company, and cannot switch suppliers like in the gas or electricity retail sectors. In this way, DH supply is a monopoly, and therefore needs be effective regulation to protect the customer. This issue is overcome in countries like Denmark by running the DH system as a not-for-profit, municipality-owned system, which keeps the customer heat price as low as possible.

Installing DH transmission pipelines, like any large infrastructure project, will cause disruption to traffic and business for a period of time. With effective planning, installation of sections of DH pipelines can be scheduled to overlap with other planned infrastructure projects such as roadworks and installations of other underground services to lessen the disruption caused and also decrease overall installation costs.

[20] Kemira (2014) *District heating cooperation reducing emissions in Helsingborg.*

Barriers to DH in Ireland

Ireland's energy supply system is different to other countries as the structure of an energy system is largely dependent on history rather than on any long-term strategic planning. The choices made regarding energy supply have been, and continue to be, economically evaluated on a very short-term basis, and not assessed based on what is best from an overall societal perspective. This has led to the current situation in Ireland, where the energy system is not structured in a way to best benefit society as a whole. Changing the current system requires more and more radical technological changes, which become more and more difficult to implement due to the lock-ins created by the existing system structures.

DH in Ireland faces organisational, technical, regulatory and economic barriers to growth. The barriers differ depending on the type of DH system; communal and localised systems face fewer barriers than when implementing medium-to-large scale DH projects. This is due to the added complexities of such systems, such as large transmission pipes requiring way leaves and planning permissions, multiple and varied customer connection agreements, and long-term planning for extensions. The following barriers are related to developing medium-to-large scale systems and the DH market as a whole in Ireland.

Organisational

Heat energy is required and created at an individual building level and is therefore fundamentally a local level issue. Currently, there are no energy planning practices carried out at a local authority level in Ireland, and national level planning overlooks local level energy synergies and characteristics that allow for an optimal, least cost, low-carbon energy system design. The role of local authorities is crucial in the development of DH, as outlined by most guides and reports on DH. A United Nations Environment Programme report on DH found that local governments are the most important actor in catalysing investment in DH[21].

There is a need for integrated land-use, energy and infrastructural planning in order to progress DH development, and the local authorities are ideally placed to oversee that this integration occurs. Most local authorities in cities with DH have used planning policy and local regulations to promote and develop DH. The local authorities in Ireland are not obliged from a national level to implement such energy plans and are not given the equivalent resources.

There is a general lack of knowledge and awareness of DH technologies and their benefits in Ireland, and many myths surrounding the use of DH still exist and are prohibitive to its consideration. Local authorities do not have the in-house skills and do not have any national framework or guidance to develop DH. DH is also often not on the curriculum for energy related college courses in Ireland, and therefore there is a lack of local skills and knowledge of DH.

Many DH systems in other countries have evolved through community co-operative group heating schemes. Ireland traditionally has not had the same level of co-operative group projects, particularly in the energy sector and in urban areas where DH is best suited.

Technical

There are far fewer technical barriers to DH because the technologies used are themselves not new or innovative; CHP generators, boilers, hot water tanks, and hot water pipes are all well-established technologies and are used together in DH systems successfully all over Europe. The technical barriers in Ireland are on the demand side rather than the heat supply. In order for DH to be economically feasible, there needs to be a sufficient heat demand within a given area[22]. This is because the denser the heat demand, the shorter the pipelines required, which means lower investment costs, and lower operational costs through lower losses and

[21] UNEP. (2015) *District Energy in Cities*. Brussels: UNEP.
[22] Heat demand densities suitable for DH are discussed later under 'Heat Demand Mapping' section.

lower pumping requirements. DH is therefore most suited to dense urban areas, which means DH will be most suited to large cities and towns in Ireland. That said, there are many examples of community cooperative DH systems in Denmark in small rural towns and villages. There are also several examples of local community heating schemes in smaller towns and rural locations in Ireland.

Certain building types, known as 'anchor loads', such as hospitals, nursing homes, and hotels are ideal for optimal DH operation as they have long hours of space heating demand and large hot water demands. Additionally, if the anchor load is a public sector tenant, it can offer security in terms of connection and payment reliability. DH is also most successful if there is a cheap waste heat source which can be utilised, such as a large electricity producer operating as CHP generator, or a large industrial facility with a waste heat source.

Regulatory

A national policy framework to encourage the development of DH is planned, as outlined in the national level energy white paper *'Ireland's Transition to a Low-Carbon Energy Future'*, but since this paper was published, there has been no announcement on the timeline of this framework. Currently, there are no guidelines, regulations, policies, frameworks or standards for DH in Ireland. This creates high risk and uncertainty when planning medium-to-large scale systems.

Currently, there are no tariffs for the production of low-carbon heat. The REFIT3 for renewable CHP generators (now closed) is awarded on the kWh electricity production with indirect recognition of the renewable heat produced. CHP does not create energy savings in the electricity sector, but in the heating sector, as it is in the heating sector that the choice is made to use heat from CHP rather than using boilers, heat pumps, etc. In this way, and according to the EU Joint Research Centre, it makes sense that the incentive should be applied to the heating output rather than the electrical power output[23]. A Renewable Heat Incentive (RHI) is currently being developed in Ireland, and details are likely to become clearer during 2017. The eligibility requirements and the level of this tariff will have a large impact on low-carbon DH systems. The effectiveness of a renewable electricity incentive (REI) and RHI on DH project feasibility is analysed in this guide in the section on potential DH sites in Ireland.

There are issues when trying to attain the high Building Energy Ratings (BER) required for new dwellings when considering a DH supply. During the initial phase of DH development, when all buildings are yet to be connected, there are higher losses in the network than will be the case when all demand is connected. The current software set-up means the end-user must account for these losses within the DH system, which negatively affects the energy rating. These losses must therefore be supplemented with additional energy savings elsewhere in the building to ensure building regulations are met. These additional elements create additional costs and make connecting to a DH system unfeasible in some cases. Therefore, the current calculation method on the DEAP software is not adequate, and modifications need to be made to the treatment of DH heat losses, particularly when dealing with renewable DH.

Economic

The largest part of the capital expenditure of a DH system is the investment in the pipeline network. This infrastructure is a long-term investment, with a lifetime of around 50 years. Due to the high capital costs, DH systems will have longer paybacks compared to other well established heating systems, but the network has a much longer lifetime. It is therefore difficult to compare DH to other solutions under the same short-term economic analysis, when the benefits accrue over a much longer investment period. In many ways, an investment in DH should be considered in the same way as other long-term infrastructure investment, such as motorways or electricity transmission assets. The results of the Heat Roadmap Europe 3 project show that the

[23] Andrews, D. *et al*. (2012) *Background Report on EU-27 District Heating and Cooling Potentials, Barriers, Best Practice and Measures for Promotion*. Petten: Joint Research Centre of the European Commission.

pipe costs account for only approximately 5% of the *annualised* district heating system cost, with the rest attributable to costs of individual heat exchangers in buildings (25%) and heat supply (70%)[24].

Any investments made in DH infrastructure by local authorities are taken account of on the government balance sheet and require approval by the Department of Finance. It can therefore be difficult to secure public funding to cover the large capital costs of the network. Privately owned networks do not have the same considerations, but do require a high return on capital. Public-private partnerships, long-term bonds or other financial options need to be considered to address the particular funding requirements of district heating.

[24] Connolly, D. *et al*. (2016) *Stratego: Enhanced Heating and Cooling Plans to Quantify the Impact of Increased Energy Efficiency in EU Member States*. Aalborg: Aalborg University, 2016.

Frequently Asked Questions on DH

Q: Is Ireland cold enough for DH?

A: The European Heating Index shows there is little variation in climatological heating demands, with only a +/- 20% difference from the north to the south of Europe. The report from the Ecoheatcool[25] project shows that only half of the variations in heat demands throughout Europe are related to climatological differences, the other variations are attributable to differences in heat costs, indoor temperatures, hot water consumption and affordability. A typical Danish household heat consumption of approximately 15MWh/year is used in Danish analysis[26], which is the same as the average dwelling in Ireland at 15MWh/year, and below the average Dublin City dwelling which consumes 18.2MWh/year[27]. The poor insulation levels in Irish dwellings and the comparatively high levels of insulation in Scandinavia means Irish households use more energy for heat than their Scandinavian counterparts per heating degree day.

There is a very successful large scale DH system in Brescia, Italy, close to Milan. 70% of the Brescia population are connected to the DH network. Brescia does not experience very cold winters, with the average lowest temperature recorded in winter at -2°C in January, and has a shorter heating season than Ireland. A map of cities in Europe with DH systems is shown in Figure 3. The map shows the low number of cities or towns in Ireland with DH compared to the rest of Europe.

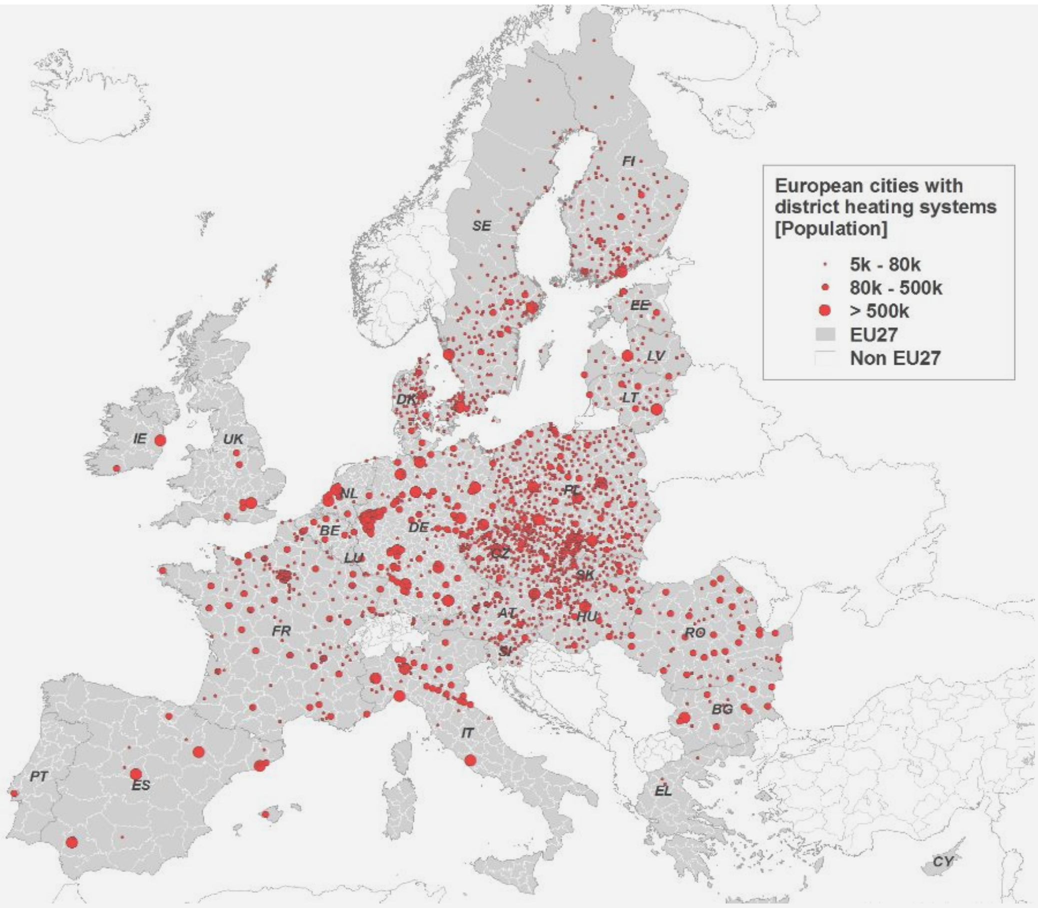

Figure 3: District Heating in European Cities (Halmstad and Aalborg Universities 2013)

[25] Werner, S. (2005) *The European Heat Market*. Brussels: Ecoheatcool and Euro Heat & Power.
[26] Lund, Moller, Mathieson and Dyrelund. (2009) 'The role of District Heating in future renewable energy systems,' *Energy*, 35, pp. 1381-1390.
[27] Gartland, D. (2014) *Dublin City Sustainable Energy Action Plan Monitoring and Reporting 2014*. Dublin: Codema.

Q. What are the key components in a DH system?

The main components of a DH system are a suitable low-cost source of heat, a suitable nearby heat demand, and a network of insulated hot water flow and return pipelines which connect the two. The main source of heat supply typically meets at least the baseload demand of heat. The DH system will then also include back-up or peak boilers, typically sized to 120% of the peak demand for heat in any hour. This means the heat demand is met in all hours and there is uninterrupted supply during any outages in the main heat supply and periods of extreme weather conditions. The DH system usually also comprises a large thermal storage unit, typically sized to meet at least 6 hours of average heat production. The pipe network connects these production and storage units to the heat demands (customers). The heat is transferred from the heat network to the customer system through a heat exchanger unit. Each customer has their own heat exchanger unit in their building, along with a heat meter for billing.

Q. Is DH suitable for low energy buildings?

The average Danish dwelling has a lower heat demand than the average Irish dwelling, yet over 60% of all residential floor area in Denmark is connected to DH networks. As already mentioned, 4GDH allows integration more RE sources by reducing the supply temperature requirements. This suits both the heating requirements of low-energy new builds and energy conservation measures within the existing building stock. There are many examples of low temperature DH supply, such as a new build scheme connected to the city DH system in Lystrup (Denmark), and a zero carbon development fed by an all-renewable localised heating system in Greenwatt Way, Slough (UK).

Q. Does DH cost a lot more than traditional systems?

For the consumer, connecting to a DH system costs less than traditional heating over the lifetime of the system, as there are much lower maintenance requirements than a traditional heating system, and the cost of heat per kWh is generally lower. The Danish Energy Agency lists prices for a one-family new or existing house with a 10kW DH substation unit, averaging at €2,500 per unit, including installation, and approximately €3,000 for the branch pipe and meter connection to the DH network. These costs are similar to those estimated in Irish case studies (see case study on The Glen in Cork). The DH company will in some cases supply the heat exchanger substation in order to ensure operational compliance.

Q. Are there changes needed to the heating system when retrofitting DH?

To optimise the efficiency of the system, DH requires a low temperature in the return hot water pipe. In order to achieve this, the consumer system must effectively distribute the supplied heat within the building, and return the water at a lower temperature. This is typically achieved using larger radiator sizes than those found in traditional systems. Therefore, when retrofitting DH, there may be a requirement to change some radiators, but in a lot of cases, radiators are already oversized for the space heating requirement, and so it is possible that existing radiators can be used and achieve less than 10% loss in output[28].

Q. Do DH pipelines require planning?

There is some ambiguity on this matter, with existing planning guidance and legislation providing insufficient clarity on the issue. It would be the expectation that DH pipes should be considered and treated the same as any other underground pipe or cable and be exempt from planning permission in most circumstances

[28] Skagestad, B. and Mildenstein, P. (1999) *District Heating and Cooling Connection Handbook*. International Energy Agency.

under the Planning and Development Act, section 5[29]. With the high capital costs entailed, this should be addressed by the Department of Housing, Planning, Community and Local Government.

Q. How can new building heating systems be designed to ensure they can connect to a planned DH system in the future?

The first thing to ensure is that the building heating system is a centralised wet system, i.e. it is heated from one central heating plant and uses hot water as the space heating medium. This means systems with numerous individual heating boilers or systems with electrical space heating are not suitable for a simple plug-and-heat DH connection. The heating system should also be designed to ensure the lowest return temperature as possible, which may require larger radiator sizes than traditional system designs.

The building will need to bring a branch pipe from the central heating plant room to connect to the DH transmission line. The size of this pipe will depend on the predicted building heat load and the distance to the DH heat supply, and will need to be designed with input from the DH company. When the DH system is ready to connect and supply heat, there will be a switch over from heat supplied by the buildings central boilers, to heat supplied by the DH company. The DH is supplied from the transmission network through the branch pipe to a heat exchanger within the building. In many cases the DH company supplies and owns the heat exchanger to ensure optimal operation of the DH system.

New tenancy relationships and commercial lease structures may be required to accommodate (and encourage) DH connections, as was found in the case studies examined in this report.

Q. What heat demand density is required for viability?

Heat demand density is a key metric for defining the potential for large scale DH. The density is important for DH economic viability as it becomes cheaper to implement when heat demands are closer together due to shorter pipelines requiring less investment costs and therefore the system becomes more cost-effective than individual solutions. Shorter pipelines also result in fewer losses and lower pumping requirements, and can therefore have a significant effect on running costs. The lower costs of DH systems associated with higher heat demand densities means there is a greater ability to supply low cost heat.

The general rule of thumb used in Danish heat planning is any heat demand density above 150TJ/km^2 (or 40-50 kWh/m^2) is suitable for DH. In areas with established and competitive DH prices, these thresholds can be much lower. In countries like Ireland, where there is higher risk attached to investments in DH due to lack of knowledge and experience, it is better to initiate DH projects in areas with highest heat densities available. The highest heat densities will be found in dense urban areas, particularly those with high-rise residential developments. Mapping heat demands is one of the first steps in developing DH, and is discussed further in this guide (p.26). When a DH zone has been identified, and the DH network route is known or can be predicted, then calculating the linear heat density, i.e. the heat demand per meter of network pipe, is a more accurate prediction of DH viability.

Q. Are the losses very high from DH?

The most significant losses in DH systems come from the heat lost through the pipeline network when delivering hot water to customers. Older, inefficient systems in areas with low heat density typically have higher losses (15-35%), and large efficient modern systems with high heat densities typically have lower losses (5-8%)[30]. Typical heat losses in western and northern Europe are between 10 and 15%, and in eastern Europe between 15 and 25%. For example, the average heat losses in DH networks in Denmark is 17%, with the worst losses up

[29] Office of the Attorney General (2000). *Planning and Development Act 2000*. Dublin: Irish Statute Book.
[30] Frederiksen, S. and Werner, S. (2013) *District Heating and Cooling*. Lund: Studentlitteratur AB.

to 50%, and the lowest around 7%, such as those found in the Greater Copenhagen system[31]. Using best practice principles and modern network technologies, system losses are typically kept to less than 10% in new DH systems.

The annual heat loss of the network depends on its linear heat density, distribution temperatures, pipe diameters and insulation thicknesses, as well as the thermal conductivity of the insulation material. The temperature loss is higher in the supply pipe than in the return pipe due to the higher supply temperature. Smaller pipes have higher heat losses than wider pipes with the same insulation thickness, as the outer diameter of the insulation, which is exposed to the cold, is a much larger area when compared to the outer diameter of a small carrier pipe, versus a large carrier pipe[32]. This means smaller DH systems found in low heat density areas can be negatively affected.

Q. What are the design standards for DH?

Currently there are no design standards for DH systems in Ireland. A good source for design guidance is the *'Heat Networks: Code of Practice for the UK'* from the Chartered Institute of Building Services Engineers (CIBSE) and the UK Combined Heat and Power Association (CHPA). This best practice guide covers areas including feasibility, design, construction, installation, O&M and customer obligations for heat networks.

Q. What type of excess heat and renewable heat is suitable for a district heating system?

Typical sources of excess and waste heat connected to DH systems are thermal power plants, waste incineration and large industrial facilities with excess heat, such as fuel refineries, iron and steel industries, and food and beverage industries. It is estimated that Ireland has approximately 102 PJ (30.5 TWh) of excess heat available, the majority of which is from currently operating thermal power plants[33]. This quantity of excess heat is over 6 times the total heat demand of Dublin City at 5 TWh[34].

Renewable sources of heat are biomass, geothermal, and large-scale solar thermal plants. To serve as a baseload to a DH system, industrial surplus heat is typically the cheapest, followed by waste incineration heat, biomass and finally, geothermal heat[35]. The output of solar heating varies seasonally and therefore cannot operate as a baseload, and is often coupled with seasonal storage units to optimise the output. Renewable electricity can also be utilised through large scale heat pumps or electric boilers.

[31] Danish Energy Agency. (2013) *Technology Data for Energy Plants*. DEA, Copenhagen.
[32] Frederiksen, S. and Werner, S. (2013) *District Heating and Cooling*. Lund: Studentlitteratur AB.
[33] Gartland, D. (2015) *South Dublin Spatial Energy Demand Analysis*. Dublin: Codema.
[34] Gartland, D. (2014) *Dublin City Sustainable Energy Action Plan Monitoring and Reporting 2014*. Dublin: Codema.
[35] Connolly, D. *et al*. (2016) *Stratego: Enhanced Heating and Cooling Plans to Quantify the Impact of Increased Energy Efficiency in EU Member States*. Aalborg: Aalborg University, 2016.

Steps to DH Growth

Local authorities and public sector bodies are seen as key stakeholders and enablers of DH development. Due to the many barriers already outlined, the development of DH will require coordinated, local-level action to effectively plan for successful wide-spread DH implementation and to de-risk potential DH projects.

Energy Strategies

One of the first key steps is to create a local level energy strategy with long-term policy goals, and with buy-in from all key stakeholders. The impacts of a local DH network should be assessed and highlighted within this strategy, and the role DH can play in reaching regional CO_2 and energy efficiency goals. This document can then be used to clearly communicate to the public the societal benefits of any planned public sector actions to reduce fossil fuel use and increase energy efficiency. There are support structures available to enable regions to develop their own energy strategy, such as the EU Covenant of Mayors for Climate and Energy initiative. Local and regional authorities can become signatories to this initiative and as part of this commitment create Sustainable Energy and Climate Action Plans (SECAPs). There are currently nine Irish local authorities signed up to the Covenant of Mayors.

The SEAI's '*Methodology for Local Area Renewable Energy Strategies*'[36] is a guide to create renewable energy strategies. Creating a Local Area Renewable Energy Strategy (LARES) allows a local authority to identify and assess the renewable energy resources in their region.

Energy Mapping

In order to create robust evidence based energy policy to support DH, energy modelling and mapping is required, and is recommended by many guides on DH development[37]. Energy mapping involves detailed analysis of energy use within buildings, and is crucial for DH analysis as the potential for DH is dependent on local heat resources and heat demand densities.

The first Spatial Energy Demand Analyses (SEDAs) in Ireland have been produced for the South Dublin[38] and Dublin City[39] county council areas, with the whole Dublin County soon to be mapped. The SEDA methodology was created by Codema, and training on how to carry out a SEDA has been rolled out by the SEAI as part of the LARES suite of training courses. An example of the heat demand density analysis from the Dublin City SEDA can be seen in Figure 4. From this analysis, it is estimated that over 75% of Dublin City has heat demand densities suitable for DH (over 150TJ/km^2).

Other key things to map in terms of DH analysis are the location of potential anchor loads and sources of waste heat from industry or surplus heat sources. Anchor loads are large heat consumers, ideally with steady day and night heat demands, such as hospitals. Mapping potential resources and demands allows the identification of zones with high DH potential, and allows analysis of potential network routes.

[36] SEAI (2013) *Methodology for Local Authority Renewable Energy Strategies*.
[37] UNEP. (2015) *District Energy in Cities*. Brussels: UNEP.
Frederiksen, S. and Werner, S. (2013) *District Heating and Cooling*. Lund: Studentlitteratur AB.
Andrews, D. *et al*. (2012) *Background Report on EU-27 District Heating and Cooling Potentials, Barriers, Best Practice and Measures for Promotion*.
[38] Gartland, D. (2015) *South Dublin Spatial Energy Demand Analysis*. Dublin: Codema.
[39] Gartland, D. (2015) *Dublin City Spatial Energy Demand Analysis*. Dublin: Codema.

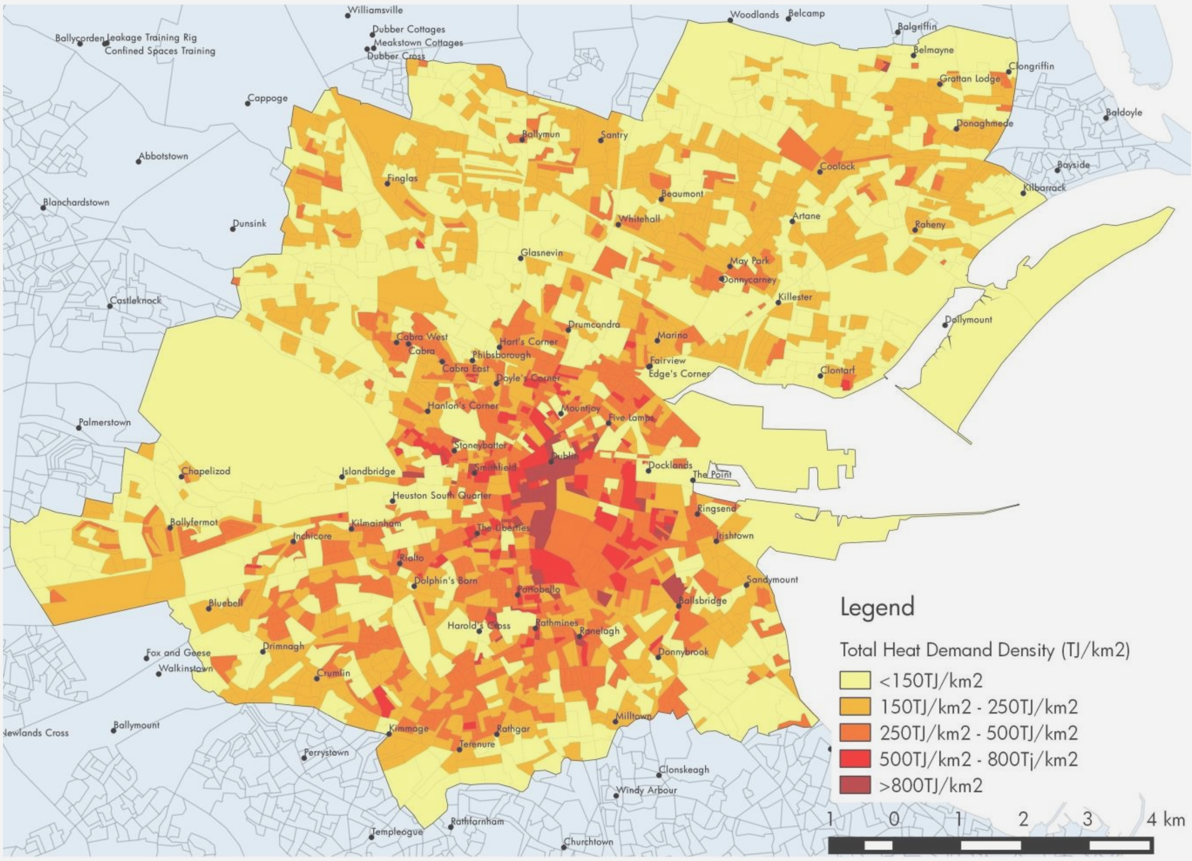

Figure 4: Dublin City Heat Demand Density[40]

Local Level Energy and Planning Policy

Energy mapping and energy strategies help to integrate energy considerations into the work of the local authority planner. Planners have a key role in driving the development of DH in an area by **creating tailored planning policies** and coordinating works. Integrating energy, infrastructure and land-use planning is essential in order to identify synergies and opportunities for cost-effective DH systems[41]. Forward planning is essential for DH, particularly to ensure there is suitable heat demand to connect to potential DH systems in the future. An example of this can be seen in Dublin City's North Lotts & Grand Canal Dock SDZ Planning Scheme, where all new buildings have to be 'DH enabled' to allow ease of connection to the planned Dublin District Heating System.

In Denmark, under the Heating Supply Law, the local authorities have the responsibility of carrying out heat planning in the municipality area. The objective of these heat plans is to promote the heating solution which has the most benefits from a societal perspective, and reduces impact on the environment.

DH Design

In order to ensure optimum efficiency and lowest running costs, the DH energy centre and network have to be well designed, taking account of many key operational parameters. If the DH system is not designed well, it can result in high system losses, interruption in heat supply, leaks, and oversized plant equipment. Many of the design considerations of a DH system are described in the techno-economic analyses later in this report (p.32).

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[40] Jordan, U. and Vajen, K. (2001) *Realistic Domestic Hot Water Profiles in Different Time Scales*. Marburg: Universitat Marburg.
[41] UNEP. (2015) *District Energy in Cities*. Brussels: UNEP.

Currently there is no specific guidance on designing DH systems in Ireland. DH manuals, such as *'The London Heat Network Manual'*[42] produced for the city of London, provide information for DH developers on principles of operation, district heating standards, construction principles, specific local regulations, and commercial and contract structures for DH within a region. These manuals can be used by local authorities to ensure high standards for DH networks are met and heat supply contracts are structured to protect customers. It is recommended that any Irish cities or towns that are planning DH developments should produce similar guidance manuals.

The CIBSE '*Heat Networks Code of Practice for the UK*'[43] and the Danfoss Technical Paper '*Optimum Design of Distribution and Service Pipes*'[44] reports are also a useful guides for designing DH networks. A detailed description of the design considerations of heat exchanger substations and how to convert a building to accept DH are outlined in the IEA's '*District Heating and Cooling Connection Handbook*'[45].

Facilitator Role of Public Sector

Due to the large number of stakeholders involved in developing DH, there needs to be a central facilitator to bring a project together. Local authorities or energy agencies are in an ideal position to be this DH 'champion' and drive the process forward. It is useful for the facilitator to set up a DH working group to regularly meet with key stakeholders.

Public sector buildings can be used as anchor tenants on new DH schemes. Securing connection to these buildings in the 1st phase of DH development decreases the risks involved in ensuring a viable heat demand is connected to the system. Public sector customers are also a reliable customer in terms of heat payments. The public sector can play a 'lead by example' role in developing the DH sector in Ireland. Demonstration projects using groups of public sector buildings are a way to promote and increase knowledge and awareness of DH design and operations.

Business Models for DH

There is a mix of public, private and public-private business models used in DH projects, but in most cases there is some public sector involvement. Most systems are fully publicly owned, and there is either an internal DH department or a wholly owned and operated subsidiary set-up. In some cities the municipality has already shared or direct control over other energy utilities such as electricity supply, and are better equipped to run another utility. The long-term investment in the DH network can be better suited to public sector investment, and the development risk is often transferred to a third party via a Special Purpose Vehicle (SPV). Public ownership allows the municipality to protect the customer in terms of pricing, and allows control over the fuel input, emissions, and environmental considerations of the system.

The most common business model found in the UK is the public-private model. There are different arrangements under this model, such as municipality ownership with operation outsourced to an ESCo, split assets with some outsourced operation (Southampton District Energy Scheme), or joint cooperation agreements (Birmingham District Heating Scheme).Wholly private business models are not as common, and are usually found in communal heating schemes.

The Danish system is based on a not-for-profit business model, and all DH systems cannot, by law, increase its income through increased customer costs. Most Danish systems are owned and run by consumer cooperatives or municipalities. This model ensures a heat supply which considers the customers best interests and what is best from a societal perspective.

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[42] ARUP (2014) *London Heat Network Manual*. London: Mayor of London.
[43] CIBSE (2015) *Heat Networks Code of Practice for the UK*. UK: CIBSE.
[44] Kristjansson, H. and Bohm, B. (2006) *Danfoss Technical Paper: Optimum Design of Distribution and Service Pipes*. Denmark: Danfoss.
[45] Skagestad, B. and Mildenstein, P. (1999) *District Heating and Cooling Connection Handbook*. International Energy Agency.

Findings of Techno-Economic Analyses and Case Studies

The experience of interacting with projects on the ground in Ireland, both existing and planned, has led to some useful learnings and input to this DH guidance. This is based on detailed DH system analysis and the feedback from owners and operators of the existing schemes or those in the process of developing a new area. These learnings, which in many cases are proving to be some of the barriers to more widespread uptake of DH in Ireland are summarised below under the relevant headings.

Industry Maturity and Knowledge-base

A consistent feedback was the lack of culture and knowledge around DH as a utility. This applies to consumers generally, but also to those involved in the supply chain for DH from concept through to operation. The lack of culture around DH and relative novelty is a contributing factor in delaying consumer uptake.

In projects already built, the workmanship is generally of a good standard, but there are certainly opportunities to improve. Examples were encountered of flaws in both the design and installation which will lead to energy losses, additional costs and longer term maintenance concerns. There is a need for additional skills and training appropriate to design and fit the various components of a DH scheme.

A common theme also is the need to secure reliable third parties to operate and maintain a DH network. In the majority of cases, the owner of the scheme would prefer not to have to operate a DH scheme, not having the in-house resources or skills to do so. While there are experienced operators based in Ireland, from a scheme owner perspective there is a need for critical mass, geographic coverage and improved confidence in this critical aspect of the DH supply chain.

DH Viability

A range of viable existing and planned DH systems across a range of scenarios are identified in this guide. Importantly, there are many viable systems identified outside of city areas, some of which are competing with natural gas supply, which is contrary to findings of other assessments of DH feasibility in Ireland. The analyses show how RHIs similar or less than the current Great Britain RHI scheme would greatly benefit the use of large scale renewable energy through DH.

Heat demand density is a key criterion for commercial viability, where sufficient load is required to justify the network costs and heat losses over long pipe runs. The type of dwellings and the layout of new housing estates will dictate the heat demand density and will affect the feasibility of DH. This needs to be considered by local authority planners when considering low-carbon DH systems for new developments. The analyses also highlight the role of local authorities in facilitating the development of DH through planning policy, stakeholder engagement and involving other public buildings as anchor loads.

The diversity of connected heat loads and the connection of anchor loads such as hospitals, leisure centres or large retail, has a positive effect on DH system viability. A diversity of customers creates a more even daily, weekly and annual heat demand curve, eliminating large peaks and creating a larger baseload. It also allows diversity factors to be applied to network designs leading to smaller pipelines to feed the same annual heat load.

There are many wider societal benefits of DH which should be taken into account when assessing DH feasibility, particularly when it is a public sector led initiative. These include flexibility of fuel sources for heat, additional security of supply, higher integration of renewables through large scale thermal storage, utilisation of locally produced renewable resources, utilisation of heat sources currently going to waste, increased local employment, reduced local emissions and reduced heating costs for customers.

New Consumer Connections

For existing schemes and new schemes assessed, consumer behaviour is an important variable in the success of the DH infrastructure. Having a cost-effective DH service pass outside a home or business does not automatically lead to a decision to connect based on normal cost-benefit logic. In cases where there is no technical impediment and the financial case makes sense, there still may be timing or budget issues which prevent connection to the DH system over the short to medium term. In other instances, there may be technical considerations, or internal investment required at the consumer side before they are in a position to connect.

In some of the locally owned schemes assessed, there will be a need to revise the typical commercial lease terms to account for DH services and perhaps include mandatory conditions around this to support the viability of investing in the service provision. For residential connections, the initial design can play a large role in consumer uptake of DH. Where alternate space heating and domestic hot water facilities are available (either because they are already there in retrofit situations, or included in a new build design), the impact of non-payment and disconnection from the DH network is limited. Situations have been identified where new customers could feasibly connect to existing DH networks, but have not taken up this opportunity. There are both legal and voluntary methods employed in other countries (in Denmark particularly where there are decades of experience dealing this such matters) to encourage rational uptake of DH schemes based either on incentive or penalties which should be further explored (so-called stick or carrot).

Planning Policy Issues

There are issues when trying to attain the energy efficiency and renewable energy requirements for new dwellings under Part L building regulations when considering a DH supply. The current calculation method on the Dwelling Energy Assessment Procedure (DEAP) software is not adequate, and modifications need to be made to the treatment of DH heat losses, particularly when dealing with renewable DH. For commercial buildings, the benefits of connecting to a DH system are not fully reflected in commercial BERs or Display Energy Certificates (DEC).

It would be the expectation that DH pipes should be considered and treated the same as any other underground infrastructural pipe or cable and be exempt from planning permission in most circumstances under the Planning and Development Act (section 5).

At the local government level, there is acknowledgement of the role of DH in enabling sustainable energy, though the local development plans reviewed in the context of this study could be improved through better understanding and recognition of the benefits, and also the complexities associated with DH in practice.

Pricing

In almost every instance, owners and operators of DH schemes have a challenge to determine a fair heat price, and are working in a quasi-monopoly supply situation. Different owners operate on different pricing models and expectation of a return on investment. For example, local authorities see DH as provision of service to social housing at a cost which is benchmarked to the cost of alternative decentralised heat supply. This is not necessarily linked to the capital and operational costs of the DH scheme. Privately managed schemes operate a different cost model which allows for depreciation of equipment and full cost recovery. This does not automatically mean that members of private schemes pay more; the evidence on the ground is that some privately managed schemes can supply heat at rates lower than publicly-owned subsidised schemes. There is a need for independent guidance and regulation of heat pricing. At the moment there is no path for members of a DH scheme to dispute their cost of energy or other terms of supply, as would be expected for the provision of a basic utility. It should be noted that there was no suggestion of any abuse or mispricing encountered during this study, but it remains as a consumer protection concern.

Funding of Long Term DH Infrastructure

In most existing and planned DH schemes assessed, the DH infrastructure is considered in tandem with the energy supply equipment. The heat generation source and heat distribution infrastructure are considered under single ownership and using the same financial conditions. The expected useful life of DH piping is over 50 years, whereas a typical 20-year project life is attached to energy generation assets. It is difficult to compare DH to other solutions under the same short-term economic analysis, when the benefits accrue over a much longer investment period. An investment in DH should be considered in the same way as other long-term infrastructure investment, such as motorways or electricity distribution assets. For example, ESB Networks consider a 50-year asset life for the investment required in a new transformer or electricity distribution lines.

Synergy with Renewable Heat and DH

The case studies and potential DH sites all used or expressed interest in renewable heat sources and had built or planned a DH system based around the concept of low carbon or carbon neutral heat supply. Many DH systems use solid biomass or municipal waste, including organic waste. It is a key enabling technology for biomass and other forms of renewable heat supply. It has also been found that low-cost heat sources which have no associated fuel input costs, such as solar thermal or industrial waste heat, greatly increase the economic viability of DH systems, and are particularly technically suited DH developments with low temperature requirements.

A challenge encountered by some of the existing or planned DH schemes is the competitiveness of renewable heat. With natural gas prices at 10 year lows, in most existing systems with gas connections it has proved commercially more attractive to use natural gas and leave biomass boilers or other renewable energy equipment idle. This is not in keeping with the policy intentions of the scheme owners who invested in renewable energy assets, and at present find it necessary to justify the higher costs for renewable heat supply. The cost challenge and other barriers to renewable heat are acknowledged by DCCAE who are currently designing a renewable heat incentive (RHI) to address this gap. It is important that renewable heat supply is supported and incentivised to ensure that this is a cost-effective option for new planned DH networks.

Techno-Economic Analyses: Potential DH sites in Ireland

Three techno-economic analyses (TEAs) of potential DH sites in Ireland are outlined in this guide. The sites chosen involve different building types, supply sources, network sizes, etc. to give an insight into a variety of DH case types. An in-depth hourly energy system model has been used to analyse the DH system viability of each site under parameters which simulate real time operation as accurately as possible. Hourly DH system analysis allows optimisation of operational parameters and therefore greater accuracy when sizing and costing the technical components of the system.

TEA inputs and considerations

Heat demands

In order to represent the actual running of a DH system as accurately as possible a modelling system[46] has been used which allows the prediction of heating demands in every hour of the year over the lifetime of the system. For space heating demands, hourly ambient temperatures for a reference year from a local weather station have been used to distribute the annual thermal demands, with an Irish reference temperature of 15.5°C. The hourly temperatures are overlaid with a typical weekly heat demand distribution profile from the building category. Building thermal demands are actual demands where existing buildings are analysed, and are estimated for new builds based on actual BERs of new builds of relevant building types. The weekly distribution profiles are attained from actual monitoring data where possible. The hot water demand is set to be independent of outside temperatures but follows the weekly distribution profile.

The yearly heat demands are linked to an index to increase/decrease the demand over the lifetime of the system. Public sector buildings are linked to indexes which model the effects of meeting the public sector energy efficiency targets. All other existing buildings are assumed to decrease demand over time with increased energy efficiency measures. Where commercial buildings are modelled and the business is expected to increase thermal demands with increased business, this has been accounted for.

Heat network

Heat losses in the network are modelled as an additional demand, and are said to equal to 5% of the total thermal demand in any hour, assuming optimal operational conditions. Pumping requirements are also taken into account, estimated at 0.5% of thermal energy demand in any hour, based on a typical difference in flow and return temperatures of 35°C and a total pressure drop of 0.6MPa[47]. Detailed geological surveys or site surveys of pipe routes and existing building thermal systems are outside the scope of these analyses. The location and length of network pipes are therefore estimated conservatively and require additional studies before a design is finalised. The network pipe types and sizes are estimated based on the capacity required to supply all thermal demands on each branch. Typical DH supply and return temperatures are between 60-80°C and 30°C respectively, and pressures and temperatures of supply and return are estimated for each case.

Pipes are typically either single or twin (sometimes called duo) steel carrier pipes with polyurethane foam insulation. In smaller dimensions and systems with <90°C supply temperatures, flexible plastic PEX pipes can be used, which are cheaper and easier to install and maintain, and require fewer bends. Most modern pipe networks include a detection system within the insulation foam which runs the length of the pipe and detects any moisture ingress or egress.

In order for the DH system to operate optimally and to reduce running costs, the system should be designed to minimise heat losses and the need for pumping, and maximise the temperature difference between the flow and return, referred to as the delta-T (ΔT). There are many reasons why the delta-T is such an important aspect of the operation and design of DH systems, and details can be found in Appendix A.

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[46] The software energyPRO has been used for this analysis. energyPRO is a well-established Danish software specifically designed with DH system modelling in mind.

[47] Frederiksen, S. and Werner, S. (2013) *District Heating and Cooling*. Lund: Studentlitteratur AB.

Thermal storage

Optimising the use of cheap thermal storage allows longer run times for CHP/biomass units and therefore decreases the number of turn on/offs, decreases the use of more expensive peak fossil fuel boilers, and increases electrical revenues in the case of CHP units. The modelling allows the increase in thermal store capacity until a cost-benefit balance is found and the optimal size is established. Thermal storage units are most commonly steel tanks, and range in size from very small scale $5m^3$ to largest $>50,000m^3$ ($1m^3$ = 1000 litres). Thermal storage capacity for CHP or biomass fed systems can be sized up to 10-12 hours of average demand, but for most systems it is typically around 6 hours. In summer time when there is little demand for heat and the thermal storage capacity is already at maximum capacity, a heat rejection unit can be utilised in combination with a CHP unit if it is economical to continue producing electricity without a matching heat demand.

CHP units

When CHP units are involved, a time series is used representing the hourly prices on the Irish all-island single electricity market, based on the latest annual hourly market prices from the Single Energy Market Operator (SEMO). The operation strategy is set to prioritise the production units with the lowest net cost of heat production in any hour, and in the case of CHP units, this takes into account the hourly electricity market prices. In this way, when the system marginal price of electricity on the market is low, the DH system can utilise other cheaper units to provide heat in those hours, therefore ensuring the lowest cost of heat production in any hour. Conversely, when the price for electricity is high, the system will utilise the CHP unit when there is sufficient heat demand or when there is sufficient capacity in the thermal store, maximising the CHP revenue.

When the electricity production unit is fuelled by a renewable fuel, the unit is set to either avail of the latest REFIT reference prices or a predicted RHI price, which are linked to an inflation index. Priority dispatch for renewable CHP and high-efficiency CHP (HECHP) units to the electrical grid is assumed, and therefore electricity export is available in all hours.

Back-up/peak load heating plant

For system redundancy, a back-up/peak load boiler needs to be included within the DH supply system. The back-up boiler capacity should be sized at approximately 120% of the maximum peak load in any hour. The full capacity of these boilers are rarely used, as the baseload unit and thermal storage will most likely be available during the peak demand period, but are needed as a fail-safe. Therefore, these back-up units are generally the cheapest boiler technology available, usually large gas or oil boilers. The standing charges associated with natural gas or LPG systems can be prohibitive for large boiler units with occasional use. In large DH systems, the peak load back-up system will constitute many smaller gas boilers so some boilers can run at full load and therefore higher efficiencies when the peaking requirement is lower than full peak demand. For smaller systems, if installing one large back-up boiler, a modulating boiler will allow higher efficiencies at a range of the full load capacity.

Costing

The capital costs and operation and maintenance (O&M) costs of the DH system components modelled are taken from Danish and Swedish technology data sheets available through the Danish Energy Agency and the Swedish DH Association. These costs have been compared against known costs from Irish DH examples and are comparable. Heat exchanger costs are from Danfoss, a heat exchanger supplier. O&M costs are modelled on a per MWh production basis. All technology costs used are full engineering, procurement and construction (EPC) prices, excluding VAT.

Where site specific fuel prices are unknown, the SEAI's domestic and commercial fuel cost comparison prices[48] are used, excluding VAT. An inflation index is used for all costs and revenues and is set at 2.5%, based on an average of annual historical consumer price index trends over the last 20 years. A nominal discount rate of 6% is applied for net present value (NPV) and internal rate of return (IRR) calculations. Sensitivity analyses are carried out on all costs and revenues which have a fundamental impact on the economic viability, such as fuel prices and tariffs.

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[48] IrBEA has previously recommended that the quality of this data be improved but it is the best independent data freely available at present.

Customer prices are set so the customer achieves at least 10% savings in comparison to their existing system. It is important to note that the customer pays for heat rather than fuel, so the cost comparison has to take into account the efficiency of the customers’ existing heating plant. In retrofit cases where information on the customers’ existing heating system is unknown, a 90% efficiency is assumed, therefore revenues from these customers could potentially be higher than estimated. A standing charge is applied to cover costs of the DH system O&M, and is based on kWh heat demand in a month. This standing charge is less than existing annual O&M costs for traditional systems.

Site 1: Killarney Town, Kerry

Kerry County Council (KCC) has identified Killarney town centre as a site for a potential DH system, fuelled by local biomass. Killarney is not on the gas grid, and so heating is currently supplied mostly by deliveries of oil or Liquefied Petroleum Gas (LPG). There are many large hotels in the town as the area has a large tourist industry. Many of these hotels have leisure centres with pools and spas, and therefore have large heated floor areas and large hot water demands. KCC would like to see the hotels, along with some other large heat users in the town, connected to a low-carbon DH system supplied by local biomass. KCC is already in discussion with these hotels.

The buildings analysed have a total annual energy consumption for heating purposes of 33,567 MWh, supplied by a mix of oil and LPG, which is equal to 7,854 tonnes of CO_2 emissions per year. The current annual cost of oil and LPG to supply this heating demand is €1,791,601.

Key figures

The 22 buildings included in the analysis are:

- 17 hotels (private)
- 1 sports and leisure centre (public)
- 1 large hospital and 1 community hospital (public)
- 1 apartment block (private)
- 1 nursing home (public)

Within these buildings there are 10 swimming pools, 8 gyms, and 8 spas. The total heat demand is 32 GWh[49] per year, with a peak winter demand of 15 MW and a baseload of 3 MW. The total heat demand increases over the lifetime of the analysis, due to hotel sector industry growth, but this is only a small increase as it is in part offset by the hotels' own energy efficiency increases and expected public sector building energy savings.

The DH transmission network is estimated to be 10.2 km in length, and branch pipe lengths to connect each building total 13.5km (some buildings have long drive-ways connecting to the main road). The linear heat demand density of the 22 buildings analysed on the transmission network is 3,153 kWh/m. As seen on the map, there are many more demands along this route which were not analysed and would increase the overall linear demand density. All transmission and distribution pipes are sized with an additional 20% peak capacity to allow for future growth of the network and additional heat demands. Network losses are estimated at 1,545 MWh per year.

[49] This is lower than the total energy used for heating purposes taking account of the losses of the current heating equipment.

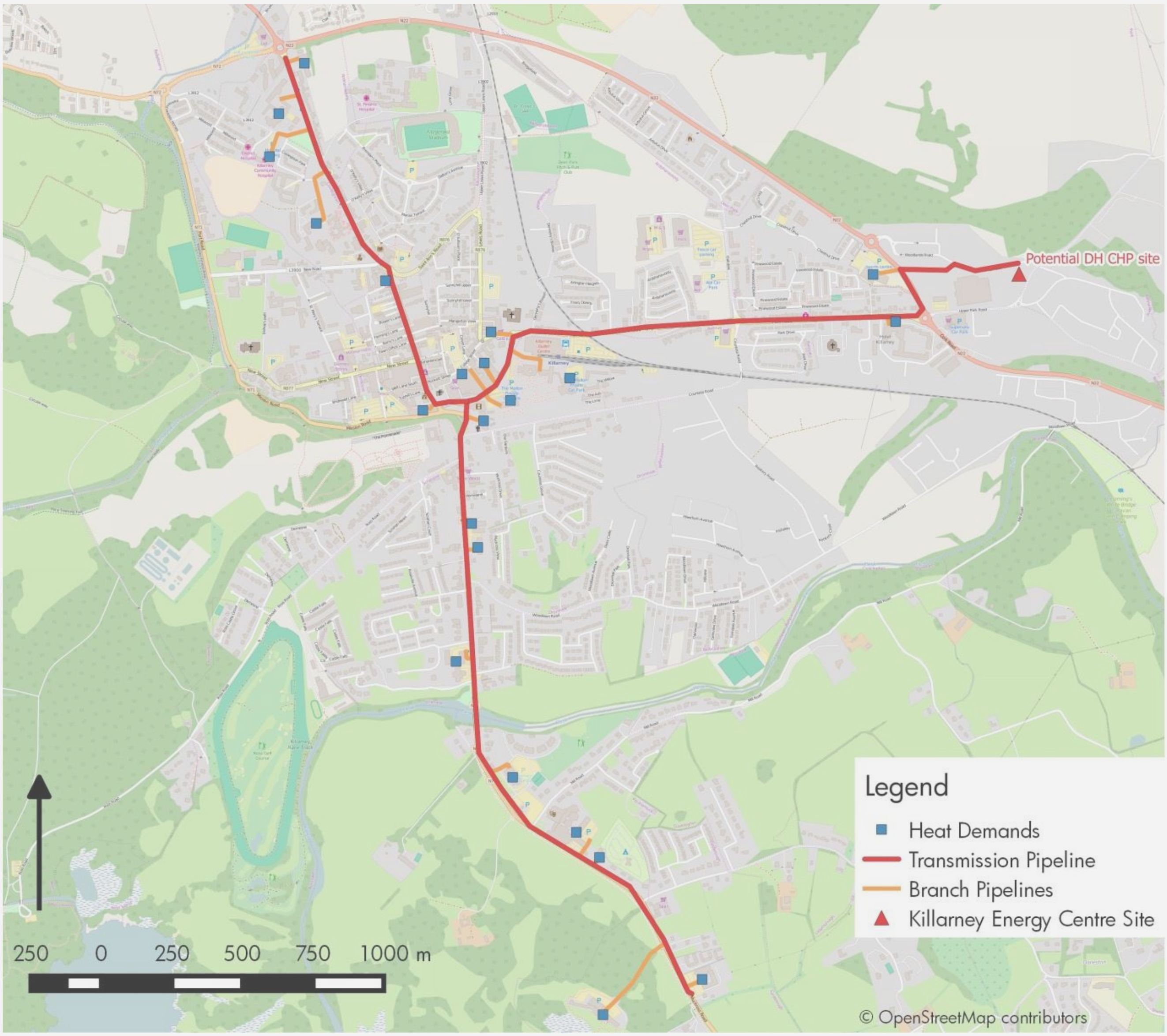

Figure 5: Killarney DH pipe network

Analysis

The Killarney DH system is analysed over a 20 year period to compare with a traditional system investment, and therefore no reinvestments are required during the period examined. The DH network has a lifetime of at least 40 years, but a reinvestment in heating plant will be required to continue operation of the DH supply beyond the 20 years examined. Ideally the investment should be considered over a 40 year period to take account of the longer lifetime of the DH pipelines.

Energy Production

A biomass CHP plant can increase overall efficiencies and economics due to the combined production of electricity and hot water. The effect of a REFIT on electrical generation versus a RHI on heat production is analysed for a biomass CHP unit. The biomass CHP unit comprises fuel storage, treatment and feed-in system, a high-pressure steam boiler, steam turbine and generator (electricity production), and a flue-gas heat recovery boiler (hot water production). The use of a stand-alone biomass boiler is also analysed, and the effect of a RHI is modelled.

The biomass CHP plant can accept fuel with moisture content as high as 60%, and biomass boilers with flue condensation can accept 45-55% moisture content. The lower the moisture content, the more heat and energy can be obtained per unit. For this reason, it is better to pay for biomass fuel according to the energy value of the wood, in GJ or MWh per tonne, rather than on delivered weight.

Heat Demands

Annual thermal demands and floor area sizes have been provided by KCC for the buildings analysed. Billed data for most buildings has been gathered for the year 2011 and matched to annual hourly temperatures for the same year. The billed data for 2011 is linked to an index to take account of the increase in tourism and hotel use to 2016, and is estimated to increase further in the coming years. Of the 22 buildings analysed, six do not supply actual energy use data, and so the energy use has been estimated based on floor area size.

Heat Network

Diversity in the transmission pipe capacity is not taken into account in this case, as the majority of the heat demands are hotels and therefore have similar annual and weekly demand profiles. A 90% boiler efficiency in current systems is assumed as this information was unavailable, although it is likely many of the older boilers will have lower efficiencies and therefore the customer savings in this analysis are likely to be underestimated. The possibility of using some of the existing boilers within the network as back-up is not examined, but could be used to reduce the investments in back-up boiler systems.

The chosen pipeline route was dictated by the largest heat demands in the town and the likely location of the energy centre site. After the best route was identified, large anchor loads situated along the route were added to the analysis where possible.

Results

A range of scenarios are outlined which analyse different technologies to meet the baseload demand and the effects of different tariff schemes.

Scenario 1: Biomass CHP

Technical

Firstly, the effects of using a biomass CHP unit are analysed. The CHP is sized to meet the baseload heat demand of 3 MW. The CHP is sized to baseload to ensure it can run at full load, and therefore at high efficiency, for the majority of the year. An optimisation analysis of larger CHP units versus additional net cash revenue was carried out, and although the annual revenue can be increased by €200k by choosing a 5 MW thermal output (MWth) CHP, the additional costs of the CHP unit and the greatly increased number of turn-on/offs means this is not a viable option.

The back-up heat production plant is sized at 120% of the peak demand in any hour of the year, which is approximately 15MW, and so back-up is sized at 18MW. This back-up capacity is split across two LPG boilers; one smaller boiler sized as a peak boiler so that the annual heat demand is met between it and the baseload CHP unit, and the other larger unit which is only needed when there is no output from the CHP and in hours of unusually large heat demand, i.e. in severe winter conditions. The optimal size for the peak boiler is 4 MW as it is found to meet all hourly demands within a normal year along with the CHP plant as baseload, and can run longer hours at close to full load and therefore higher efficiencies. The other larger back-up boiler is therefore sized at 14 MW and will operate only in cases previously described. The CHP maintenance should be scheduled at a time where the 4MW boiler and thermal store can manage to meet the demand.

The optimal size of the thermal storage unit is modelled based on the optimum increase in CHP output. The output of the CHP needs to be optimised as firstly the net cost of heat production from the CHP is lower due to the revenue from both heat and electricity sales, and secondly, because it is run on biomass and will offset hours of heat produced by the gas fuelled peak boiler.

shows how increasing the thermal storage to 300m^3 gives the highest return of increased output for increase in storage size and costs. This is modelled for the existing system demands only, and so an additional 100m^3 is added to ensure thermal capacity will allow optimal operation with predicted future growth in the network.

This size of storage unit has the capacity to store 18.54 MWh. The storage losses are also modelled based on height of the unit, storage level in each hour, insulation thickness and associated thermal conductivity, and the losses fluctuate according to outside temperatures.

With this combination and size of plant, all heat demands are met in all hours of every year, the thermal storage is fully utilised, the plant operates at highest efficiencies possible and has the least number of turn on/offs possible. Because the demands supplied are primarily the same industry type, the demand peaks will likely run concurrently[50]. For this reason, there is a large difference between the peak and baseload demands. To correct this, and allow for a larger more profitable CHP, there should ideally be a larger diversity of customers connected to increase the baseload demand.

Figure 7 shows a 7 day period of hourly operation in winter. The top window in the figure shows the demand and production of heat, and the bottom window shows the storage content in each hour.

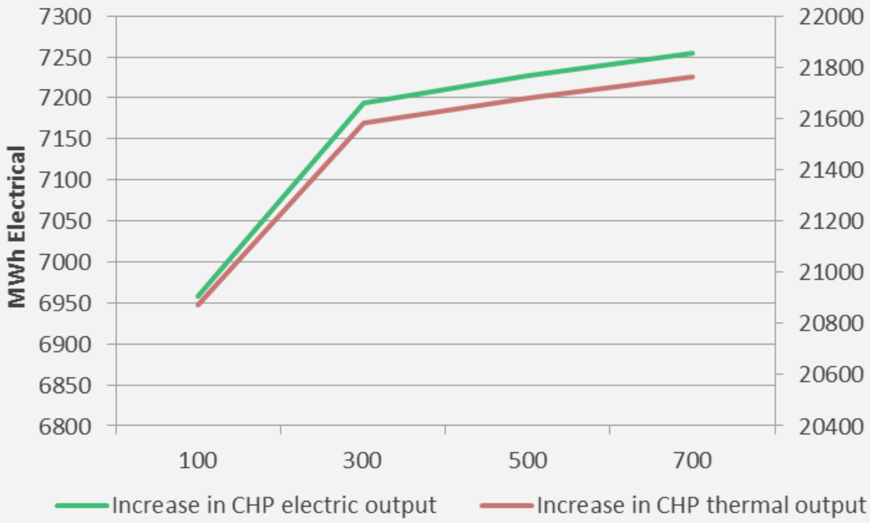

Figure 6: Optimising Size of Thermal Storage

Figure 7: Production graphic; CHP, back-up boilers and thermal store

50 Hotels will have similar peak demands for DHW and SH, and similar peak weekend and holiday seasonal occupancy.

It can be seen that the biomass CHP (red) runs consistently to meet the baseload demand at 3MW. Back-up boiler 1, the 4MW peak boiler seen in green, produces heat to meet the daily load above the baseload, operating at its full 4MW capacity in most hours. It is possible to see the beneficial effects the thermal storage has on the turn on/offs of these units and how it negates the need for the large back-up boiler (yellow) in most hours. The back-up boiler 2 will turn on and run as close to full load as possible when needed, and store heat when there is capacity in the thermal store.

Figure 8 shows the annual production of heat and electricity from all energy units and the fuel demand. It shows that the peak demand for woodchip is 4.9MW and the peak LPG demand is 20MW. It also shows how the units produce more heat to meet growing demands of the hotel industry over the 20 year period, particularly the increased use of the back-up boilers and therefore increase in LPG use.

Biomass CHP + LPG Back-up Boilers	2016	2035
Heat demand [MWh]	32,449	36,959
Electricity produced by energy units [MWh]	8,307	8,511
Exported electricity [MWh]	8,307	8,511
Peak [MW]	1	1
Energy unit: Biomass CHP		
Fuel consum. [kg wet]	12,720,093	13,032,468
Fuel consum. [MWh]	40,704	41,704
Heat prod. [MWh]	24,921	25,533
Elec. prod. [MWh]	8,307	8,511
Turn ons	328	168
Operating hours	8,307	8,511
Energy unit: Back-up Boiler 1		
Fuel consum. [Litre]	1,181,987	1,735,802
Fuel consum. [MWh]	8,380	12,307
Heat prod. [MWh]	7,449	10,939
Turn ons	348	325
Operating hours	3,578	4,238
Energy unit: Back-up Boiler 2		
Fuel consum. [Litre]	17,221	78,593
Fuel consum. [MWh]	122	557
Heat prod. [MWh]	110	503
Turn ons	66	132
Operating hours	457	478
Fuel consumption: Biomass Wood Chip		
Fuel consum. [kg wet]	12,720,093	13,032,468
Fuel consum. [MWh]	40,704	41,704
Peak [MW]	4.9	4.9
Fuel consumption: LPG Gas		
Fuel consum. [Litre]	1,199,209	1,814,395
Fuel consum. [MWh]	8,502	12,864
Peak [MW]	20	20

Figure 8: Annual production and fuel use of all units 2016 and 2035

Economics

The biomass wood chip fuel is assumed to have 35% moisture content and a heat value of 3.2kWh/kg. Price of woodchip is taken from the SEAI commercial fuel cost comparison values. KCC receive its LPG gas from a supplier chosen through central procurement, therefore the LPG price is set at the price currently paid by KCC. In this analysis heat payments are set at the current commercial price of large deliveries of bulk LPG (ex VAT and linked to inflation), which are currently at a 10 year low. If a ten year average LPG cost is applied, the paybacks are decreased, and the effects are analysed in detail later.

The upfront investment costs include:

- Biomass CHP
- LPG Back-up/Peak Boilers
- Twin Pipe Network
- Grid Export Connection
- Heat Rejection Unit
- Thermal Store
- Woodchip Store
- Heat Exchangers and Meters

The total investment costs for such a system amount to €19.8m, and of this figure, the pipe network is estimated to be €13.6m.

Firstly the biomass CHP unit is set to receive a Renewable Electricity Incentive[51] (REI) payment for electricity produced, and is assumed to be received over the 20 year project lifetime. All electricity is set to export (none used on-site) and priority dispatch is assumed. The price for electricity export is set to the current REFIT price for large biomass CHP of €126/MWh. Operating expenditures include all O&M and fuel costs for heat production and pumping. Revenues include all heat payments including standing charges, and the electricity feed-in tariff payments.

Over a 20 year operational period (minus initial construction time), the **system payback with a REI is 14 years, the NPV is €-2.7m, and the IRR is 4.4%.**

The same analysis is run with the biomass CHP unit now receiving a RHI tariff for heat delivered and the system marginal price in each hour from the single electricity market for electricity exported. The latest[52] RHI price from Great Britain's RHI scheme for solid biomass CHP of all capacities is 4.22p/kWh, or £42.2/MWh, and this is used as a reference for the initial RHI calculations. It is possible that a combination of a REI on the electricity production, such as the current REFIT for non-CHP biomass combustion, and a RHI on heat production could be available for biomass CHP plants, but for this analysis it is assumed the plant is only eligible for one or other support mechanism.

Over a 20 year operational period (minus initial construction time), the **system payback with RHI is now 10 years, the NPV is €4.4m and the IRR is 8.5%**. This shows that the RHI is more beneficial than the REI to the proposed Killarney DH system with biomass CHP. This scenario is further examined to show the effects of varying RHI and LPG costs, and additional heat demand.

Emissions

The DH supply system described uses local biomass resources for heat and electricity production, which is considered CO_2 neutral. The back-up boilers use LPG and there will be associated CO_2 emissions for heat produced from these units, and CO_2 associated with any imported electricity. The total annual emissions of the DH system are 2,032t CO_2[53], and when comparing the CO_2 emissions of the current heating provision of 7,854t CO_2, the DH system saves 5,821t CO_2 per year. This is when accounting for heat only, and therefore does not account for the main benefit of using CHP; the combined production of heat and electricity. The biomass CHP will also offset grid electricity which would have been generated with a mix of generation on the grid, which converts to 0.511kg CO_2/kWh[54]. The biomass CHP produces 8295 MWh electricity per year, which offsets CO_2 emissions of 4,238t annually. Taking this into account, the **DH system saves 10,060t CO_2 per year**. Although this is a small project, this saving is equal to 0.8% of the total energy related CO_2 emissions for the whole of Kerry, showing that a number of similar projects in the county can have a large impact on the county's CO_2 targets.

Sensitivity analysis

Figure 11 shows the impact of a range of RHI tariffs on the NPV and it is clear that the RHI is a major influencing factor on the economic viability of the biomass CHP system. For this system, the NPV becomes positive at approximately 2.75c/kWh.

The effect of varying LPG costs and the associated change in heat payments have been modelled. The heat payments are directly linked to costs of LPG as the customer will require a heat cost lower than the costs of the cheapest alternative system in order to secure the connection. The cost of the LPG used for back-up boilers is also adjusted accordingly, while still retaining a discounted cost attained through central procurement. Figure 10 shows the effects of the LPG costs over a range of heat prices. The lower end of the price scale is where the price of LPG currently stands, which is at a 10 year low, and the prices increase to €100/MWh which is close to the highest price of LPG in the last ten years. It can be seen that at the average 10 year price of LPG (ex. VAT) of €78/MWh, the NPV is approximately €12m with an IRR of 12%, and the payback reduces to just over 8 years. At peak LPG prices, the payback reduces to 6 years.

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[51] A new support scheme for renewable electricity is yet to be announced.

[52] As of the 1st July 2016 , source: Ofgem. (2016) *Tariffs and payments: Non-Domestic RHI.*

[53] The emissions vary annually with varying demands, but this is year one emissions to compare to most recent emissions calculations of the current system.

[54] Latest available figures for electrical CO_2 emissions from SEAI for 2014

The impact of adding more heat demands along the existing transmission line were analysed. An average cost per MWh of additional demand was calculated based on the additional costs of adding capacity to the transmission network, additional branch pipes and heat exchangers. Figure 9 shows the total system costs and simple payback[55] across a range of additional heat demands. There is a simple payback of approximately 3 years per MWh added at a cost of €216/MWh.

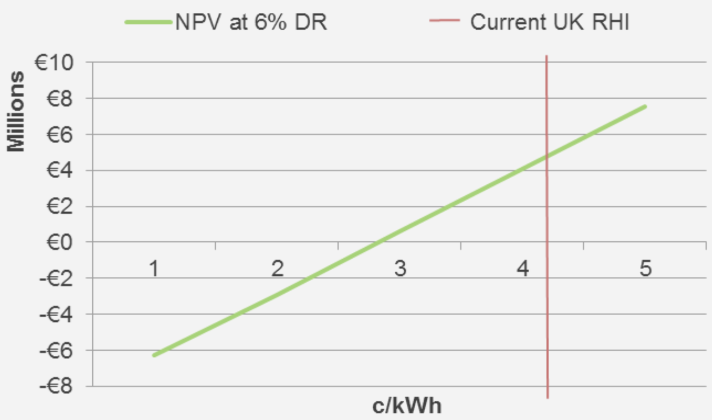

Figure 11: Biomass CHP Scenario; NPV vs RHI Tariff

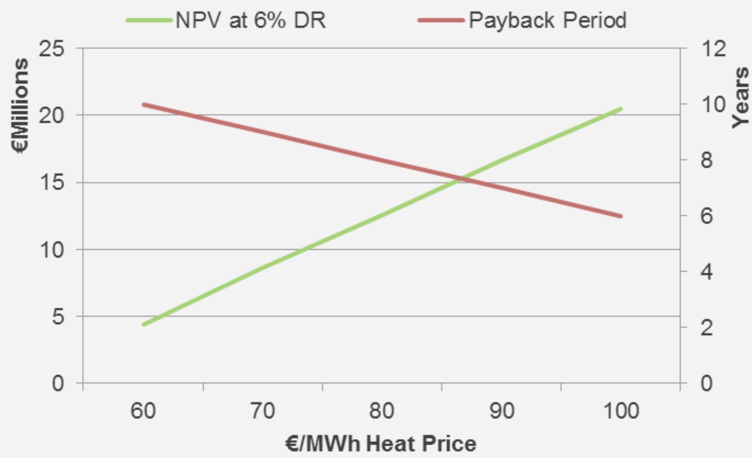

Figure 10: NPV and Payback over a range of Heat Prices €/MWh

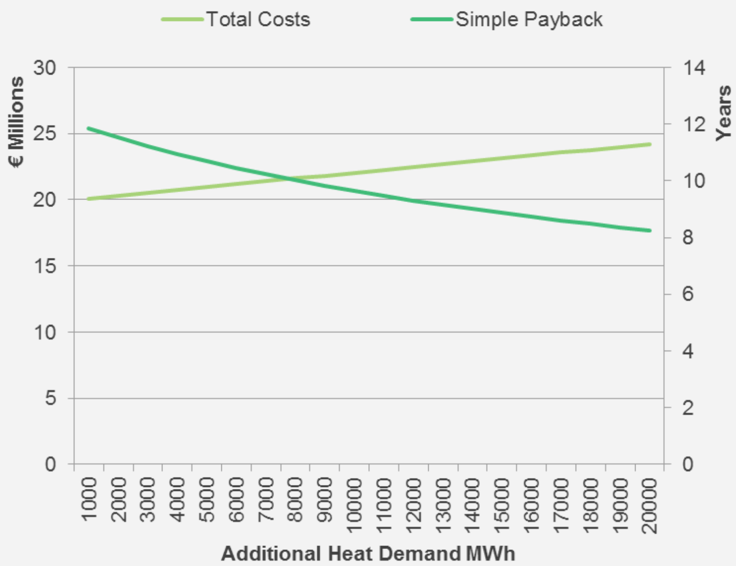

Figure 9: Effects of additional heat demand on the system costs and payback

[55] Simple payback differs slightly to previous paybacks calculated as inflation and other indexes are not included.

Scenario 2: Biomass Boiler

Technical

The same system is analysed with the use of a biomass boiler to meet baseload demand. A biomass boiler is a less costly unit than a biomass CHP unit, has a higher overall efficiency, and no grid connection costs, but does not have the ability to sell electricity and gain additional revenue. The same size thermal storage and back-up boilers are utilised, as the biomass boiler is sized to the baseload and therefore directly replaces the heat from the CHP. The production graphic, Figure 12, shows the production over a 7 day period in January. The top window shows that the biomass boiler (red) now meets the baseload demand, the back-up boiler 1 (green) provides the daily peak demands, and the back-up boiler 2 (yellow) provides heat in peak hours in winter. The thermal storage is utilised to peak capacity during this period in winter, as seen in the bottom window of the figure.

Figure 13 shows the production of heat and fuel usage over the period. The demand differs slightly to the CHP scenario as the losses in the network and the thermal store differ slightly due to the different hours of operation of each unit. The imported electricity covers the pumping requirements.

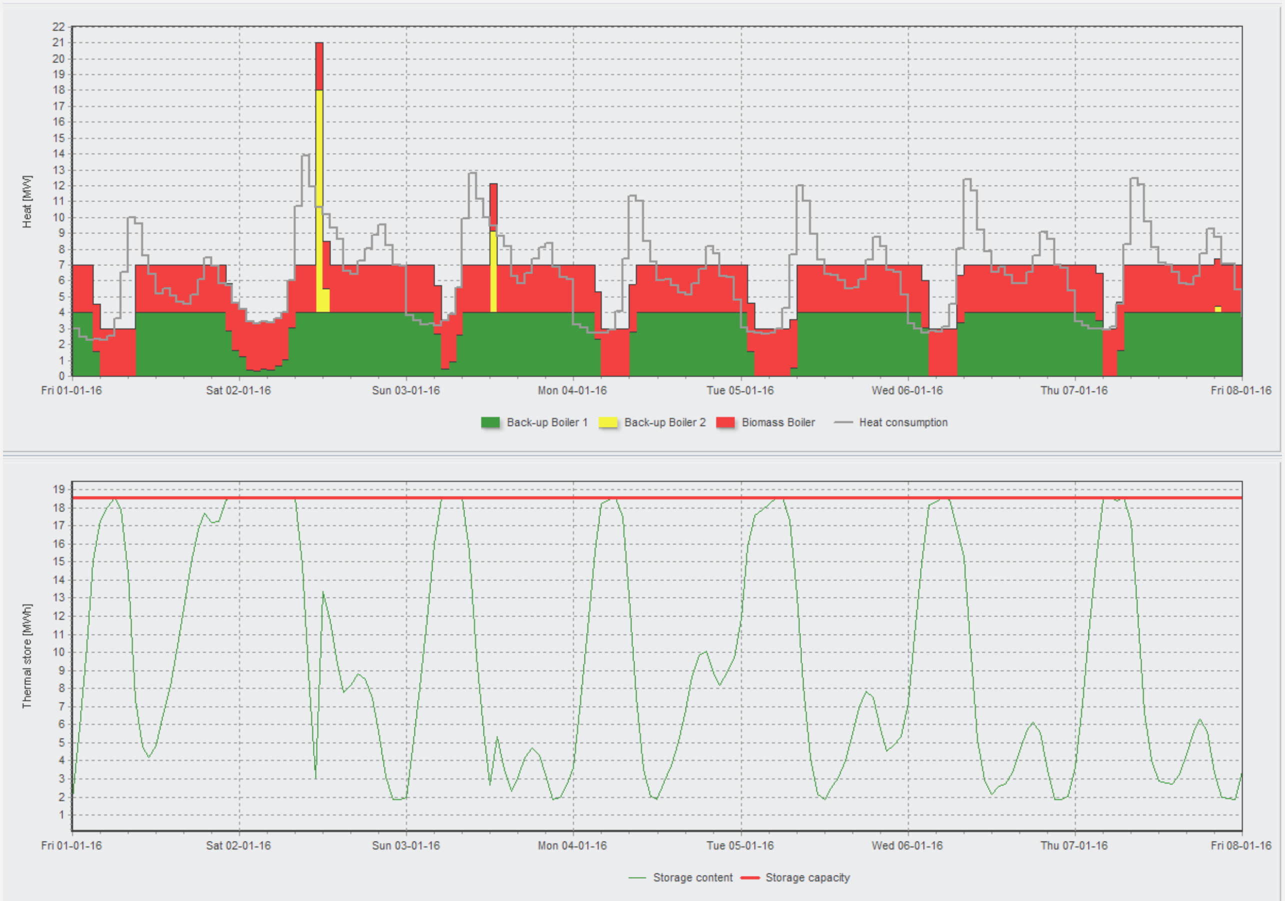

Figure 12: Production Graphic; Biomass boiler, back-up boilers, thermal storage

Economics

Due to the lower cost of the biomass boiler, the investment costs decrease from €19.8m to €18.6m, which is a small percentage as the largest investment in the pipe network remains the same. A RHI at the same level as the Great Britain RHI scheme tariff is applied, which is currently at 2.05p/kWh, or £20.5/MWh. With this RHI applied and the small reduction in investment costs, the NPV is now €2.5m and IRR 7.5%, with a payback of 11 years. This result shows the investment in the CHP plant is a more attractive prospect when the same RHIs are applied as are available from the Great Britain RHI scheme. In order to match the economics of the CHP scenario, the biomass boiler would need to receive approximately 2.6c/kWh. There are additional benefits of shorter implementation timelines, fewer complications in terms of grid connections/licences and simpler project planning when implementing a biomass boiler rather than a CHP unit. The cost to the exchequer will also be lower for each unit of renewable heat supported.

The effects of a range of RHI tariffs on the NPV of the biomass boiler scenario are shown in Figure 14. The figure shows the NPV becomes positive when there is a RHI tariff of approximately 1.25c/kWh.

The impact of increasing heat demand on the biomass boiler system has been analysed. While the cost of adding a MWh of demand to the network remains the same as the CHP plant scenario, the addition of more heat demand has larger effect on the system payback, as seen in Figure 15.

Emissions

The biomass boiler saves 5,909t CO^2 emissions when compared with the current scenario. The biomass CHP scenario offers far higher CO_2 reductions due to the additional production of electricity from a carbon neutral resource.

Biomass Boiler + LPG Back-up Boilers		2016	2035
Heat demand [MWh]		32,390	36,888
Electricity demand [MWh]		155	154
Imported electricity [MWh]		155	154
	Peak [MW]	0.053	0.053
Energy unit: Back-up Boiler 1			
	Fuel consum. [Litre]	1,181,137	1,726,913
	Fuel consum. [MWh]	8,374	12,244
	Heat prod. [MWh]	7,444	10,883
	Turn ons	322	321
	Operating hours	3,381	4,248
Energy unit: Back-up Boiler 2			
	Fuel consum. [Litre]	16,814	77,137
	Fuel consum. [MWh]	119	547
	Heat prod. [MWh]	108	494
	Turn ons	53	132
	Operating hours	147	443
Energy unit: Biomass Boiler			
	Fuel consum. [kg wet]	8,285,000	8,509,000
	Fuel consum. [MWh]	26,512	27,229
	Heat prod. [MWh]	24,855	25,527
	Turn ons	81	44
	Operating hours	8,285	8,509
Fuel consumption: Biomass Wood Chip			
	Fuel consum. [kg wet]	8,285,000	8,509,000
	Fuel consum. [MWh]	26,512	27,229
	Peak [MW]	3.2	3.2
Fuel consumption: LPG Gas			
	Fuel consum. [Litre]	1,197,951	1,804,051
	Fuel consum. [MWh]	8,493	12,791
	Peak [MW]	20	20

Figure 13: Annual production and fuel use of all units in 2016 and 2035

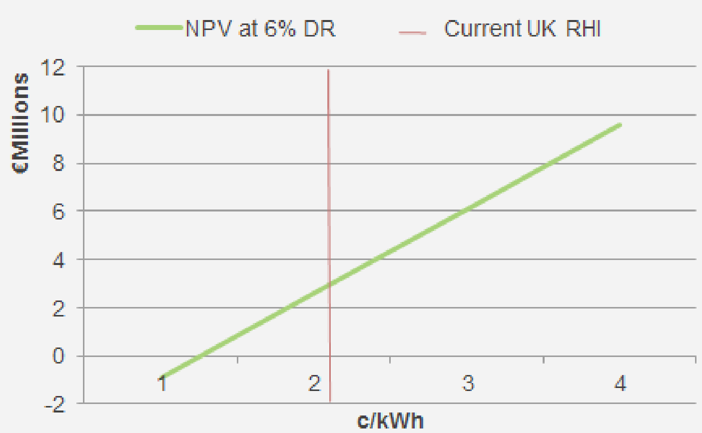

Figure 14: Biomass Boiler Scenario; NPV vs RHI Tariff

Conclusion

In conclusion, the proposed KCC DH system in Killarney would have a positive effect on emissions, reduce costs of heat for customers, use local biomass resources, and is technically and economically viable providing there is an appropriate RHI to support the first phase of the scheme.

The technical and economic viability of the system would greatly improve with a higher variation of heating consumers connected, as at the moment there are high peak demands and no diversity allowance in pipelines due to the high number of hotels. If KCC can secure the connections of the hotels, it may be easier to encourage a greater variation of businesses to consider connecting. The pipeline lifetime is 40 to 50 years, thus a reinvestment in DH heating plant after 20 years will compare favourably with replacing all individual boilers systems.

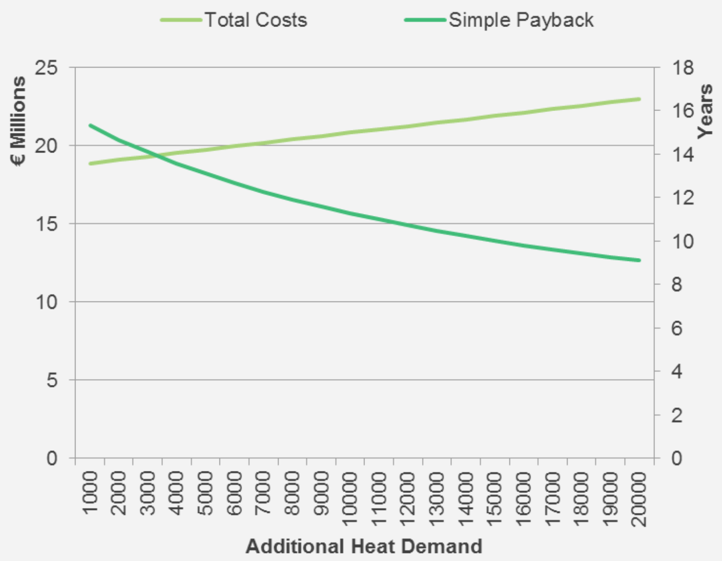

Figure 15: Effects of Additional Heat Demand on Scenario 2

The biomass CHP scenario shows more social and economic benefits than the biomass boiler scenario, and produces both renewable heat and flexible renewable electricity, but requires a higher support tariff. If the system is under the ownership of KCC, the local authority will seek to ensure a local biomass supply is contracted to the Killarney DH system, and therefore the system will have a greater economic benefit to the county of Kerry. The Killarney area will also benefit from increased 'green' tourism. There are many advantages for the customer when connecting to the proposed DH system, such as:

- Reduced CO_2 emissions – there is an average saving of 388t CO_2/year per customer
- Reduced annual energy cost – the savings per customer range from €3,000 to €35,000 per year
- No on-going burden or cost of maintaining own heating plant
- Less space required in own buildings to house individual heating plant
- No requirement for bulk fuel buying
- Increased security of supply as the DH system ensures demand is met in all hours

Site 2: Teagasc Grange Research Centre, Meath

The Teagasc Grange campus is a beef production research centre in Co.Meath. Teagasc are in the process of constructing an Anaerobic Digestion (AD) unit, feeding a biogas CHP unit on the campus grounds, and would like to use the surplus heat to supply buildings on the campus grounds. The AD will digest a mixture of animal manure and grass silage. This localised heating system will seek to connect buildings on-site which are currently heated by oil or LPG boilers. Two buildings onsite are electrically heated, and are deemed unsuitable for connection at this stage. The six buildings which will connect to the localised heating system currently use a total of **442 MWh** of fossil fuel per year, which equates to **103.6t CO_2 per year**. The current cost of heat provision is estimated at **€29,700** per year (ex.vat).

Key figures

The six buildings on-site have a combined heat demand of **398 MWh** per year (assuming a 90% efficiency in current boilers). The CHP will supply most of its heat production to the AD tank for process heat, which will require approximately **410 MWh** per year. The total heat demand of the system is therefore **820 MWh** including losses, which are estimated to be approximately 3%. The electricity will be exported to the grid, and a REFIT tariff has been secured. The tariff awarded is made up of a combination of both the small AD CHP and small AD non-CHP tariffs, as the plant will not always provide useful heat due to the limited hours of heat demand of the college buildings.

The size of CHP unit has already been decided, and has a **150kW electrical output and 195kW recoverable heat output**.

Figure 16: Teagasc Grange CHP and proposed DH network

Analysis

Energy production

The CHP is set to run as many hours as possible to produce electricity as it receives the REFIT on electrical production, and will utilise heat when possible for demands, with the excess heat dissipated through flues or heat rejection.

The current boilers can be used as back-up to the system, with a total 357 kW capacity, thus saving on investment in further heating equipment. Using the CHP unit alone will not cover the heat demand of the buildings in all hours. A thermal store is sized so that the heat demand can be met between it and the CHP unit. This allows further use of the heat produced by biogas rather than utilising fossil fuelled back-up boilers. The LPG and oil boilers are therefore not required during a normal year, but are required when there is unexpected loss in CHP output combined with low hot water storage, or during extreme winter weather conditions. When there is no requirement for heat from the CHP generator, the heat is dissipated through the exhaust flue or a heat rejection unit.

The system will utilise approximately 652,000m^3 of biogas annually on average, which is equal to approximately 3,500 MWh[56]. The CHP will export approximately 1,300 MWh of electricity per year. The pumping requirements for the system are approximately 2.1 MWh per year.

Heat Demand

The metered heat demands are distributed according to outside temperatures and a weekly distribution profile based on actual monitoring of a typical office heating system. The heating demand of the buildings reduces to near zero demand during the summer holiday period in July and August, with the heat demand for the AD being the only demand during this period. The baseload heat demand is approximately 50 kW, and peak heat demand in any hour is 450 kW. These figures show how this CHP is not designed in the same way as a typical DH CHP system design, where the CHP is sized to meet the baseload demand in order to ensure optimum operation.

Excess heat, that is heat not used to supply useful heat to buildings or the AD system or heat needed to cover system losses, occurs in summer and out of office hours at weekends. This rejected heat amounts to approximately 870 MWh per year. Ideally a better diversity of building types should be connected to the heating system in order to utilise heat in all hours and seasons.

It is also proposed to try to connect another nearby office building located half a kilometre away. This building will have a similar weekly heating demand profile to the Teagasc Grange buildings. From estimates of floor area and applying typical energy benchmarks for office buildings, it is estimated this building has a heat demand of between 700 and 900 MWh/year. To add this demand to the system would mean investing in 0.5 km pipeline, additional heating plant and larger storage. Ideally a demand consisting of residential, hospital or 24-hour industrial activities would be a better addition to optimise the use of heat outside of office hours and to lessen the impact of increasing peak hourly demands and therefore increased heating plant capacities. There are no users of this nearby however.

Heat Network

No diversity factor is applied to pipeline sizing as all demands are operational at the same time, during normal weekly working hours. The estimated pipe line sizes range from 100DN in the main transmission line to 40DN in the branch connections, and Figure 16 shows a proposed network route. The longest branch pipe required is to supply the AD tanks on the south-east end of the site. The bioscience building has the largest annual heat demand and the highest peak demand in any hour and so is connected as close to the heat source as possible to reduce the length of larger pipe diameters required to carry larger heat capacities. The heating systems within each building may need to be adjusted to ensure a low return temperature.

[56] The energy content varies depending on the percentage volume of CH_4, CO_2 and other gases

Results

Technical

The heat demands of all six buildings and the AD system are met in all hours of the year using the heat supply from the biogas CHP, either directly, or through heat stored in a 30m^3 storage tank. No back-up heat plant is required to turn on during a normal year, provided CHP maintenance is scheduled during summer months or weekends.

Figure 17 shows the heat production over a 7-day period in January. The Biogas CHP production seen in the top window (red) is constant as the CHP is set to produce at full load when possible. It can be seen how the heat demand (blue line) exceeds the maximum CHP heat output Monday to Friday in the middle of the day. The thermal storage capacity, seen in the bottom window (green line), stores the out-of-office-hours heat production in order to utilise it during the daytime peaks. In this way the thermal store allows maximum use of the CHP heat production.

The top window also shows the heat rejection (green line) utilised to ensure maximum CHP electrical output. It shows the weekends are when most heat is rejected as the thermal store is full and there are no demands.

Economic

The largest part of the investment is in the AD and CHP plant. There are several revenues and savings to be made from this investment. The biogas CHP plant feeds electricity to the grid, and the operator receives a REFIT price which is around double the average system marginal price. The AD plant not only produces biogas, but will also produce digestate which will be used by Teagasc on-site, and will off-set €5,100 of annual fertiliser costs. The heat production from the CHP saves approximately €29,700 per year in LPG and oil costs. The costs to supply the AD tank with manure and silage have not been assessed.

Figure 17: Production graphic; Biogas CHP, heat rejection and thermal store

The purchase of the AD and biogas CHP system is primarily for research purposes. With just the investment of the AD and CHP, the system has a payback of 11 years and an IRR of 6%. The DH system is small and limited to one site, and so the lower cost PEX duo pipe system could be utilised instead of insulated steel piping. The initial costs of the network are also likely over estimated as the ground work at the Grange site will not be as costly as typical city or town network installation costs. The total pipe work required is less than 1km in length, the longest section being the supply to the AD tanks. A range of network costs are analysed in Figure 18. At the lowest estimated DH network costs, the NPV is negative at €-180,000 and the IRR is approximately 5%. The payback is approximately 12 years.

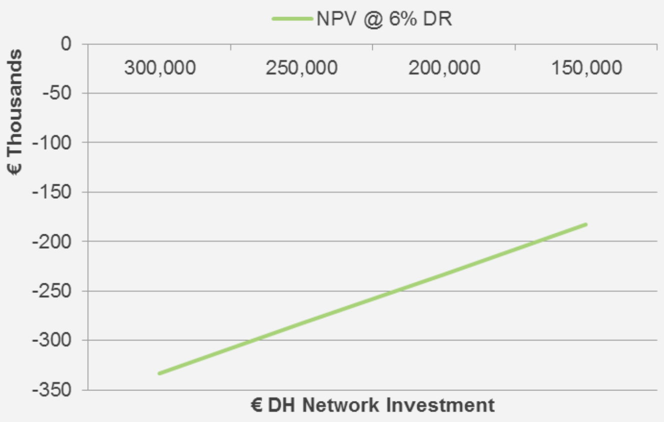

Figure 18: NPV vs DH Network Costs

The current Great Britain RHI Scheme price for small biogas combustion is 5.9p/kWh thermal output. When this RHI is applied in this case, and the system marginal price received for exported electricity, the payback is 15 years, and IRR 2.8%. As referred to in the Killarney study, it is possible that a combination of a REI, such as the current REFIT for non-CHP biogas combustion, and a RHI on heat production could be available for biogas CHP plants, but for this analysis it is assumed the plant is only eligible for one or other support mechanism.

If all heat produced by the CHP was utilised, and therefore the RHI was received for every kWh of heat produced by the CHP, the payback would reduce to 11 years, with an IRR of 6.9% and NPV €178,030.

Emissions

The system will supply 100% renewable heat to the Teagasc Grange buildings, which saves 103.6t CO_2 per year. The CHP also produces renewable electricity, which off-sets 664t CO_2 emissions per year; therefore the Teagasc AD CHP reduces emissions by approximately 767t CO_2 annually.

Conclusion

In conclusion, the Teagasc biogas CHP will utilise a local farm waste and grass silage, and off-set fossil fuel use in both the heating and electricity sector. The CHP must deliver heat in order to qualify for higher REFIT payments. The cost of adding the DH network does not drastically change the system economics, and the system achieves an IRR of between 4 and 5%. The system would benefit from increased diversity of heat loads connected to the DH network.

Site 3: Ardaun Development, Galway

Ardaun is an area located on the east side of Galway City, approximately 5km from the city centre. Because of Ardaun's significant development opportunities, Galway City Council is developing a Local Area Plan for the area, which provides more detailed planning policies for the sustainable development of the area. The vision for Ardaun's urban village is to have a compact, walkable, and sustainable neighbourhood. The area is expected to deliver 2,500 residential units, housing approximately 6,800 people.

The first phase of development in the southern section of Ardaun (section below the main road route running through Ardaun seen in Figure 19) is expected to see 1,098 of these residential units built. These new units will be built to the latest Building Regulations, with the energy considerations in line with Technical Guidance Document L 2011 – 'Conservation of Fuel and Energy – Dwellings'. From BER analyses, new builds in Galway, built since the start of 2011, have achieved at least a C2 rating, with the vast majority achieving A and B ratings. The new Ardaun dwellings will achieve similar high building energy ratings when built to the Part L regulations. Around half of the dwellings built in Galway since 2011 use oil or gas as the main space heating fuel, with the other half predominantly using heat pumps. Many of the recently built dwellings are detached units, and would have been built in isolation and not part of a development, and so heat supply from DH would not have been considered.

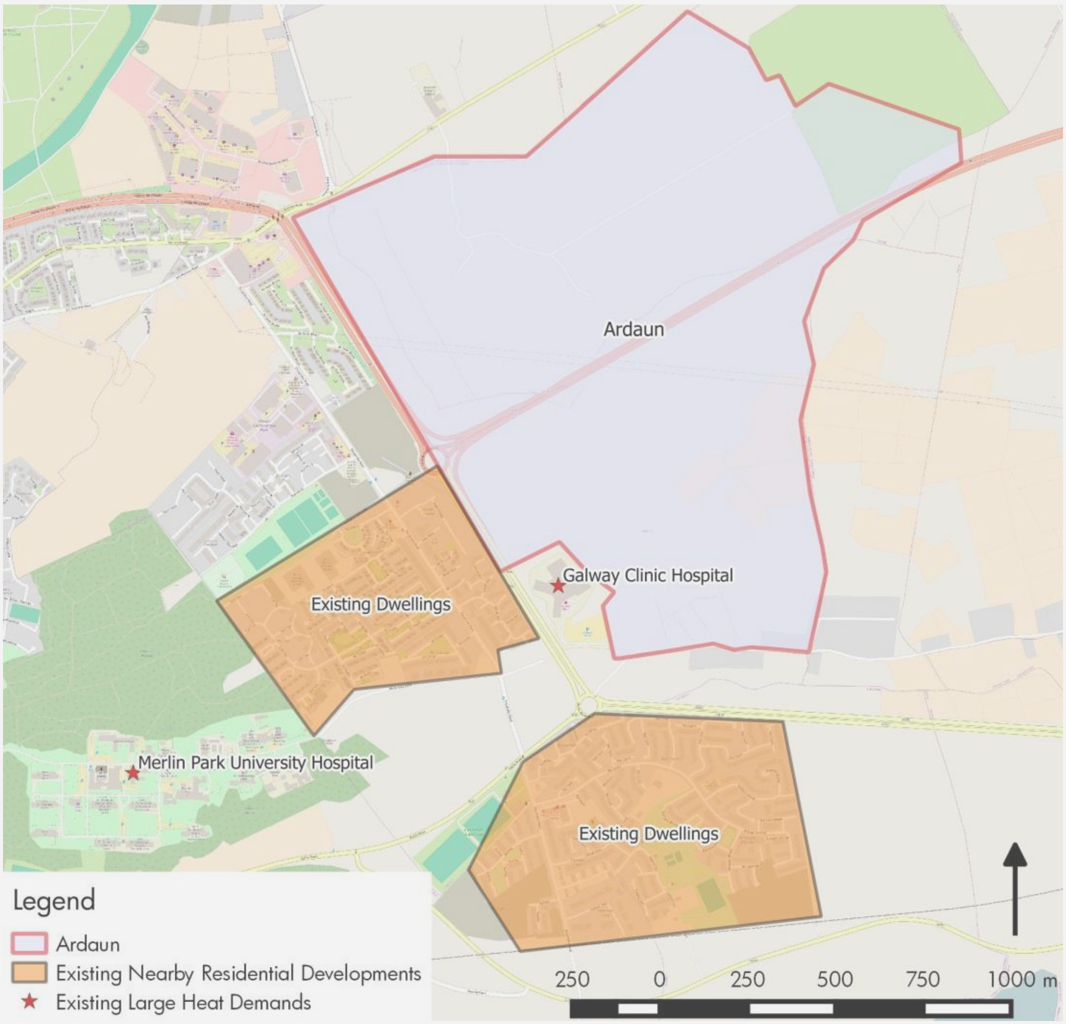

Figure 19: Ardaun area

The Galway City Council planning team have estimated that a maximum 83,000 m^2 of commercial activities will be developed in the Ardaun LAP area. There is also potential to connect nearby existing heat demands which may be very beneficial to DH feasibility, shown in Figure 19, such as the Galway Clinic Hospital, located next to Ardaun, and the Merlin Park University Hospital, located approximately 1.5km away. Existing nearby housing estates could also offer a viable heat demand to connect to future extensions of the Ardaun system.

There is an opportunity for Galway City Council to consider DH for the Ardaun area, and in keeping with the sustainable and energy efficiency vision for the area, the DH should be supplied by local sustainable or renewable sources.

Analysis

Heat Demand

The mix of dwelling types is currently unknown, and so an estimate of the mix of detached, semi-detached, terraced and apartment units has been made. For DH purposes, the more compact the dwellings are the better for viability, as the heat demands will be located closer together meaning shorter transmission network pipelines. Therefore a higher share of apartment units is preferable. The number of each type dwelling actually chosen for the development will have a large effect on the heat network, as discussed in the next section.

The heat demands for each of these new units is calculated based on average demands for each building type from BERs of new builds since 2011. What differs when analysing new builds for DH connection rather than existing buildings is the difference in the ratio of space heating to hot water, which stems from higher building thermal efficiencies and therefore a lower requirement for space heating. In new build apartments, there is almost a 50-50 split between hot water and space heating demands. Detached housing, due to the large floor areas, has a higher space heating requirement, which amounts to approximately 64% of the total heat demand. New semi-detached and terraced housing use on average 40% of their total heat demand on space heating requirements. This changes the typical demand profile for heat supply, as less of the demand is dependent on outside temperatures. The daily domestic hot water demand profile is modelled based on profiles established for the International Energy Agency (IEA)[57].

The maximum heat demand per dwelling is very low, due to the overall lower space heating requirements. The modelling of the space and water heating demands has shown a maximum capacity requirement in detached housing of 4kW. Substations (heat exchangers and meters) per housing unit are therefore conservatively priced at €2,000/unit, which is 20% lower than the typical costs for a 10kW system. Apartments have the smallest capacity requirements and so a lower cost of substation is estimated at €1,500/unit.

Heat Network

A typical distance between dwelling units is used to estimate the length of heat network required to connect all units. It is assumed that the housing developments have dwellings on either side of the same street, with DH transmission pipes running through each street. Most DH pipes need only to be buried at a minimum depth of 600mm, and can have the positive side-effect of melting ice and light snow on the ground above in winter, and so are useful to place beneath footpaths or cycle lanes.

Average Dwelling Type	Annual kWh heat demand /dwelling	Trans-mission pipe (m) /dwelling	Linear heat density kWh/m
Detached	8248	8	1031
Semi-D	4682	6	780
Terraced	4128	4	1032
Apartments	3415	1	3643

Table 1: Linear Heat Density of Dwellings

Table 1 shows the estimated linear heat density per dwelling type analysed under the assumptions outlined. Using the new build BERs to assess the estimated heating demand of new dwellings shows detached units have a significantly larger heat demand than other units, and require a longer transmission network than other units. These dwellings have larger floor areas and exposed external area, and therefore a larger heat demand. Thus, even while requiring longer networks, detached housing has similar heat densities as terraced housing. Semi-detached housing requires shorter pipelines, but has lower heating demands, and so has the lowest linear heat

[57] Jordan, U. and Vajen, K. (2001) *Realistic Domestic Hot Water Profiles in Different Time Scales*. Marburg: Universitat Marburg.

density. Apartments have by far the most attractive linear heat density, even when using conservative assumptions with small numbers of apartments per block and approximately 16m transmission network per block.

As the final design of the area has yet to be defined, it is assumed the heat source will be located at one end of the neighbourhood, and all demands are connected on a linear branch network stemming from this point. An additional 20% network length is added to allow for other elements of the development layout. The distance of the main heat supply or energy centre to the nearest demand is assumed to be approximately 500m. A diversity factor will be applied as peak demands are not likely to occur simultaneously, and will vary with occupancy patterns and other consumer behaviours. Costs of the heat network will be lower than typical network costs for urban areas as this is a green field project. The costs of the branch pipe to connect each dwelling, estimated at approximately €1000/dwelling, are assumed to be recovered in the sale price of each dwelling. Heat exchangers remain the ownership of the DH company in order to ensure optimum technical operation.

Energy Production

Because Ardaun is a completely new development, and no analysis of DH potential for the area has been carried out to date, there are numerous heat sources that can be considered. From initial observations of nearby commercial and industrial activities, there are no obvious sites for viable waste heat recovery, although this potential should be analysed in more detail through stakeholder engagement with nearby businesses and an assessment of any new commercial activities planned which may produce waste heat. Due to the expected high energy efficiency of new builds in Ardaun, there is also potential to use resources which would usually have too low a temperature to meet traditional heat supply temperatures of 80-100°C. There is a gas grid available in the area and so a back-up plant fed by natural gas can be considered.

The analysis will firstly assess renewable technologies that are well established for DH use, such as biomass fed boilers and CHP plants. Due to the ratio of space to hot water heating requirements described earlier, there is less difference between the base and peak load requirements. If the heat plant can be located anywhere on the site, it should preferably be placed close to existing large heat demands, such as the Galway Clinic Hospital, so heat can be delivered more efficiently when these demands are ready to connect to the system. It should also ideally be placed close to main road access in the case delivery of fuel is required. Developments with highest linear heat densities should be developed as close to the supply source as possible to reduce the network costs.

Key Figures

The Arduan Phase 1 development of housing will have a baseload demand of 500 kW and a peak demand of 1,800 kW. A predicted mix of units is used for modelling of the first phase development of the Ardaun area (1098 units), with an even distribution of 250 detached, semi-detached and terraced units, and the remaining 398 units being apartments. Apartments are conservatively assumed to be blocks of 16, with 4 floors and 4 apartments per floor. Based on this mix of units, the total annual heat demand, including losses is predicted to be 5,725 MWh. If these units were to be built with typical individual heating systems found in new builds, the predicted CO_2 emissions are 1,665t per year.

Results

Mix of Dwelling Units

The mix of units has a large impact on the length and size of the network and therefore the network investment. It also has an impact on the total and peak heat demands of the system and therefore production unit costs. With the initial mix of units outlined above (referred to as development 1), the total transmission network length is estimated to be 6.4km. The total network costs, including branch pipelines, are estimated to be €2.5m. Other investments in production units, thermal storage, heat exchanger and meters amount to €2.5m.

When more units with high linear heat densities are chosen, i.e. apartments and terraced housing, the investments are lowered. A mix of 100 detached, 100 semi-detached, 350 terraced and 548 apartment units (referred to as development 2) is analysed to show the difference in overall costs. The network length is reduced from 6.4km to 4.5km. The costs of the network reduce by nearly a third to €1.7m, and the other production related costs reduce slightly to **€2.4m**. The latter costs do not change dramatically as the number of individual substations required remains the same. When the numbers of detached and semi-detached housing units are reduced and replaced with units which have a lower annual heat demand, the overall heat demand of the system is lowered from 5,725 MWh to **4,840 MWh**. While the network costs are lowered, the decrease in demand has the effect of lowering the predicted sale of heat revenues, and therefore adversely affects the payback.

Production

Biomass Boiler

The first analysis investigates the use of local biomass resources in a biomass boiler supplying the development 1 mix of dwelling units outlined. An RHI is set to the equivalent Great Britain RHI rate for biomass combustion at 2c/kWh. The cost of biomass is taken from the current SEAI commercial rates for wood chip, although a reduced price could be obtained with a local supplier.

Initially the biomass boiler is sized to meet the baseload demand of approximately 500 kW, and a gas back-up boiler is sized to meet 120% of the peak demand in any hour at 2150 kW. With these generating capacities, the modelling analysis shows the gas back-up boiler provides 24% of the annual heating demand. In order to lower the contribution of gas and utilise more biomass, the biomass boiler size is increased to a 700kW output capacity. This additional capacity, combined with the use of a 65m^3 thermal store, decreases the contribution of the gas fired boiler to less than 8% of the annual demand. The inclusion of a larger biomass boiler increases the investment costs, but increases biomass use and therefore reduces fuel costs and decreases CO_2 emissions. The annual emissions decrease to approximately **87t CO_2**, which is a **95% reduction** on the predicted emissions with individual heating systems.

Varying RHI and Biomass costs

The economic analysis shows the biomass boiler DH system with an RHI tariff of 2c/kWh has a pay back within 18 years, and has a €-2.1m NPV. For the project to have a positive NPV and a payback of 11 years, a RHI of nearly **5c/kWh** is required. The analysis is also run with a 2c/kWh RHI and a reduced biomass cost. The current cost of biomass is 11c/kg, and when reduced as far as 7c/kg, the payback reduces to 14 years but the NPV remains negative and the IRR is only 4%. The biomass price would therefore need to be unrealistically low to enable a positive NPV.

Increased Demand Density

The same analysis is run again with the initial cost and tariff settings, but this time supplying development 2 with the higher heat density housing. The lower network costs have a positive effect on the overall system economics, and a RHI tariff just over **4c/kWh** is required for an **IRR of 6%**. The difference in the NPV of each development type over a range of RHI can be seen in Figure 20.

The analysis shows the economic benefits of higher heat demand densities, and in order to further improve the economics in this case, a higher heat demand density, ideally with longer hours of demand, is required. A possible connection to the nearby Galway Clinic Hospital could positively affect the economics of the system. Any planned commercial developments with high linear heat demand densities should be located close to the Ardaun Phase 1 housing development. This kind of dense urban development also fits well with other considerations of sustainable planning such as facilitating more sustainable transport modes.

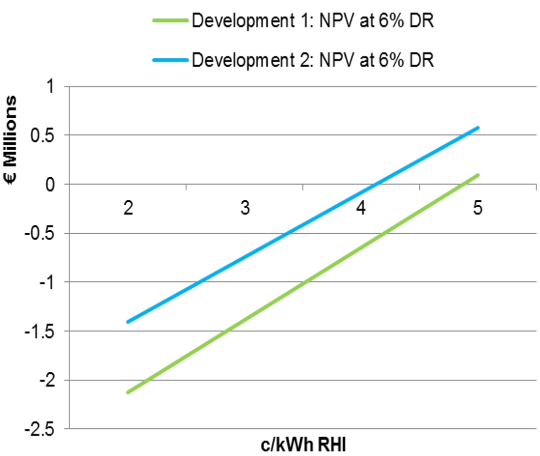

Figure 20: NPV versus RHI for Development Type 1 and 2

Varying Customer Price of Heat

This analysis has used a price of heat per kWh which is the same as the current cost of gas per kWh, ex. VAT, as there is natural gas available in the area and the likely alternative individual heating system would utilise gas boilers. Using the current gas price means the customer will save approximately 10% on the total fuel costs that they would have had to spend with an individual gas boiler, assuming a 90% boiler efficiency.

The price per kWh of heat sold is therefore approximately 6c. If the cost of gas increases, the customer price of heat could also be increased. The effects of an increase in the customer heat price are shown in Figure 21. With a 2c/kWh RHI and current cost of biomass, a customer price heat price of at least 8.7c/kWh will give an IRR of 6% or higher.

Solar Thermal

Solar thermal technology is well established and there are many examples of its use as part of DH supply systems in Europe. There are two main technology types; evacuated tube and flat plate collectors. Typical solar thermal arrays on DH systems combined with thermal storage cover 10-25% of the annual demand. The latest costs of large scale solar thermal DH arrays are approximately €425/MWh, but these costs are expected to decrease to €386/MWh by 2020. The higher costs are used in this analysis, but could be lower when Ardaun is being developed.

The addition of a 2000m^2 array of flat plate solar collectors is analysed. The biomass boiler and gas back up boiler capacities remain the same, as the solar collector will produce most in summer and therefore the demand in winter will still require the other units to operate to full capacity. The addition of extra thermal storage capacity is analysed in order to optimise the solar output, and the analysis shows additional capacity does not allow a higher solar thermal yield, and so the 65m^2 store is sufficient. The only additional investment required is therefore in the solar system itself, and annual O&M costs are added. The solar collectors contribute **1,032 MWh** per year to the DH supply, which is **18%** of the annual heat demand. This also reduces the CO_2 emissions of the DH system further to **50t** per year.

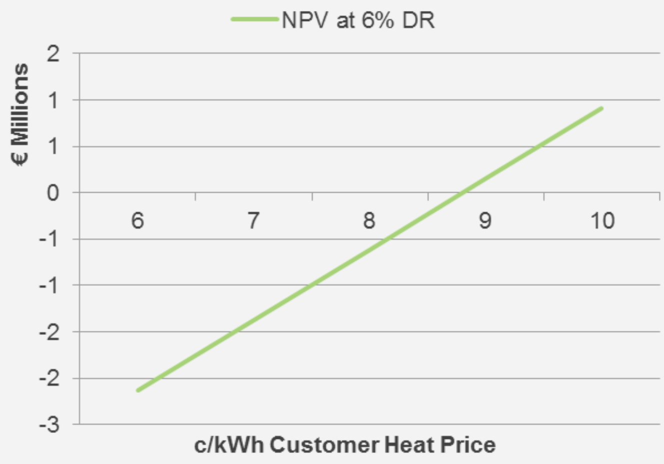

Figure 21: NPV versus Customer Heat Price

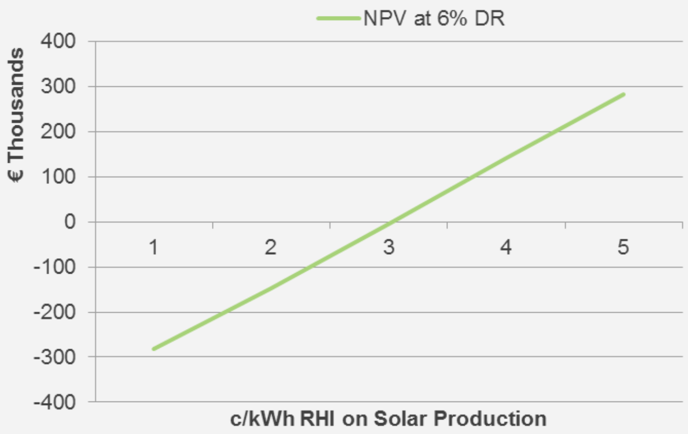

Figure 22: NPV versus RHI on Solar Collector Production

Figure 23 shows the production of each unit over a seven day period in March. The top window shows the solar radiation levels recorded at a weather station close to the Ardaun site. The second window shows the priorities of each production unit which depends on their net production cost of heat. The blue line represents the solar collectors, and has a production cost close to zero, with the only running cost being O&M. The biomass boiler (red line) has the next lowest cost of heat production, and is therefore prioritised over the gas boiler, which has the highest cost and is utilised last. The third window from the top shows the production output of each unit. It can be seen how the solar collector output follows the profile of the hourly radiation shown in the top window. The biomass boiler meets the majority of the rest of the demand, with the gas boiler only turning on in hours when there are low radiation levels, a peak in demand, and/or there is not sufficient heat stored in the thermal store.

The system including the solar array is again modelled used the original cost and tariff assumptions, and supplying the development 1 mix of dwelling units. The addition of the solar array has a very positive effect on the economic viability of the DH system, improving the NPV to €-400k and now pays back within **13 years,** and has an **IRR of 5%**.

This return on investment is without any RHI on the heat produced by the solar collectors. The solar collector RHI in Great Britain is 10.28p/kWh, but is limited to systems less than 200kWth. The effects of a RHI tariff for large DH solar thermal is analysed for the Ardaun case. Figure 22 shows how a range of RHI tariffs on solar production affects the NPV. The NPV increases from €-400k to €0 when a tariff of 3c/kWh is applied.

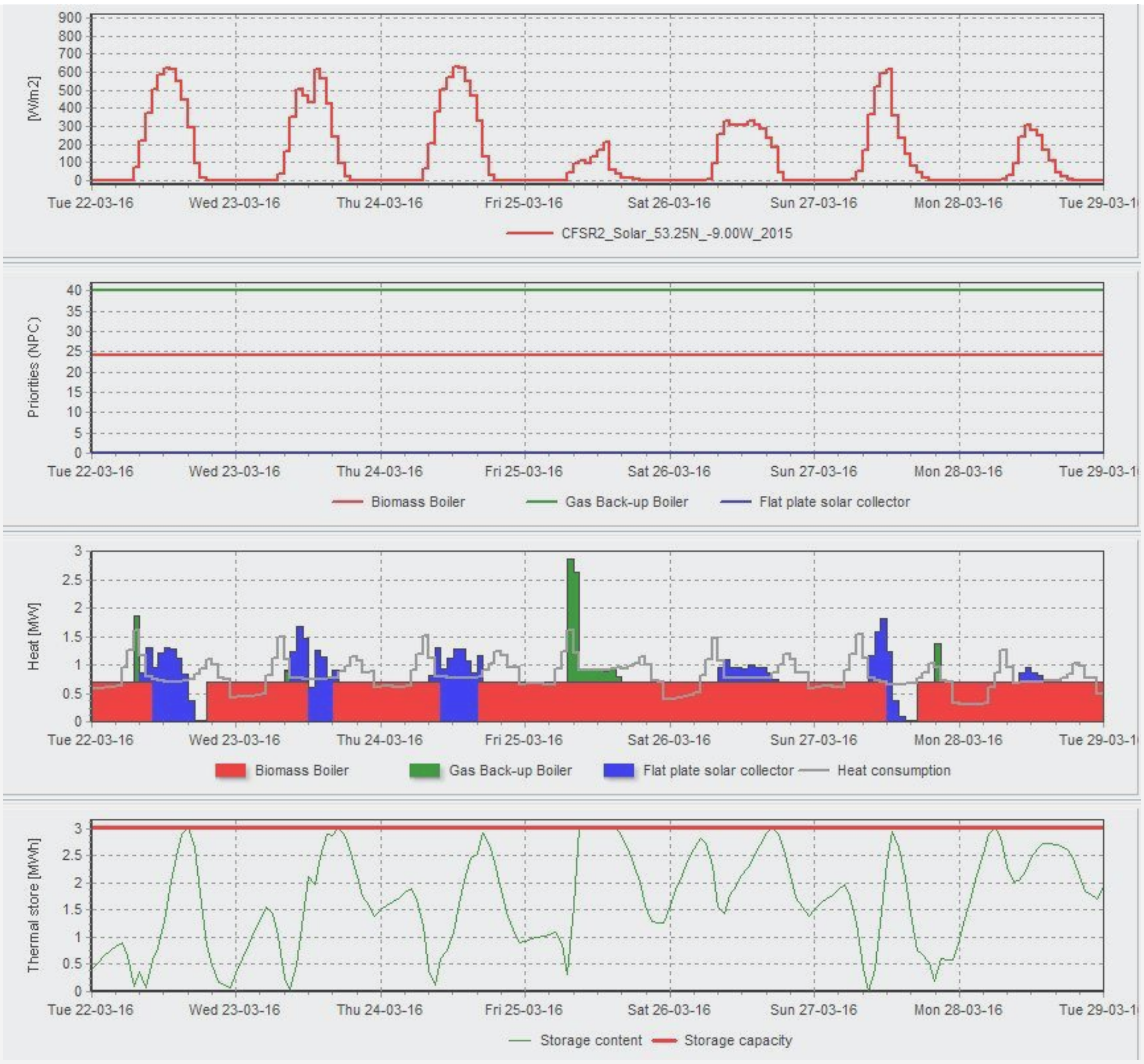

Figure 23: Production Graphic; Solar Collectors, Biomass Boiler and Gas Back-up Boilers

Geothermal potential

An assessment of the geothermal potential of the Ardaun area has been carried out for this analysis[58]. The bedrock in the Ardaun area is a type of limestone similar to that found in the Burren, and this type of bedrock allows increased permeability due to the its fissures and fractures. In terms of hydrogeology, the area is classified by the GSI as "Rkc – Regionally important aquifer – karstified (conduit)". The deep geothermal potential of the area is not well known, but based upon an average geothermal gradient of 25°C/km and a minimum depth of 500 m, it is possible that groundwater with temperatures of approximately 20°C may be obtained, however the temperature of the groundwater is expected to increase further with depth.

Due to the geology of the area, it is classified as "suitable" for open loop geothermal installations, given the likely high permeability of the bedrock. The suitability of the area for open and closed loop systems can also be seen on the SEAI Geothermal Mapping System[59]. Open loop systems can create problems as the underground water is used directly, and can cause corrosion and other problems in the equipment if these issues are not addressed during design. Also, with open-loop systems, the volume of water attainable is as important as the temperature, as high volumes are needed for optimal performance. An alternative to an open-loop geothermal system is the closed-loop or heat-exchanger type installation, where a thermally efficient fluid is circulated in a closed loop to bring geothermal heat to the surface. The SEAI mapping tool shows most of Ardaun is suitable for vertical closed loop systems.

It is estimated that 46% of DH geothermal plant investment is in wells and well tests[60]. For viability of a geothermal DH system, the geothermal supply should be sized to the baseload demand so it can be utilised in almost all hours. In this case, the baseload demand is too small for an investment in a deep geothermal system. When the Ardaun development grows and a range of potential commercial and industrial customers can be defined, the viability of a deep geothermal supply option should be re-evaluated.

Conclusion

The Ardaun area is an ideal case to analyse the viability of DH supply in new low energy housing developments. The analysis has shown that a mix of solar and biomass renewable sources supplying the lower heat density mix of dwelling units significantly lowers predicted CO_2 emissions, utilises local biomass resources, and returns an IRR of 5% under current market conditions with the addition of a RHI on biomass boiler heat production. The analysis has also shown how the density of the new development will have a significant impact on the economic viability. The low temperature requirements for new dwellings means there are more opportunities to integrate low cost renewable heat into the Ardaun DH system.

If Ardaun is designed as a high heat density development, such as the development 2 scenario described, and there is a small RHI offered to large scale solar collectors, the solar and biomass fed DH system becomes a very competitive solution. A greater diversity of heating demands would better suit this project, and if the nearby hospital could be connected as an anchor load it would increase the over viability of the system and de-risk the project. As part of the Ardaun LAP, an energy masterplan for the Ardaun area would help to guide developers, define the network route, coordinate infrastructure works and outline how the DH system will develop from phase 1 to phase 2.

[58] This assessment was kindly carried out by Sarah Blake, Gavin and Doherty Geosolutions.
[59] SEAI (2016) *Geothermal Mapping System*.
[60] Danish Energy Agency. (2013) *Technology Data for Energy Plants*. DEA, Copenhagen.

Other Potential DH Sites in Ireland

There are many other areas suitable for DH or are at early stages of planning a DH system. Some others areas which were not analysed in this report are;

- Dublin District Heating System – The Dublin DH system is a Dublin City Council initiative, supported by Codema, and has been in planning for a number of years. The first phase of the system will be developed in the Docklands area of the city, and there are already many sections of the DH network in place. Thanks to forward planning, the council has ensured new builds in the area are DH enabled and ready to connect when the system is available. When complete, it will be the largest DH system in Ireland.
- Tallaght District Heating System – South Dublin County Council and Codema are planning the first phase of a DH system in the Tallaght area. The county area has had a heat demand density analysis, and Tallaght town centre has ideal heat densities for DH development. The project will be part of a recently approved[61] EU INTERREG V NWE project called HeatNet, and will receive funding to help implement the first phase of the system, connecting Tallaght Hospital and municipality buildings to a central energy centre.
- Letterkenny Institute of Technology DH system– LYIT has a proposal for a campus wide district heating scheme and is participating in the SEAI exemplar programme to progress the project. The project is currently on hold pending details of the proposed RHI.
- Waste to Energy, Cork – There may be potential for a commercial DH system in Cork if the proposed Indaver Waste to Energy plant is granted planning in Ringaskiddy. The plant could potentially supply nearby large commercial and industrial customers.

[61] The HeatNet project has been approved subject to conditions

Case Studies: Examples of Existing DH in Ireland

Prepared by Tom Bruton, Chartered Engineer

Case Study 1: Charlestown Mixed-Use Development

Charlestown is a mixed-use development in Dublin 11 comprising of 285 apartments with an 18,800m^2 shopping centre with Dunnes Stores as the anchor tenant. The retail park and apartments in phase 1 opened in 2007. A further phase 2 expansion has also been completed, with the addition of a cinema and additional retail units. Further apartments and commercial buildings are planned for future phases.

District Heating

Charlestown has its own local district heating system (DHS). There is an energy centre where the combined use of biomass boiler, natural gas boilers and a combined heat and power plant (CHP) deliver a continuous supply of hot water and heat to each apartment which is metered and invoiced monthly to each resident.

The electricity is used onsite for the landlord electrical services, which generally includes equipment such as lighting, lifts/escalators, pumps. Dunnes Stores also is supplied with heating from the CHP unit. The CHP unit runs for 16 hours a day, switching back to the grid for daily off-peak periods.

There is approximately 4MW of combined thermal heating capacity available in the energy centre. The gas engine also has an output of 228 kWe.

A number of the other retail units in phase 1 use DHW and heating from the central network, although several choose to operate their own HVAC units and don’t procure from the DH network. New piping has been run to connect with future demand in phase 2, though this is blanked off at present. There is an estimated 1 MW new thermal load to service the new retail units there (cinema, bowling alley, restaurants etc.), which currently use gas-fired AHUs.

The operators of the DH network were disappointed not to include the new area in the DH scheme. A particular factor behind this decision is the high cooling load requirement of a cinema, with cooling accounting for up to 80% of overall thermal demand.

Figure 24: Charlestown, Dublin 11; Phase 1 in background, Phase 2 in foreground

Figure 25: Phase 2 pipes and booster pumps ready for expansion

Figure 26: Gas piping to roof-mounted units in phase 2

Centralised Cooling

There is a centralised cooling concept for the retail units in phase 1. This is via fan-assisted heat exchange of internal air with ambient air in 4 different cooling plant rooms. This provides some limited cooling capacity and is not metered, but incorporated within the allocation of overall electricity costs from landlord services.

Figure 27: Chilled water flow and return piping DN150

Trends in Heating and Cooling of Retail Premises

During 2014 SEAI commissioned an extensive survey of commercial building stock[62]. The findings of this reveal the very high extent of electric heating in the commercial sector.

The survey found that the vast majority of the 40,000 retail premises in Ireland are electrically heated, and over half of the office and restaurant/pub building categories are also electrically heated.

Despite the prevalence of electrical heating and cooling in the retail sector, there are significant opportunities to move away from this expensive reliance on electricity, as demonstrated at Charlestown shopping centre. According to the SEAI survey of building stock there are about 3,000 large retail units in Ireland (where large is defined as > 1,000 m^2 footprint).

[62] SEAI (2015) *Extensive Survey of the Commercial Buildings Stock in the Republic of Ireland*.

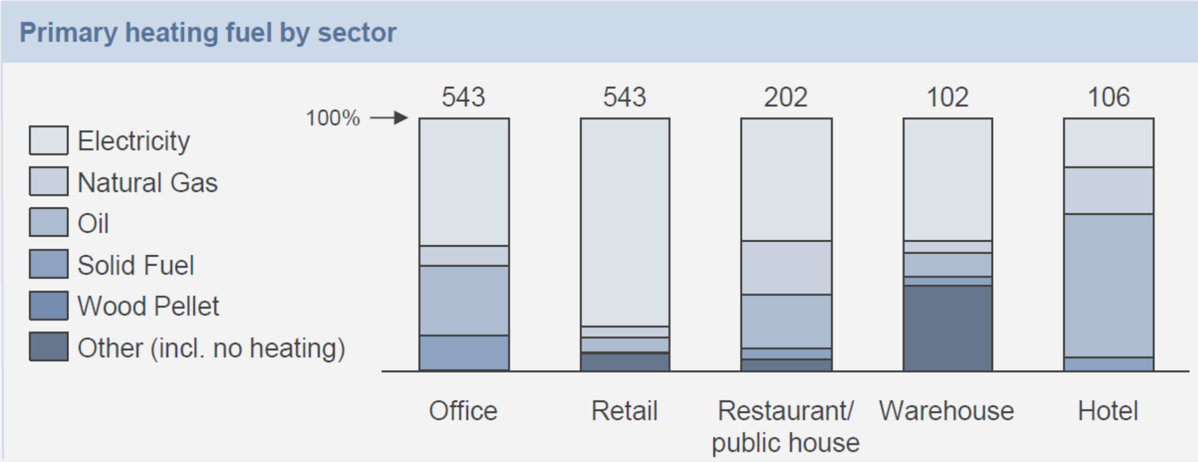

Figure 28: Primary Heating Fuel Survey of Commercial Building Stock (SEAI 2014)

Figure 29: KOB 1.2 MW wood pellet boiler (photo Kaizenenergy.ie)

Figure 30: Ground level fill point for wood pellet store

Policy Context

The Fingal Draft County Development plan 2017-2023 is currently in formation and public consultation phase. With regard to district heat it sets out objective PM25: "Encourage the production of energy from renewable sources, such as from Bio-Energy, Solar Energy, Hydro Energy, Wave/Tidal Energy, Geothermal, Wind Energy, Combined Heat and Power (CHP), Heat Energy Distribution such as District Heating/Cooling Systems, and any other renewable energy sources, subject to normal planning considerations and in line with any necessary environmental assessments."

The wording of this reflects a common misconception – that district heating is a form of renewable energy, when it is in fact decoupled from the energy source and is a piece of enabling infrastructure. It would be preferable to see district heating as a standalone objective, with a role in energy efficiency and business competitiveness and not just facilitating renewable energy.

The current method of evaluating buildings, the BER (building energy rating) for commercial buildings or DEC (display energy certificate) for public buildings does not provide any positive recognition if a premises is supplied from a district heating scheme. A common refrain from facilities managers and building owners is "what recognition do we get for investing time and effort in district heating if it doesn't improve the BER/DEC?".

Clearly there are challenges in implementing this but it would be useful to have a tool to recognise the positive impact of investing in DH.

SEAI provided a capital grant to support the procurement of a biomass boiler and other elements of the DH scheme installed under the REHeat programme. This funding came to an end in 2009 and there has been no fiscal incentive to encourage similar developments, or indeed to support further investment for Charlestown phase 2.

The CER's role in certifying high-efficiency CHP has been a support in the Charlestown DHS. The utilisation of gas in a high efficiency CHP engine means that a carbon tax refund applies on the gas procured, in recognition of the useful capture of heat from the gas engine to supply the commercial and residential tenants in the development.

Commercial Structure

A special purpose company was established dedicated to the ownership and management of the DH scheme, Charlestown Centre District Heating Ltd. The board of this company consists of representatives of both the residential apartments and the retail complex, which are separately managed.

Kaizen Energy is a third party facilities management firm specialising in the operation of district heating schemes. They are contracted to provide the day to day plant operation, planned and reactive equipment maintenance, fuel procurement, customer and energy management, financial accounting and end user billing. All energy and commercial data is presented transparently back to Charlestown District Heating Ltd.

The approximate costs of metered district heat are 4 c/kWh for commercial users and 6 c/kWh for residential users. This includes all maintenance and management costs, as well as making provision for sinking fund for eventual renewal of key equipment.

This represents good value for money from an end-user perspective and compares favourably with the cost of standalone gas boilers meeting the same need. That being said, there is very little protection or assurance for consumers at present that they will be charged fair and appropriate rates, as private operators are free to amend prices as and when they see fit. It is reasonable to suggest that the CER or equivalent body has a role in ensuring stable and appropriate pricing for DHS customers, particularly as the number of consumers increases.

Further Learnings

While the workmanship is of a very good standard, there is evidence of a need for improvement in design and installation of DH schemes.

Some simple examples include:

- Installation methods that undermine the mechanical integrity and thermal efficiency of the distribution piping
- Redundancy in the design of heat substations and pumping arrangements, leading to additional capital, electrical energy and maintenance costs.

A very positive element of the design is the simplicity of the residential heat stations, and in particular the facilitation of access for maintenance and control via an external service shaft.

The operators of the DHS at Charlestown have indicated the need for greater industry networking, knowledge sharing, training and promotion of DH. It is understood that the Irish Bioenergy Association is proposing to host such a group for its members and other interested parties.

Figure 31: No insulation through brick wall

Figure 32: Box metal hanger undermines insulation and does not accommodate vibration

Additional data

- The system was designed by Varming Consulting Engineers.
- The KOB biomass boiler was installed by Clearpower/Flogas renewables. 1.2MW
- Gas CHP engine rating is 228kWe / 385 kWth.
- There are 2 x 1.2MW gas boilers for back-up and peak load supply.
- There are 2 x 8,000 L buffer tanks.

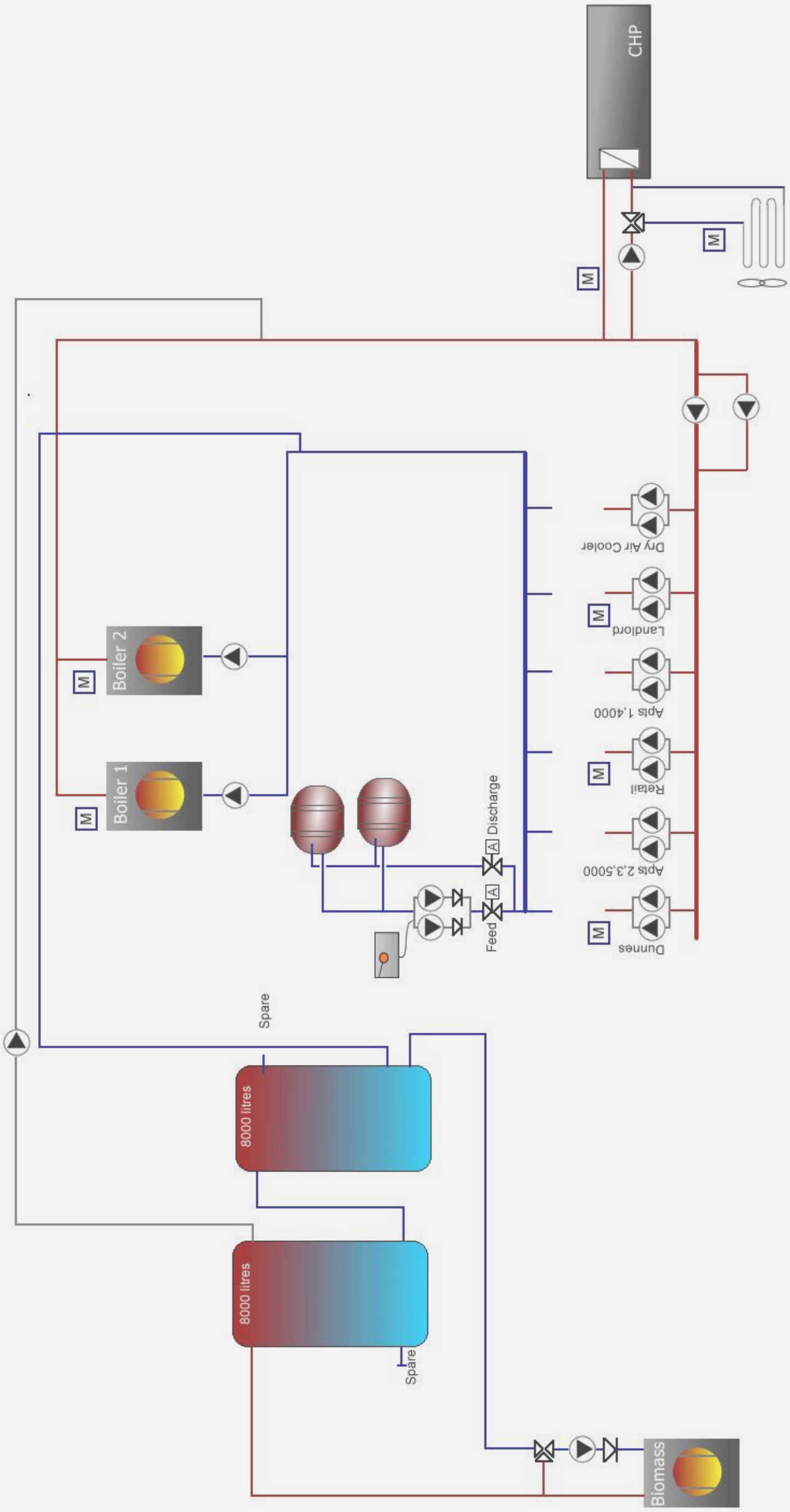

Figure 33: Process diagram for energy centre (Kaizen energy)

Case Study 2: The Glen District Heat Network

Figure 34: The Glen Energy Centre and Network Location

The Glen is a predominantly residential area in the northeast of Cork City. The land in the area is mostly publicly owned, and in the 1970s a number of flats were built by the council on the land. These have been demolished under a regeneration programme for the area and replaced with more modern infrastructure and housing. Under phase 2 of the Glen regeneration project, completed in 2013, a localised district heating system was completed, supplying 58 no. housing units and a Community Centre (which has 4 sub-tenants including a crèche and a youth club), i.e. 62 heat consumers in total.

The heating Centre has a Herz 500 kW biomass boiler with fuel storage, buffer tank, controls, flues etc. and it is fuelled by wood pellets. The wood pellets to-date have been sourced from Laois sawmills, although this is subject to normal competitive procurement. There are also 5 no. 100 kW condensing wall-hung gas fired boilers.

There is an existing district heating network, complete with inspection chambers, isolation valves and leak detection system. Each consumer has a Danfoss heat interface unit (HIU) for indirect heating and DHW, which has a built-in meter, which can be remotely read.

Operation and Management

The energy centre and network was built under a turnkey contract along with the entire housing development. This allowed the council to ensure the energy infrastructure was integrated under the umbrella of a single contractor (BAM). The arrangement also included a 2-year initial contract to operate and maintain the network. The energy network operator is responsible for everything that happens inside the energy centre, up to the inlet of the HIU at each customer.

This included the following items:

- Preventative maintenance for the boilers and equipment in the energy centre
- Procurement of wood pellets and gas with pass-through of costs to the city council. Other fixed and variable costs (e.g. water, electricity) are absorbed by the operator.

Figure 35 Energy Centre at The Glen

Figure 36: Wall-hung Gas Boilers 5x 100kW

- Emergency maintenance and call-out service for the energy network, including customer service
- Monthly billing, collection of monies and reconciliation of heat account against readings

Learnings

After the first period of operation, a number of changes are currently being made by Cork City Council. A public tender was issued to contract with a longer-term operator for a period of 5 to 10 years. Some key items being addressed during this change are described here.

Some bad debts were incurred, and the council have decided to implement a blanket prepay system. Some minor changes will be required to the control of the HIUs and also to the data logger and communications systems. The HIUs and associated metering technology should in future be specified to cost-effectively integrate control and prepayment systems from the outset.

On occasion the energy centre operated on natural gas only for extended periods, as there was no minimum renewable fuel requirement set. Cork City Council has invested in the biomass boiler and the ongoing maintenance of it, and has a policy to promote renewable energy, so a minimum 50% target is being set for biomass use.

An analysis undertaken by BioXL sustainable energy consultants has indicated that there are opportunities to operate the network more efficiently. In the new tender for a long-term operator, a bonus is proposed to reward the operator for finding and implementing efficiencies and reducing the gross energy consumption in the energy centre. How this is achieved is at the discretion of the operator, but could include changing the operating temperatures and/or the control regime of the heat distribution network.

Heat Interface Considerations

Many social housing heat networks have a Heat Interface Unit (HIU) which supplies the individual home owner with space heating and domestic hot water (DHW). A key decision is whether to maintain a DHW tank within the house, or to rely exclusively on plate heat exchangers for supply of DHW. There is a space saving, capital cost saving and improved network efficiency by leaving out the DHW tank where possible, and that is the recommended design. However, occupants have no backup DHW (e.g. immersion) if the DH service is disconnected at any stage.

The housing units in The Glen do have an internal DHW with electric immersion. This has had the following consequences:

- Some occupants are unaware that the HIU provides DHW, and there is scope for improved customer education
- Some residents choose to disconnect from the DH network entirely

Since the specification of this project, there have been further advances in HIU technology and efficiency. A welcome initiative in the UK is the independent testing of market-leader's HIU units by heat networks consultancy FairHeat[63].

City Development Plan

The Cork City Development plan (2015-2021) does contain an objective to "support the principle of district and geothermal heating, and will further examine ways in which impediments to their use can be overcome". The DH project at The Glen is referenced, and also a feasibility study for the Docklands area that was produced in 2009. The conclusion in the development plan is that "district heating is too costly to retrofit… and is currently limited by lack of a reliable biomass fuel supply and by a lack of expertise in this area".

These conclusions highlight knowledge gaps and the need for a more proactive approach in forward planning for district heating. The decoupling of a DH network from a particular energy source (biomass or geothermal in

[63] FairHeat (2016) *HIU Testing: Overview of Test Regime*.

this instance) needs to be emphasised, as the wording of the City Development Plan treats DH as a source of alternative heat in and of itself.

Economics

Cork City Council are responsible for setting the standing and unit charges for heat supply, in line with social housing policy. This is normally determined with reference to the lowest market cost of heating. Any shortfall between the lowest market cost and the actual cost is a social cost absorbed by the council. There is no predetermined review period or methodology for determining the lowest market cost. The most appropriate data at present for independent freely available fuel cost data would be the SEAI quarterly commercial fuel cost comparison. Based on the April 2016 SEAI data, the lowest market cost would be just under 6 c/kWh delivered (VAT inclusive) for a boiler consuming up to 2,778 MWh of gas with a seasonal efficiency of 80%.

The rates set by a local authority do not take account of the initial investment in the network, the depreciation of the assets over time and the need to replace them at end of life. In private developments this might be foreseen through a sinking fund. This method also subsumes the cost of maintenance of the network within the local authority.

The advent of district heating networks has placed a new responsibility on local authority housing unit – to set heat prices. There is a lack of expertise, independent data and methodology to set and review heat rates in a transparent manner. There is a case to be made that the energy regulator would take this responsibility at a national level, and determine rates in line with government policy on fuel poverty and the affordability of energy.

A further challenge that a social housing network presents is that it is not feasible to transfer much risk to a third party. Some local or district heating networks are fully financed, operated and maintained by a private operator on a long-term lease of perhaps 20 years, such as a Local Energy Supply Contract (LESC) developed by SEAI. With revenue rate setting and ultimate responsibility for debt enforcement retained within the local authority, it is not possible to provide certainty on cashflow over any sustained period. It is possible however, as Cork City Council are currently undertaking to contract with a third party for O&M services.

Unit Connection Costs

As a benchmarking exercise we have estimated the overall network cost, and the marginal cost of adding an additional unit to the network.

The network cost from the exit of the boiler house to the end user, including the HIU is approximately €10,000 per customer. As this is a housing-estate style layout, it is necessary to run a flow and return spur of 11m DN25 pipe to each house and install a new HIU and heat meter. Given that there is now a primary network in place the marginal cost to connect additional consumers is about €4,500. It would be significantly more cost-effective to connect apartment blocks or single large consumers.

Case Study 3: Údarás na Gaeltachta – Gweedore Business Park

Context

Údarás na Gaeltachta is a state agency for implementing jobs, enterprise and innovation policy (as are Enterprise Ireland and the IDA outside of Gaeltacht areas). Údarás na Gaeltachta client companies employ over 7,000 people in Gaeltacht areas, and are providers of business supports and infrastructure for existing and future enterprises in the Gaeltacht.

The dispersed and geographically isolated nature of many Gaeltacht regions means they are poorly serviced by infrastructure, which applies also to energy supply. Very few Údarás business parks have access to natural gas for example, and most businesses presently rely on oil, LPG or electricity for their heating needs.

Gweedore Business Park in northwest Donegal is one of the largest sites managed by Údarás na Gaeltachta. It has 30 different commercial and industrial buildings spread over 70ha.

The business park was established in the 1970s. Initially driven primarily by heavy manufacturing industry, today the park is comprised of a mix of technologically-driven modern enterprises and facilities for education. It is home to a number of successful companies which operate in very competitive markets (e.g. Euroflex, RAP, Irish Pressings, Sioen and VHI). There are approximately 400 full-time jobs in companies supported by Údarás na Gaeltachta within the business park.

Existing Experience of Údarás with District Heat from Biomass

Údarás na Na Gaeltachta has already embraced renewable energy technologies at a number of its sites, and has a policy to promote new enterprises and innovation around the development and deployment of renewable energy supply.

Údarás installed a 300 kW biomass boiler in 2013 to heat six buildings on their head office campus in Furbo, Galway. This uses wood chip to heat the head-office buildings but also units leased to client companies. It was installed by Clearpower under an ESCO arrangement with a fixed price 5 year heat contract.

From the Údarás perspective, a key advantage of a centralised energy centre for feeding a district heat network is that the energy source becomes technically decoupled from the individual buildings and the heat network (subject to some technical considerations such as temperature or flue emissions).

This leaves the energy centre operator free to procure different fuels based on the equipment available to them within the energy centre and the particular procurement policy and strategy to suit the end-users needs (whether that be cost as a priority or low carbon emissions for example). By achieving critical scale, district heating facilitates the easier integration of renewable heat solutions.

Figure 37: Modern office block with 18 tenants using renewable heat from the energy centre

Figure 38: Existing Energy Centre with rooftop solar thermal

Figure 39: Wood pellet boilers in energy centre

Existing Energy Centre

There is an existing energy centre at Gweedore Business Park with 2 x 150 kW KWB wood pellet boilers and 46 m^2 solar thermal on the roof. This is sized to heat the users in the building adjacent and was constructed at the same time, but there is ample room for expansion.

Existing End Users

The Aislinn Gaoth Dobhair is a modern 3-storey office block in the centre of the business park. It was constructed in 2011 with individual tenancies (Figure 37). It is supplied with heat from the energy centre adjacent to it. The principal tenants include a crèche and a library on the ground floor. There are individual enterprise units and serviced office space on the first floor. At present the top floor is unoccupied and unheated.

There is individual heat metering of all tenants on a monthly billing cycle. At present the management of the energy centre is carried out by the Údarás facilities team and the billing is done by the finance department, but the intention has been to contract the operation and maintenance of both the energy centre and the local heat network to a third party. There are 19 end-users with separate heat meters, although several of them are small serviced offices of $50m^2$ or less, and this includes a meter on the landlord or common areas.

Tenants are being charged 4.2 c/kWh of metered heat in 2016. An innovation in the design is the use of low temperature radiators, which are able to utilise heat more efficiently at low flow temperatures. This in particular can facilitate the use of the solar thermal heat.

Figure 40: Existing and potential heat network customers

Figure 41: Industrial building for potential connection to district heat network

Expansion/Future Plans

Údarás have already instigated a process for expanding the delivery of renewable heat via a district heat network as a service across the business park. In 2016 they appointed Mott MacDonald Engineering consultants to support them with a design and costings of the district heat network. This design will be constructed to the new EXEED (Excellence in Energy Efficient

Design) standard and Údarás are part of the EXEED[64] programme supported by SEAI.

The proposed district heat network will entail approximately 2.8km of insulated pipes and 1.8km of trenches. An initial estimate indicates that 1.5MW of biomass boilers, together with 60,000 litres of thermal storage could provide over 95% of the annual energy demand for the network from biomass, with some peak capacity provided by an oil boiler. The project is likely to proceed to tender in 2017.

Renewable heat supply and indeed biomass is likely to be a substantial component of the overall heat supply to the network.

Heat network operating temperatures

One of the challenges faced in connecting existing building heating circuits to a district heat network is operation temperatures. There is often a mismatch between the existing heating circuit design practice and the requirement for as low a return temperature as possible for a heat network.

There is a trend towards lower flow temperatures on heat networks, with current best practice[65] recommending load circuit temperatures of 70°C flow and 40°C return giving a ΔT of 30°C across the network. Furthermore, the trend is ever downwards with a new emphasis in Ireland and the UK on the use of heat pumps to drive heat networks operating at a maximum of 55°C. The required network flow temperature is determined by the need to supply water at a minimum temperature to a building's heating circuits.

To maximise the ΔT and minimise pipe sizes and capital cost, where new heating circuits are to be installed, they should be designed to operate at a maximum of 70°C with a 30°C ΔT. The heat losses from heat network pipework are directly linked to the ΔT. Best practice is to limit network losses to 10% of the overall heat demand on an annual basis. This is not possible without achieving high ΔT of at least 30°C.

Learnings

A common theme is the need to secure reliable third parties for operation and maintenance of the network. Údarás would like the present network and any future expansion to have an external O&M (Operations and Maintenance) contract.

There were some teething problems with the solar thermal, the biomass boilers and with the heating distribution controls. An additional buffer tank was installed in 2015 to ensure the heat from the solar thermal installation was being injected into the network. Some modifications were also necessary to the wood pellet storage.

A decision was taken early in the project to provide individual metering and full autonomy to each subtenant in the office building. For very small users/areas, it is not certain that the extra administration and expense of additional meters is worthwhile. In the case where there are short term flexible tenancies, there is also then an education gap for each new user to understand their individual heating controls and billing.

The heat rate being billed to end-users is subsidised and does not allow for recovery of the significant capital invested in the system.

Údarás face the same complexities as others in defining new tenancy relationships which reflect district heat services. Due to the high level of investment entailed, it would be desirable to design leases and contracts that oblige tenants to use the district heat network where they have an appropriate space-heating or hot water requirement. In almost every instance there would be substantive reconfiguration of internal heating systems and controls to accept heat from a district heat network. Tenants may defer that change indefinitely unless obliged to do so.

[64] SEAI (2016) *EXEED Certified Program*. Available at: http://www.seai.ie/Your_Business/EXEED-Certified-Program/
[65] CIBSE (2015) *Heat Networks Code of Practice for the UK*. UK: CIBSE.

It would also be desirable to include criteria to ensure the return of heat at materially lower temperatures than the heat received to increase the efficiency and reduce losses on the heat network.

It may not be possible or advisable to connect all end users to the district heat network for a range of reasons including but not limited to the following:

- The requirements for process heating or cooling can't technically be met by a low temperature district heat network
- Sufficient load may not exist to merit the investment in a particular length of piping and district heat interface
- In some cases, the network losses from a pipe run may exceed 10% of annual usage, and in that case decentralised heating would be more appropriate
- The internal investment in the building may not be justified
- Uncertainty over tenure or longevity of some tenants may present a risk
- In cases where there is no technical impediment and the financial case makes sense, there still may be timing or budget issues which prevent connection to the district heat over the short to medium term

Other Existing DH and Localised Heating Systems

In addition to the case studies assessed, a number of other sites were potential candidates for assessment. It is useful to highlight some of these[66] for completeness and to give readers guidance on localised or specific types of DH sites that already exist in Ireland. A number of these projects already have detailed case studies available.

- Mitchells-Boherbee Tralee, Co. Kerry; This is a 1MW scheme supplying 42 social housing units from a centralised biomass boiler
  A comprehensive case study has been prepared and is available at:
  http://www.seai.ie/Publications/Renewables_Publications_/Bioenergy/The_Mitchels_Boherbee_Regeneration_Project.pdf
- Teagasc Mellowes Campus, Athenry, Co. Galway; A 250 kW wood chip boiler has replaced 3 individual fossil fuel boilerhouses for the supply of renewable heat to this agricultural research and training centre. A presentation on the project is available at:
  http://www.raslres.eu/wp-content/uploads/2011/11/Teagasc-Mellows-Capmus-Michael-OKane.pdf
- Furbo Headquarters of Udarás na Gaeltachta, Co. Galway; A 300kW wood chip boiler with 500kW oil boiler were installed to supply heat to a complex of buildings interconnected by 600m of DH piping. A detailed case study is available at:
  http://www.biopad.eu/wp-content/uploads/Udaras-case-study-for-BioPAD-for-website-01.08.14.pdf
- Leinster House DH, Kildare St, Dublin 2; A 1MW wood pellet boiler at the energy centre under the Leinster House and Department of Agriculture building complex supplies c. 20% of heat supply from renewable biomass with the balance supplied from the existing natural gas boilers. Detailed case information is available here:
  http://www.biomasstradecentre2.eu/scripts/download.php?file=/data/upload/D3_4_IrBEA_WP3_Final_Events_Report_FINAL.pdf
- CRESCO, Callan, Co. Kilkenny; a small District Heating network where a 220kW wood chip biomass boiler serves a number of buildings within a 75m radius.
  A presentation on the project is available here:
  http://www.seai.ie/Renewables/Bioenergy/Information_and_Resources/Proceedings_of_Bioenergy_Conferences/Bioenergy_2009_Conference/The_Callan_Case_Study_Callan_Community_Network.pdf
- University College Dublin, Belfield, Dublin 4; UCD has invested in 5 different CHP units at 3 locations on campus, as well as natural gas and wood pellet boilers. Many of these are interconnected via DH piping. Further information available at http://e3.ie/ucd/
- Elm Park, Dublin 4; This is a c. 2.5MW mixed use development with gas CHP and biomass supplying the DH network
- University College Cork
- Lansdowne Gate Apartments
- Heuston South Quarter
- Dublin Institute of Technology Grangegorman, Dublin 7; 2.2km of DH piping have been laid as public infrastructure as part of the ongoing development of this new campus where DIT will be centralised. Additional information available at www.ggda.ie
- Guinness Brewery, St James Gate

[66] This is not an exhaustive list of existing systems

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Appendix A

Optimising the operation of heat networks – Delta-T

The heat power delivered to customers is proportional to the temperature difference between supply and return, therefore the most affective DH systems have a high delta T (ΔT), i.e. a large difference between the two temperatures. A high ΔT also reduces the mass flow rate, and therefore decreases pumping needs. If the customer unit does not transfer enough heat within their own systems and produce a low return temperature, more flow is required to transfer the same heating power to the customer. A well-designed customer substation configuration can help to reduce the return temperatures. Often the DH supplier will offer financial incentives to customers who return water at low temperatures.

From the supply side, the only parameters within the control of the DH supplier that can affect the heat delivered to the customer are the supply temperature and mass flow rate. The return temperature can only be controlled by the customers, and the specific heat capacity of the fluid is set. Adjusting the mass flow rate can have negative effects on equipment such as network pumps if there is a large mass flow working range. Lowering the supply temperature increases the efficiency of production and decreases network losses.

Ensuring the customer units return a low temperature has the effect of reduced peak flow rates, leading to smaller pipes and lower costs. Low return temperatures under part-load conditions are important to keep heat losses and pumping requirements low. If return temps are not maintained the network capacity will be reduced. Variable flow control through variable speed pumps will result in lower flow rates and lower return temperatures at part-load and maintain minimum pressures at network extremities. There will be large differences in load flow between winter and summer[67].

Temperatures of flow and return have a large effect on plant such as heat pumps and CHP, and much less effect on heating only-boilers. Low return temperatures for heat pumps increase the COP, therefore reducing electricity costs for production. In CHP units, the energy in the exhaust gases leaving through the stack is recovered to heat the DH return water to supply temperatures. The return temperature of the water therefore has to be below the dew point of the flue gases in order that the water content is condensed effectively and heat is recovered; the lower the return temperature, the more heat that can be recovered from the CHP exhaust. The water content of flue gases of biomass or waste CHP are particularly high and therefore low return temperatures are particularly important for these types of plants.

[67] CIBSE (2015) *Heat Networks Code of Practice for the UK*. UK: CIBSE

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